REFERENCE MANUALS ON CONSTRUCTION AND OPERATIONAL PRACTICES OF EHV SUBSTATIONS & LINES AND COMMERCIAL AND LOAD DESPATCH OPERATIONS

VOLUME - II

APTRANSCO

TRANSMISSION CORPORATION OF ANDHRA PRADESH LIMITED

Transmission Corporation of Andhra Pradesh Limited
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FOREWORD

In the year 2000, APTRANSCO brought out a "Technical Reference Book". With the introduction of reforms in power sector in Andhra Pradesh in 1999, the erstwhile APSEB was unbundled into separate entities for Generation, Transmission and Distribution. Number of technological advancements, commercial and Regulatory procedures were introduced in APTRANSCO in the last decade, with a view to improve Transmission system and improve quality and security of power supply. Thrust was given on improving the efficiency and commercial viability. Number of measures were initiated to reduce transmission losses, increase the transmission system availability and optimal operation of the grid.

Growth in power sector has been phenomenal in the last decade after the reforms were introduced. Strength of transmission network rose from 229 nos. EHV Substation and 19826 km lines to 404 nos. substations and 31634 km lines. It is felt necessary to bring out a Reference Manual for Transmission duly updating the relevant topics in the earlier Reference Book and include various measures introduced in the last ten years. An attempt has therefore been made to bring out a Reference Manual covering the topics in Transmission Planning and Design, Construction and Maintenance practices relating to EHV substations and lines and Commercial and Load Despatch operations, in one or two volumes which would serve as a guide to the practicing Engineers of APTRANSCO.

Sri M.Gopal Rao, Former Director, APTRANSCO who has been requested to prepare a Reference Manual on the above lines, has a rich and varied experience of over 40 years in the fields of MRT, O&M of hydro generating stations, O&M of EHV substations & lines, commercial operations, planning, tendering and execution of Transmission projects. He had been a member of the expert committee of CBIP in the preparation and publication of Manuals on maintenance of EHV substations equipment and EHV Substations Design & Layout published in 2006. He has introduced Auto transformers without tertiary windings in 220 kV, 100 MVA capacity to minimize the failures and introduced 30 KVAR shunt capacitor banks at 132 kV level to improve transmission efficiency in AP. He was instrumental in the implementation of condition based maintenance with the help of diagnostic equipment such as Tanδ test equipment; off-line electronic fault locators etc.

A comprehensive Manual covering most of the technical functions in Transmission including various new technological measures and procedures introduced in the last ten years has been prepared by Sri M.Gopal Rao in two volumes. He has availed assistance from a team of Engineers drawn from different technical wings in the preparation of the Manual.

I appreciate the work done by Sri M.Gopal Rao and his team, and complement them for the best efforts they have put in. I am confident that this Manual (containing two volumes) will be very useful to all practicing Engineers of APTRANSCO. APTRANSCO would strive to update the Manual depending on the need and relevance from time to time.

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ACKNOWLEDGEMENTS

I worked in erstwhile APSEB and later in APTRANSCO for 37 years in various cadres from Assistant Engineer to Executive Director and retired in 2006. Then I served APTRANSCO as Director (Transmission) for two years and later as Advisor & Head (Power & Energy Division), Engineering Staff College of India, Hyderabad.

In the last 40 years, I have seen many technological developments such as SCADA, HVDC, GIS, Compact transmission line structures viz. Narrow based , multi circuit, Mono poles; Shunt Capacitor Banks and Underground cables at EHV level, Composite Insulators, New generation conductors to name a few.

After detailed discussions held by Sri.K.Vijayanand, then JMD(HRD) (presently MD, APGENCO), Sri P.SriRama Rao, Director (Grid Operation) and myself on the need for a Manual on Transmission for the guidance of technical staff, it was proposed to bring out a Reference Manual covering technical functions and duties of various technical wings. APTRANSCO during June 2009 issued an order requesting me to prepare Reference Manuals on construction and operational practices relating to EHV substations and lines and Commercial and Load Despatch operations. A final version of the Manual was prepared in December 2010. The Manual has been brought out in two volumes.

At the outset I express my sincere thanks to CMD and Board of APTRANSCO in having reposed confidence in me and entrusted the task of preparation of Manual to me.

During the preparation of Manual, reference has been made to relevant articles from various CBIP publications. I thank the CBIP for permitting me to extract useful information from these Manuals.

Sarvasri Y.L.Narasimha Rao, J.Devanand, Superintending Engineers, J.V.Hanumad Sastri, K.Ramanadh Gopal, T.M.Madana Sekhar, G.Seetarama Murti, N.Anand, D.Koteswara rao, B.Koteswara Rao, Prabhakar, G.Sivaiah, V.Rama Krishna, P.V.Satya Ramesh, M.Vedavyas, P.Suresh Babu, M.Bala Subrahmanyam, Divisional Engineers, L.Murali Krishna, B.Chandra Sekhar, M.JaganMohan Rao, K.Vikram, G.E.Madhukar, S.Srinivasan, Srinivas, Srinivasa Rao, Asst.Divisional Engineers, have extended assistance and supported me during the preparation of the Manual. My sincere thanks to them for all their support.

Sarvasri K.Srinivasa Rao, Asst. Secretary, B.Surya Kumar, PO and A.S.V.Ramana, JPO extended assistance in arranging meetings as and when required. My sincere thanks to them for all the assistance they extended. Sri V.V.S.Srikanth, extended full cooperation in arranging team meetings at short notice and providing all computer assistance in the preparation of the Manuals. My special thanks to him for all the assistance and support extended by him.

In the last decade of post reforms, we have witnessed several technological and commercial developments in Power sector for improving the efficiency. Therefore there is a need to take stock of the developments periodically and update the Manual accordingly.

M. Gopal Rao

(M.GOPAL RAO)

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MANUAL ON CONSTRUCTION OF TRANSMISSION PROJECTS

1.1 PROJECT MANAGEMENT

After award of contract, CE (construction) at Corporate office will assign the project execution to the construction unit in the field-SE (TLC). The SE will authorize one of the Executive Engineers to take up the work, who will be the Project Manager. The EE will be assisted by ADE/AE of electrical and civil wings in the execution of the project.

The Projects Construction unit at head quarters shall ensure that the approved schemes are completed as per the schedule and within the given time frame. In case of any deviations where extra items are found absolutely necessary during execution of the scheme, the EE/TLC in the field in-charge of the work, shall submit the details with full justification for such deviation / new item to Headquarters without any delay: The CE/Construction shall approve such deviations based on the justification. However, the CE/Construction shall submit a monthly return on the above to the Committee of Technical Directors for their review and seek ratification of the action taken by them. In case the cost is expected to exceed 10% over the sanctioned scheme cost, then the CE/Construction shall submit a report immediately and obtain approval of the Board.

APTRANSCO has been adopting Enterprise Resource Programme (ERP) in the following modules.

1) Project Management and Execution
2) Finance Management
3) Stores Management and Inventory Control
4) Operation and Maintenance management

Upon award of contract, execution and monitoring of the project are carried out by both field and headquarters units through Enterprise Resource Planning system (ERP).

1.1.1 About ERP: It is an IT tool useful in optimizing the resources available, be it man power, material, finance technology etc. The ERP is aimed at bringing in more transparency, accountability; unhindered data flow across the functions, availability of data and help in forecasting, and to cut-down delays. Implementation has initially been taken up in four areas viz., (i) Project Module (ii) Material Module (iii) Maintenance Module and (iv) Finance Module. The entire APTRANSCO has been connected through an intranet and any licensee in APTRANSCO can access the data through his login and pass word. Thus any user with requisite authority can view all the data and find out the stock position from all the stores, raise the indent for material, get the allotment, view the project progress and process all the financial activities for payment .

(i) Project Module: The project module is aimed at facilitating smooth implementation of the project giving necessary time lines, alerts and to transparently transfer the entire data across the organization for all the concerned to view. The project implementation can be viewed pictorially and PERT techniques can be applied to quickly complete the projects. This module also provides strict material control as well as budget control. The day to-day progress of the works can be updated from the field immediately and can be viewed from any where in the state. The material indents also can be raised, allotted and the expenditure booked to the project.

(ii) Material Module: The material module basically covers the functionality of the procurement and material management. The material management process consists of planning and procurement of materials, receipt and storage of material and issue of material. The planning and procurement process consists of identification of material requirement on a periodic as well as continuous basis, selection of appropriate vendor for supply of the required material, raising of Purchase Orders on the required material, placing of orders and following up for receipt of the material. Receipt of materials process has been segregated into the following sub-processes.

a) Centralized Purchases and Receipt from other stores.
b) Devolutions
c) Localized Purchases.

(iii) Maintenance Module: The maintenance module is aimed at improving the O&M of the equipments. All the equipments are identified by a unique ID and they are tracked based on this unique ID. The maintenance schedules and periodicity against each equipment are stored in the database. As per the periodicity, the mail will be triggered to all the concerned to take up the work. The steps to be followed for each of the preventive activity are also stored in the database. Thus whenever an activity of preventive maintenance is triggered, it gives all the necessary steps involved in the work and the user will be able to update the information with the no. of resources used, the works which were carried, material consumed etc. Likewise data can also be entered in case of breakdowns. Thus the history of the equipment from the date of commissioning will be available with all details such as no. of years served, preventive maintenance details, material consumed for preventive maintenance, the persons who attended preventive maintenance, the time taken for preventive maintenance activity, similarly for breakdown maintenance. This will help in planning the maintenance works and estimating for repair and maintenance.

(iv) Finance Module: All the payments and payment processes like raising of LOAs, passing LOAs, passing of bills, check measurement, creation of balance sheet, profit & loss account, budgetary control, capitalization, inventory valuation , project expenditure monitoring are tracked through this module.

CONSTRUCTION OF TRANSMISSION PROJECTS:

TRANSMISSION LINES:

Major steps in a transmission line construction are a) appropriate selection of route adopting most suitable technical procedures, and b) geo-technical investigations.

1.2 Important Technical specifications for Line Works:

The specification covers check survey, distribution of all the material to work locations, setting to work, erection, testing, commissioning of EHV Transmission lines.

Length of the line and the quantities specified in the Schedule against various items may vary depending upon the actual site conditions and also the changes / deviations in the alignment of the line that may have to be carried out depending upon the right of way, forest clearance, PTCC Clearance and other problems that may arise in the course of execution of the contract. The contractor shall execute works to the extent required and shall have to complete the work as a whole (i.e. the Transmission line which is the ultimate work to be put into use). The contract shall specify his role and responsibility for all such deviations in quantities arising due to changes in alignment or other reasons.

1.2.1 Route: The actual route of the transmission line shall depend on the results of the survey carried out by APTRANSCO and is also subject to the approval of the Power Telecommunication Coordination Committee.

In case of any deviation found necessary at the time of execution of works in the finalized profile, number/ type of finalized towers etc., the same shall be placed immediately before the committee of technical Directors for approval

1.2.2 Topography: Along the route of the transmission line the altitude varies from sea level to about 1000 meters above mean sea level. The topography of the terrain is fairly plain having hilly terrain, cultivated fields, gardens, and small thick jungles.

1,2,3 Type of Construction: The line shall be constructed on self-supporting galvanized lattice steel towers suitable for assembly at site by bolt connections. The conductors shall be in vertical formation for DC or DC/SC line and in horizontal formation for a SC line. Continuous earth wire shall be provided above the conductors for effective shielding etc. The line shall initially terminate on terminal towers situated at a distance of not more than 1/3rd of normal span from the out-door substations at either end. From the terminal towers, the line shall be connected to the terminal structures in the sub-stations.

1.2.4 Permits and Priorities: The contractor shall make his own arrangements in using private roads, pathways, etc., in connection with the construction work. The contractor shall himself arrange for permits required for the operation of the vehicles used in construction works. The APTRANSCO may, however assist the contractor in obtaining controlled commodities necessary for the execution of the works.

1.2.5 Cement and Reinforcement Rods: The cement and steel reinforcement rods required for the work have to be supplied by the contractor. Ordinary Portland cement of Grade-43 manufactured as per IS-8112 of 1989 shall only be used. Storage, certification, delivery and testing of the cement shall conform to IS-

8112 with latest amendments. IS Certification mark is obligatory. Cement procured from major/ approved cement manufacturing plant ACC Limited , Kesoram Cements, Orient Cements, Zuari Cements, CCI Limited, Andhra Cements, Coramandel Cement, Raasi Cement, Sri Vishnu Cements, Madras Cements, Ultra Tech Cement Limited, KCP Limited, Penna Cements, Panyam Cement, Grasim Cement, Rajashree Cement, Mysore Cement, Century Cement, Ambuja Cement, Priya Cement, Duncan cement, Parashakthi cement, Maha cement, Dalmia cement, to name a few) with the approval of APTRANSCO shall be accepted. Reinforcement Steel shall conform to IS 1786 and shall be procured from standard manufacturers i.e. TISCO, SAIL & VSP for use in tower foundations.

1.2.6 Materials required for the work: In case of a turnkey contract, the Successful bidder shall supply all the material as required in the specification for erection of the line. The material shall be delivered at the site stores. The contractor will be responsible for proper handling and maintenance of the materials up to the time of handing over of the completed works to APTRANSCO and return of surplus materials if any, at APTRANSCO's stores.

After completion of the Check Survey, the contractor has to furnish actual quantity of material required for each item covered in Schedule and proceed to procure the requisite quantity of material only. Should however, on completion of all the works, any surplus materials for which payments have been made by APTRANSCO are lying with the contractor, all such material shall be handed over to the Engineer at the APTRANSCO's stores. This shall be done within two months after completion and handing over of the line. If the materials are not returned within this period and / or in the opinion of the Executive Engineer in charge of the work, are not in a fit condition for use, such surplus materials will be treated as sold to the contractor at the rate equal to the stores issue rate plus 10% centage charge or at the prevailing market rates plus incidental charges, whichever is higher, and recoveries made accordingly. The 10% retention amount against the contract will be released only after all the balance materials are handed over at APTRANSCO's stores in proper shape and material accounts are rendered.

The contractor shall ensure safety for the materials lying with him for erection purpose. The contractor has to insure the materials during erection and ensure safety of the materials till the line is handed over for operation

1.2.7 Loss of Material in Erection: The following maximum additional quantities of materials may be permitted, to cover damages and losses during erection.

i)	Disc insulators required	:	Up to 1% of the quantity.
ii)	Conductor and earth wire	:	Up to 1% of the route length of the line. (The 1% wastage includes additional lengths required to account for sag and jumpers).
iii)	Bolts and Nuts, washers and Hardware & accessories required for conductor & earth wire.	:	Up to 2% of the quantity

1.2.8 Standard specifications: Unless specifically mentioned, works shall be carried out in accordance with relevant Indian standards and A.P.S.S. or any revision thereof which may be issued during the currency of the contract, and all the clauses relating to materials and workmanship, responsibilities, liabilities, commencement of works, completion delays and extensions, suspension works, and forfeitures etc., as provided in the A.P.S.S. shall be binding.

The Indian Standard specification (IS) mentioned below or International Standards as amended up to date shall be applicable to the material and process used in the manufacture of towers and tower accessories.

Sl. No	Indian Standards (IS)	**Title**	International & Internationally recognised Standard
1	IS:2-1960	Rules for rounding off numerical values.	
2	IS:209-1992	Specification for Zinc	ISO/ R/ 752 ASTM B 6 BS: 3436- 1986
3	IS:278-1991	Specification for Galvanized Steel Barbed wire	ASTM A131
4	IS:432-1982	Mild steel & medium tensile steel bars & hard drawn steel wire for concrete reinforcement.	
5	IS:456-1978	Code of practice for plain & reinforced concrete	
6	IS:802(Part I/ Sec-I)-1995 Sec-II)-1992	Code of practice for use of structural steel in overhead transmission line towers: Materials and loads Permissible stresses Section – I : Materials and Loads Section – II : Permissible stresses	ASCE 52 IEC 826 BS 8100
7	IS:802 (Part-2)-1990	Code of practice for use of structural steel in overhead transmission line: Fabrication, galvanizing, inspection and packing.	ASCE 52
8	IS:802 (Part-3) – 1990	Code of practice for use of structural steel in overhead transmission line: Tower Testing.	ASCE 52 IEC 652
9	IS:808-1991 Part-V Part-VI	Dimensions for hot rolled steel beams, column channels & Angle sections. Equal leg angles Unequal leg angles	

10	IS:1367(Part-1)-1992	Technical supply conditions for threaded steel fasteners	
11	IS:1573-1991	Specification for Electroplated coatings for zinc on iron and steel.	
12	IS: 1893-1991	Criteria for earthquake resistant design of structures	
13	IS:2016-1992	Specification for Plain washers	ISO/R887-1968
14	IS: 2062-1992	Specification for Structural general purposes	
15	IS:2551-1990	Danger notice plates	
16	IS : 800 – 1991	Code of Practice for general building construction in steel	CSA 6.1
17	IS:2629-1990	Recommended practice for hot dip galvanizing of iron and steel	
18	IS: 2633-1992	Method of testing uniformity of coating on zinc coated articles	ASTM A123 CSA G164
19	IS:3063-1994	Specification for single coil rectangular section spring washers for bolts, nuts and screws	DIN-127 1970
20	IS:3757-1992	High strength structural bolts	
21	IS: 4091-1979	Code of practice for design and construction of foundations for transmission line towers and poles	
22	IS:4759-1990	Specification for Hot dip zinc coatings on structural steel and other allied products	
23	IS: 5358-1969	Specification for Hot dip galvanized coating on fasteners	
24	IS:5613-1993 (Part-2/) Section.1 Section.2	Code of practice for design, installation and maintenance of overhead power lines: (up to 220kV) Design Installation and maintenance	
25	IS:5613-1989(Part-3/Sect-1 Section-2	Code of practice for design, installation and maintenance of overhead power lines: (400kV lines) Design Installation and maintenance	
26	IS:6610-1991	Specification for Heavy washers for steel structures	
27	IS :875 –1992	Code of practice for design loads/ other than earthquakes for Buildings & Structures	

28	IS :1852 1993	Rolling & Cutting tolerances of Hot Rolled steel products	
29	IS :3043 –1991	Code of Practice for earthing	
30	IS : 6623-1992	High Strength structural nuts	
31	IS:6639-1990	Specification for Hexagonal bolts for steel structures	
32	IS: 6745-1990	Specification for Methods for determination of the weight of zinc coating on zinc coated iron and steel articles	
33	IS:7215-1991	Specification for Tolerance for Fabrication of steel structures	
34	IS:8500-1992	Specification for weldable structural steel (Medium and High Strength Quality)	
35	IS:10238-1989	Step bolts for steel structures	
36	IS: 12427-1988	Transmission tower bolts	
37		Indian Electricity Rules	
38	Publication No. 19 (N)/ 700	Regulation for Power Line crossings for Railway tracks – 1987	
39	C B I& P Publication No 268	Transmission line Manual	
40		ASCE Manual-72	

The standards mentioned above are available from:

Abbreviation	Name and address
BS	British Standards, British Standards Institution, 101, Pentonvile Road, N1 9ND United Kingdom,
IEC/CISPR	International Electro-technical Commission. Bureau Central de la Commission, Electro Technique International, 1 Rue de Verembe, Geneva, Switzerland.
BIS	Bureau of Indian Standards, Manak Bhavan, 9, Bahadur Shah Zafar Marg, New Delhi – 110 001, India

ISO	International Organization for Standardization, Danish Board of Standardization, Danish Standardizing Sraat, Aurehoegvej-12 DK-2900, Heelprup, DENMARK.
NEMA	National Electric Manufacture Associate, 115, East 44th Street, New York NY 10017, U.S.A.
JIS	Japanese Standards Association 1-24 Akasaka 4-Chome, Minato-ku, Tokyo, Japan
DIN	Deutsches Institute flir Normung Burggrafen Strance 4-10 Post Farh 1107 D-1000, Berlin 30 (GERMANY)
ASTM	American Society for Testing & Material 1916, Lace Street Philadelphia, PA 1903 1187 USA

1.2.9 QUALITY ASSURANCE PLAN:

The Contractor shall invariably furnish Quality Assurance Plan giving the following information along with his offer. Information shall be given for each type of equipment offered separately.

- Statement giving list of important raw materials, names of sub suppliers for the raw material, list of standards according to which the raw material are tested, list of tests normally carried out on raw material, copies of test certificates.
- Information and copies of test certificates as in (i) above in respect of bought out items.
- List of manufacturing facilities available.
- Level of automation achieved and list of areas where manual processing exists.
- List of areas in manufacturing process, where stage inspections are normally carried out for quality control and details of such tests and inspections.

The material shall conform in all respects to high standards of engineering, design, workmanship latest revisions of relevant standards at the time of ordering and Purchaser shall have the power to reject any work or material which in his judgment is not in full accordance therewith.

Sub vendor items: For the entire sub vendor items the following are to be furnished at the time of sub vendor approval after the award of contract.

i. Quality Assurance Plan

ii. Drawings.

iii. Type Test reports conducted not earlier than five years.

iv. Guaranteed Technical Particulars.

1.2.10 Materials to be supplied by the Contractor – Standards to be complied with: The following shall be the standards for materials to be supplied by the bidder, for erection of the lines.

Sl.No.	Indian standard Specification	Title
1.	IS-8112 of 1989 of Latest issue	Ordinary port land cement of grade 43
2.	IS-1786	Tor steel for reinforcement
3.	IS-456-2000	For Plain&Reinforced concrete
4.	IS-383-1970	For aggregates (Coarse&Fine)
5.	IS-1239 (part-I)	Hot dip galvanized M.S.Pipe and galvanizing conforming to ISS-2633/1986
6.	IS-5613 (Part-II)	Danger Boards, phase plates, Bird Guards and Number plates
7.	IS-3043	Pipe earthing
8.	IS-2062-1992	Steel for General structural purpose - For M.S.Flat 50 x 6mm for earthing of tower lines.

a) The material shall be procured from the regular suppliers of APTRANSCO

b) The material shall be procured after taking approval of concerned SE/TLC/APTRANSCO

c) In respect of tower accessories, the contractor has to use the material on the line only after approval by SE/TLC.

Body Extensions: The towers have to be designed so as to be suitable for adding 3M, 6M, 9M, 12M, 18M & 25M body extensions for maintaining adequate ground clearance without reducing the specified factor of safety in any manner. The strength of tower members for all loading cases is adequate with and without extensions.

Leg Extensions: To spot the tower in the hilly terrain leg extensions/Hill side extensions for all types of towers ranging from 1.5M to 9.0M suitable to be fitted to normal towers to plus six metres towers as well as with other extensions shall be provided.

1.2.11 TOWER ACCESSORIES

Step Bolts and Ladders: Each tower shall be provided with step bolts conforming to IS: 10238 of not less than 16mm diameter and 175mm long spaced not more than 450mm apart and extending from 3.5 metres above the ground level to the top of the tower. For double circuit tower the step bolt shall be fixed on two diagonally opposite legs up to top of the towers. For single circuit tower the step bolt shall be fixed on one leg up to waist level and on two diagonally opposite legs above waist level up to top of the towers. Each step bolt shall be provided with two nuts on one end to fasten the bolt securely to the tower and button head at the other end to prevent the feet from slipping away. The step bolts shall be capable of withstanding a vertical load not less than 1.5 KN. For special towers, where the height of the super structures exceeds 50 meters, ladders along with protection rings as per the Purchaser approved design shall be provided in continuation of the step bolts on one face of the tower from 30 meters above ground level to the top of the special structure. From 3.5 m to 30 m height of super structure step bolts shall be provided. Suitable platform using 6 mm thick perforated chequered plates along with suitable railing for access from step bolts to the ladder and from the ladder to each cross-arm tip and the ground wire support shall also to be provided. The platform shall be fixed on tower by using counter-sunk bolts.

1.2.12 Number, Danger, Circuit and Phase Plates: Each tower shall be fitted with a danger plate, number plate & 2 sets of phase plates for double circuit tower. The transposition towers should have provision of fixing phase plates on both the transverse phase. Circuit plates (set of 2) shall be provided on all the Double Circuit Towers. Danger plates shall conform to IS: 2551-1990 in all respects, except that the plate shall be of vitreous enameled Red with letters, figures and the conventional skull and bones in white.

The number, circuit and phase plates shall conform to IS: 5613 (Part 3/section-1)-1989.
The corner edges of the danger, number & circuit plates shall be rounded off to avoid sharp edges.

The letters of number & circuit plates shall be red enameled with white enameled background.
Anti -Climbing Device: Towers are to be provided with anti-climbing devices as per drawing and conform to IS: 5613 (Part 3/section-1) -1989.

Necessary holes, as shown on the fabrication drawings, are to be provided on the tower members for installation of the anti-climbing device.

The barbed wire used shall be of TYPE - A and SIZE -1 as per IS-278, 1991 (latest).
The barbed wires shall be given chromating dip as per procedure laid down in IS: 1340.
Bird Guards: The bird guards for suspension towers shall be made of galvanized iron sheet and shall conform to IS: 5613 (Part-3/Section-1)-1989.

Statuary Requirements: Statutory requirements as laid down in the `Indian Electricity Rules 1956' or by any other statutory body applicable to such structures shall be satisfied/observed.

1.2.13 Ground Clearance: The minimum ground clearance from the lowest conductor shall be considered as given in the following table. The provisions made for considering the ground undulations, errors in stringing, is 150 mm extra.

System Particulars

a)	Line Voltage (kV)	400	220	132
b)	Highest system voltage (kV)	420	245	145
c)	Number of circuits	2	2	2
d)	Frequency (Hz)	50	50	50
e)	Neutral	Effectively earthed	Effectively earthed	Effectively earthed
f)	Number of sub conductors	4 or 2	2 or 1	1
g)	Bundle arrangement	Square/ Horizontal	Horizontal	-
h)	Bundle spacing	450	450	
i)	Basic insulation level BIL kV(RMS) (peak)	1550	1050	650
j)	Power frequency withstand voltage wet (kV) rms	680	460	275
k)	Switching Surge withstand voltage wet kV peak	1050	NA	NA
l)	Corona extinction voltage: Dry condition kV rms	320		
m)	Radio interference voltage at one MHz for phase to earth voltage of 266kV rms dry	1000 volts		
n)	Short circuit level KA	40	40	31.5
o)	Maximum temperatures deg C Conductor Earth-wire	75 53	75 53	75 53
p)	Power line crossing i) Another power line (mm) ii) Telecommunications line (mm) iii) Railway line (mm) Above track (mm) Above crane (mm) iv) Major roads	 5490 4480 17900 6000 As per IE rules – 1956 12.2	 4580 3050 15400 12.2	 3050 2750 14600 12.2

Clearances of live parts to Tower Members: The minimum clearances between the live parts, tower and cross-arm members are given below.

Clearances	**400kV**	**220kV**	**132kV**
Minimum ground clearance from power conductor (mm)	8840	7050	6100
Provision for survey and sag errors (mm)	150	150	150
Minimum phase to phase distance (mm)	4000		
Minimum vertical midspan clearance between power conductor and earth wire in still air (mm)	9000	8500	6100
Swing angles and minimum clearance from live to earthed metal	20º	30º	30º
Suspension insulator string in still air and when deflected upto 22 degrees from vertical (mm)	3050	1830	1370
Suspension insulator when deflected by wind up to 44 degrees from the vertical (mm)	1860	1675	1220
Jumpers in still air and when deflected up to 20 degrees from the vertical (mm)	3050	1675	1070
Jumpers when deflected by wind up to 40 degrees from the vertical (mm)	1860	-	-
Tension insulator string (mm)	3050	-	-

The minimum weight spans shall be verified by the Designs division, based on actual spans and deviations and such issues that may arise, before deciding on next type of tower or extension.

1.2.14 INSULATOR STRINGS AND EARTH WIRE CLAMP ATTACHMENTS: For the attachment of suspension insulator strings a suitable hanger on the tower has to be provided so as to obtain required clearance under extreme swinging conditions and free swinging of the string**.** The hanger has to withstand the highest possible load that may be imposed on it.

a) Earth wire peak/ cross arms have to accommodate the shackle of the suspension clamp.

b) At tension towers, strain plates of suitable dimension on each cross arm tip and top of the earth wire peak; have to be provided for taking the D-Shackles of the tension insulator strings or earth wire tension clamps as the case may be.

1.2.15 Shield Angle: The angle of shielding is defined as the angle formed by the line joining the center lines of the earthwire and power conductor/outer power conductor, in still air, at tower, to the vertical line through the center line of the earthwire. The drop of 150 mm on account of earthwire suspension assembly has to be considered while calculating the minimum angle of shielding.

Limit for shield angle for 400kV lines is 20º and for 220 and 132kV lines is 30º. No. of shield wires (earth wires) depends on these limitations. Normally two wires are provided for400kV lines and one no. wire is provided for 220 &132kV lines for shield.

1.2.16 Fabrication: Mild steel and high tensile steel should not get mixed up during fabrication and as such identification mark shall be embossed on each and every H.T. Steel section.

All parts of the towers shall be cut to correct lengths and fabricated in accordance with the shop drawings approved by the purchaser. Welding of two or more pieces to obtain the length of member specified shall not be allowed. Members shall be straight to the permissible tolerances to ensure proper fitting before being laid off or worked and after galvanizing.

The tower members shall be accurately fabricated to bolt together easily at site without any undue strain on them or the bolts.

The diameter of the hole shall be equal to the diameter of bolt plus 1.5 mm. No angle member shall have the two leg flanges brought together by closing the angle. All parts of the towers shall be accessible for inspection and cleaning. Drain holes shall be provided at all points where pockets or depressions are likely to hold water.

All similar parts shall be made strictly inter changeable. All steel sections before any work is done on them, shall be carefully leveled, straightened and made true to detailed drawings by methods which will not injure the materials so that when assembled the adjacent matching surfaces are in close contact throughout. No rough edges shall be permitted in the entire structure.

1.2.17 Bolts, Nuts and Washers: All tower members shall be joined together with Bolts and nuts. The redundants of first two (2) panels from ground level shall be connected with Anti-theft bolts and nuts along with spring washers whereas the balance joints shall be connected with hexagonal bolts & nuts. All hexagonal bolts and nuts shall conform to IS –12427. They shall have hexagonal head and nuts.

Anti-theft bolts and nuts shall have round tapered heads with hexagonal shear nuts. They shall conform to IS: 12427 and IS: 1367 for property class 5.6/5. The bolt shall be of 16/24 mm diameter and of property class 5.6 as specified in IS: 1367 (Part-III) and matching nut of property class 5.0 as specified in IS: 1367 (Part-VI).

Nuts for hexagonal bolts should be double chamfered as per the requirement of IS: 1363 Part-III. It should be ensured by the manufacturer that nuts should be over-tapped beyond 0.4mm oversize on effective diameter for size up to M16.

Nuts for Anti-theft bolts should be round tapered with hexagonal shear nuts. The hexagonal portion of shear nuts shall break away at specified torque recommended by the supplier to ensure proper tightening of members and the fasteners shall not be opened subsequently with tools. The tightening torque and shearing of anti-theft nuts shall be verified during proto-assembly.

Fully threaded bolts shall not be used. The length of bolts shall be such that the threaded portion will not extend into the plane of contact of the member All bolts shall be threaded to take the full depth of the nut and threaded enough to permit firm gripping of the members, but not beyond. It shall be ensured that the threaded portion of each bolt protrudes not less than 3 mm and not more than 8 mm when fully tightened. All nuts shall fit and tight to the point where the shank of the bolt connects to the head.
Flat and tapered washers shall be provided wherever necessary. Spring washers shall be provided for insertion under all nuts. These washers shall be steel electro galvanized, positive lock type and 3.5mm in thickness for 16mm dia bolt and 4.5 mm for 24mm bolt.

To avoid bending stress in bolts or to reduce it to minimum, no bolt shall connect aggregate thickness of members more than three (3) times its diameter.

Spacing of Bolts and edge distance: The minimum spacing of bolts and edge distances shall be as given below:

Bolt diameter (mm)	Hole diameter (mm)	Minimum bolt Spacing (mm)	Minimum edge Distance	
			Hole center to rolled or sawn edge	Hole center to sheared cut edge
16	17.5	40	20	23
20	21.5	48	25	28
24	25.5	60	33	38

Not more than two diameters of bolt shall be used on any one tower. Step bolts are excluded from this requirement.

Locking Devices: Spring washers designated as B-16-IS-3063 Electro galvanized shall be provided for insertion under all nuts. These washers shall be of steel and electro-galvanized, conforming to IS: 1573-1986 and positive lock bolt as per IS: 3063-1972. Washers of the following thickness shall be provided under all nuts.

Bolt Diameter (mm)	Thickness of spring washers (mm)
16	3.5
20	4.0
24	4.5

Check Assembly of Towers: Before proceeding with the mass fabrication of any type of tower, the contractor shall fabricate and assemble at his works for inspection by the purchaser or his authorized representative, one tower of each type as finally approved by the purchaser for checking the fabrication accuracy and workmanship (Proto assembly). The prototype assembly made on the ground in the horizontal position shall be adequately supported to prevent distortion and over-stressing of members. Proper fit shall be accomplished without extraordinary effort to align bolt holes or to force members into position. For the check assembly, bolts and nuts shall be not more than finger tight.

1.2.18 Check Survey: The Contractor shall carryout check survey. After the approved profiles are received, the contractor must fix up locations based on the approved spans indicated in the profile / tower schedule and only conspicuous variations in the chainage and physical features as indicated in the profile and as actually noticed during check-survey must be brought to the notice of the APTRANSCO's Engineer for taking remedial action. If the site of a tower location is not suitable for locating a tower, the location will have to be shifted suitably keeping in view the limitation of span and this will be decided by the Executive Engineer.

1.2.19 Stub setting and Foundations:

Excavations for Foundations in different soils, setting of stubs, laying of foundations to be carried out is described in construction of transmission lines

The contractor shall undertake full responsibility for the correct setting of stubs in accordance with the approved methods of the exact locations and alignment and in precisely correct level. Stub setting templates shall be used for proper setting of stubs.

Cement concrete foundations shall be constructed complying with the foundation drawings to be furnished to the contractor. The type of foundation to be laid at each location will be decided by the Executive Engineer after inspection of site and for this purpose the locations must be excavated for dry type foundations initially and offered for inspection. Foundation at a location shall be laid only on receipt of written communication from the Executive Engineer indicating the type of foundation to be laid.

In case, foundations of types other than those mentioned are found necessary in the course of execution of contract, such foundations shall have to be laid only on communication of drawings for such foundations by the Engineer.

APTRANSCO shall reserve the right to uncover and examine any foundation if it is found to be not in accordance with the specification. The contractor shall be required to open up and rectify all defective foundations if any and backfill at his sole expense and cost.

Cement concrete footing shall be used for all types of towers in conformity with the present day practices followed in the country. They will be mostly pyramid, stepped and chimney type. In very loose soils and wet locations R.C.C type of foundations may have to be provided to suit actual conditions. All the four footings of towers will be similar. Bidders shall quote for concreting including cost of dewatering.

In case of river crossings it may be necessary to use well foundations or other special type of foundations based on actual conditions.

1.2.20 Classification of Foundations: Classification of soil shall be made according to IS: 200 (Part I) 1974 for footing cast in open pits. The Foundation Drawings as finalized by the Civil Engineering Wing for various soil conditions suitable for different Types of Towers being deployed in the construction shall be followed. When in the opinion of contractor, the classification of soil and foundation design for a particular location given by the Executive Engineer differs from his own assessment; the contractor may submit his reasoning and analysis for examination by CE (Civil), APTRANSCO. The foundation work at this location shall commence only after specific approval from CE (civil).

1.2.21 Foundation Concrete:

(a) Pad Concrete: The cement concrete used for the base/pad of foundations shall be of 1:4:8/ 1:3:6 mix with 40mm well graded hard broken granite metal.

(b) Foundation Concrete: The cement concrete used for the foundations (frustum/stepped and chimney) shall be of 1:2:4 mix ratio with 20 mm well graded hard broken granite metal.

The sand used for the concrete shall be composed of hard silicon materials. It shall be clear and of a sharp angular grit type and free from earthy or organic matter and deleterious salts. The aggregate shall be of clean broken hard granite or other stone specified or approved by the Engineer. It shall be of hard, close grained quality. It shall also be as far as possible cube like, preferably angular, but not flaky, perfectly clean and free from earth organics or other deleterious matter. 20 mm aggregate shall be of size as will pass through 20 mm square mesh measured in clear.

The water used for mixing concrete shall be fresh, clean and free from oil, acids and alkali. Saltish or blackish water should not be used.

Methods of concrete mixing, conveyance and depositing of concrete, curing and back filling are explained in construction of lines.

In special cases, the APTRANSCO Engineer at site may authorize use of quick setting or rapid hardening compound in certain foundations.

As the uplift strength of the foundation depends upon proper consolidation of backfilled earth, extreme care shall be taken in this regard with special emphasis. Thereafter both the backfilled earth and exposed chimney top shall be kept wet for the remainder of the prescribed time of 14 days. The backfilling of foundations shall be so carried out that after one monsoon the level of the backfilled earth does not go below the surrounding ground level. However if any foundation settles below ground level after one monsoon it would be filled up by the contractor to be in level with the surrounding ground at his expense. The Stub setting templates shall be opened only after the completion of backfilling.

After backfilling, about 150 mm high earthen embankment along the sides of excavation pits will be made and sufficient water will be poured in the backfilled pits so that standing water remains above the backfilled earth for at least 24 hours. The uncovered concrete chimney above the backfilled earth shall be kept wet continuously for 14 days after concreting by providing wet empty gunny bags fully wrapped around the concrete chimney for curing and ensuring that the bags are kept wet by frequent pouring of water on them. The excavated earth left over should be spread within the four legs of the tower location.

1.2.22 Earthing: Tower footing resistance (TFR) of each tower after it has been erected and before the stringing of the earthwire shall be measured during dry weather. Each tower shall be earthed and the tower footing resistance shall not exceed 10 ohms. Pipe type earthing and counter poise type earthing wherever required shall be done in accordance with the latest additions and revision of

IS : 3043	Code of practice of Earthing
IS:5613	Code of practice for Design, Installation and maintenance (Part-III/ section 2) of overhead power lines

The provision of holes on stubs shall be made as per approved earthing drawings. The earthing will vary depending on soil resistivity.

Pipe Earthing: At locations where pits can be excavated, the towers shall be earthed by pipe earthing. The grounding shall be effected by making about 325 mm dia and 3850 mm deep pit at a distance of not less than 3650 mm diagonally away from the stubs and filling in the pits with finely broken coke having granule sizes not more than 25 mm thick. The coke shall be maintained up to a distance of 150 mm from the pipe on all sides. The top edge of the pipe shall be at least 600 mm below the ground level. The steel strip shall be buried not less than 600 mm deep from the ground level. The earth flat shall be of G.I. Pipe shall be of 25mm dia and 3050mm long class-B, with 6mm holes at 150mm apart and GI flat shall be 50x6mm, 4050mm long.

Counterpoise Earthing: In locations of high resistivity soils especially in rocky locations special earthing arrangement shall be employed in the form of counterpoise earth to bring down the tower footing resistance to 10 ohms. The counterpoise earth shall consist of 4 Nos. 7/3.15mm galvanized steel wires running radially from all the four tower legs for a distance of about 15 to 70 meters. The galvanized steel wire shall be connected to the tower legs by galvanized steel lugs forged or compressed at its one end, complete, with 16 mm (5/8") dia bolts and nuts, required for connecting the earthing to the tower and the other ends of the earthwire shall be connected to an electrode of 20mm dia and 600mm long, and the counterpoise shall be buried radially from the tower base at 600 mm below/ground level. The lugs should be preferably covered in chimney portion of the foundation to avoid pilferage.

For soil resistivity less than 1500 Ohm-meter, earthing shall be established by providing 4 length of 30 meter counterpoise wire (Total 120m length wire). Otherwise for soil resistivity greater than 1500 Ohm-meter, earthing shall be established by providing 4 length of 70m counterpoise wire (Total 280 m length wire)

1.2.23 ERECTION OF TOWERS:

Procedure for tower erection, insulator hoisting, conductor paving, stringing of conductor and earth wire and clipping is given under construction of transmission lines.

All the bolts & nuts in the towers up to the height below the bottom cross arm level including the bolt connecting the cross bracings at the bottom cross arm level, shall be seam welded in the upper half round portion (25mm length) of the bolt & nut circumferentially by using 10 gauge welding rods. This shall be done immediately after the tower is erected and its verticality is checked and found to be within the limits. After seam welding, one coat of zinc rich paint shall be applied on the seam-welded surface matching the galvanized portion of the tower to prevent rusting.

Each tower shall be fitted with number plate, danger plate and phase plate. Anti climbing devices shall be provided on towers erected at all railway crossings, important road crossings etc. Bird guards shall be provided on suspension towers. These accessories shall conform to the relevant standards.

(a)Insulator Hoisting: Suspension insulators shall be used on all tangent type towers in the line and tension insulators on all angle type towers.

For ensuring insulation co-ordination, the suspension or tension strings on approach and terminal towers near the substation ends up to a length of 1.5 kilometers shall be provided with adjustable arcing horns on tower side and fixed arcing horns on line side, keeping the arcing gap as may be stipulated by the Engineer at site.

(b)Stringing of Conductor and Earth wire: Before commencement of stringing, the contractor shall submit stringing charts for the conductor and earth wire showing the initial and final sags and tension for various temperatures and spans along with equivalent spans in the line, for approval by the Engineer.

The contractor shall be entirely responsible for any damage to the towers or the conductor during stringing. He shall also be responsible for proper distribution of the conductor drums as per drum schedule to keep the numbers and lengths of cut pieces of the conductor to the minimum.

The earth wire shall be strung and securely clamped to the towers before the conductors are drawn up, in the order of the top conductor first, then the middle and the bottom conductor at the end. It shall be ensured that all the conductors of one section should be identically tensioned.

During pulling out operation the tension in each conductor and earth wire shall not exceed the approved working tension of the conductor at the actual prevailing temperature. After being pulled, the conductor and earth wire shall not be allowed to hang in the stringing blocks for more than 96 hours before being pulled to the specified sag. During the time the conductors and earth wire are on the stringing blocks, before sagging in, it shall be ensured that the conductors and earth wire are not damaged due to wind, vibration or other causes.

The conductor shall be pulled up to desired sag and left in travelers for at least one hour after which the sag shall be rechecked and adjusted, if necessary, before transferring the conductors from the travelers to the suspension clamps. The conductors shall be clamped within 36 hours of sagging in. Pre-stressing of conductor is not required. Instead, the conductors should be strung to sag of one inch per foot less than the sag (in feet) shown on the final sag charts provided by the erection contractor in case of 132 &220kV lines. A temperature compensation of - 26ºC shall be made in initial stringing charts in case of 400kV and above lines. i.e. a temperature equal to prevailing temperature – 26º is to be considered to arrive the tension at prevailing temperature at the time of stringing, towards creep compensation, when conductors are not pre-stressed.

In respect of bundle conductors the adjustment of the sub-conductor sag by means of sag adjustment devices provided in the insulator string shall not be permitted at the time of stringing of conductors. The sag adjustment plates shall be kept in fully open position at the time of stringing of conductor.

Dynamometers shall be used in checking the tension in the conductors and earth wire and these instruments shall be periodically checked with a standard dynamometer. The sag shall also be checked when the conductors have been drawn up and transferred from aerial rollers to the insulator clamps.

The stringing block, when suspended on the transmission structure for sagging, shall be so adjusted that the conductor on the traveler will be at the same height as the suspension clamp to which it is secured.

The suspension insulator assemblies shall normally assume vertical position when the conductor is clamped. Sagging operation shall not be carried out under wind, extremely low temperature, or other adverse weather conditions, which prevent satisfactory sagging.

Any departure from the correct sag in any span shall not exceed 4 per cent. The sag of any conductor shall not depart by more than 3 percent from the mean sag of all the conductors in the same span.

1.2.24 Execution of works at Power line and Railway Crossings: Works such as erection of towers underneath an existing power line and paving out of conductors and earth wire and stringing the power line crossing span or a railway crossing span, will have to be done only after receipt of approval from the concerned officer, which, sometimes, may not match with the programme of the contractor. In such cases, the contractor shall be prepared to execute such works as and when approvals are received.

1.2.25 The following general terms form part of the specification:

a) APTRANSCO shall provide approved profiles, tower schedules, foundation drawings, Bill of materials, and other technical particulars and vendors list for procurement of materials.

b) The contractor shall procure the materials as per specification from the approved vendor list and execute the works as per the approved profiles. It is the responsibility of the contractor to complete the works in full shape and handover to APTRANSCO in fully operational condition within the time specified in the contract.

c) All the material such as transmission line towers including stubs & cleats, templates, tower accessories, bolts, nuts, spring washers, flat washers, ACSR conductor, disc insulators, HTGS earth wire, hardware & accessories for conductor & earth wire, etc. are to be supplied by the successful bidder.

d) The successful bidder shall execute the line works of conducting check survey and fixing up tower locations as per approved profiles, laying of foundations, erection of towers including accessories, stringing of conductors & earth wire, testing and commissioning of the lines.

1.3 SURVEY:

As transmission lines have to traverse a long distance, the topographical & geographical nature of the terrains play significant role in the project cost and implementation time. Hence, it is essential that at the planning stage itself various alternative routes and technical solutions for transmission lines are examined in detail. For undertaking such studies, one of the major requirements is obtaining adequate information regarding physical constraints, environmental factors etc. along the route so that optimum solutions are found. Subsequently, during implementation of the project, it is required to obtain elaborate details about terrain, soil conditions, constraints etc. of the route for proper resource planning, costing etc. as well as reduction in implementation time.

Presently, conventional methods of survey like walk over survey, preliminary survey and detailed survey are carried out at various stages from planning of the project to implementation, which are time consuming tasks. As manual methods are used for these surveys, which are conducted in not so friendly terrains, there is possibility that the results do not reflect adequately the true picture of the terrain in great details.

Modern methods to conduct route survey using remote sensing, aerial survey, GPS based survey, etc are available today. These techniques are said to have edge over conventional techniques in terms of credibility of data but are expensive, require lot of expertise, specialized equipment and may have certain other limitations.

Safety clearances as per Indian Electricity Rules (1956) as amended from time to time are to be maintained from any earthed object in the vicinity of the transmission lines. The clearances from the line conductor to the ground as well as to adjacent objects are ruled by the sag of the conductor that takes the form of a catenary, which increases with the span length between two adjacent locations. The atmospheric conditions like ambient temperature, solar radiation, wind velocity etc as well as power flow influences the sag. The conductor also swings under heavy wind and it is required to maintain clearances under such conditions. Hence placing of intermediate supports at appropriate intervals becomes essential. Further, the line has to take deviations from the straight line route at certain locations along the route to maintain necessary clearances from permanent establishments, to avoid forest areas wherever possible , if not, minimize involvement of reserve forests and minimize major crossings. Transmission line should not involve any human rehabilitation and should avoid wildlife sanctuaries, national parks, monuments of cultural or historical importance etc.
When routing of line through forest areas can not be avoided, it should be aligned in such a manner that tree cutting requirement is minimum.

The transmission line requires a right of way along its route to keep minimum clearances from earthed objects. All objects within this zone are to be cleared. Normal power transfer capacities and right of way requirements of transmission lines of various system voltages is shown in the table below.

Sl.No.	System Voltage	Power flow per circuit	ROW requirement
1	132 kV AC	85 MVA	27 m
2	220 kV AC	200 MVA	35 m
3	400 kV AC	800 MVA	46-52m
4	800 kV AC	2500 MVA	72-92m
5	500 kV HVDC Bipole	2000 MW	52m

Surveys are done by the construction units in the field taking into consideration the following, to optimize the costs and to reduce implementation time:

a) Site conditions

1. Minimum number of river crossing towers
2. Accessibility i.e. approachability to the site from construction as well as from law and order point of view
3. Type of soil - loose hills areas prone to landslides, type of terrain - benching and revetment requirement, requirement of leg extensions, area of submergence as well as river meandering.

b) Power line crossings, railway and road crossings etc, clearance from habitation

c) Environmental clearance, minimum forests, areas of archaeological importance, national parks and wild life sanctuaries.

d) Shortest route clearing various objects

Various stages in a transmission line project requiring map study/ surveying and

the types of surveys associated are detailed below:

1.3.1 System Planning Stage

For effective power transfer with good reliability, security and economy, different alternatives are studied at the system planning stage; for example, different voltage level of transmission lines, different routes of transmission lines, different connecting points etc. Therefore the routing and the cost of transmission line projects depends on factors like terrain conditions (plain, hilly), soil conditions, river crossings, power line crossings, railway crossings, reserved forests, agricultural fields etc through which the line traverses. At present, general routing and estimation of cost of each alternative at planning stage is done with reference to certain empirical rules as well as forest and physical maps. As these maps are not updated frequently, percentage error in assessment may be large. Even though this may not largely affect the selection of alternatives it will be prudent to identify more accurate and faster methods of collecting details at planning stage itself so that a large number of possible alternatives can be examined. The requirement generally would be to have updated information on maps so that the planning engineers can study various line routes and then identify and recommend cost effective solutions.

1.3.2 Project Feasibility Stage

After conducting system planning studies and identifying suitable transmission system, feasibility reports for the transmission line projects are to be submitted for techno-economic clearance from the CEA and investment approval from the Government. At the project feasibility stage, detailed elaboration of the project is done for the technical details, BOQ, cost and implementation schedules of the project.

The type of surveys adopted at feasibility stage is generally ruled by time constraints for fast track projects. Reconnaissance forms the most important aspect of transmission line survey as the cost of line is influenced by the route chosen. Best route selected gives the following benefits:

Line construction cost can be brought down.

Any possible delay/hindrance likely to occur during the execution of work can be avoided after taking due care of various statutory provisions while selecting the route alignment.

Approvals from PTCC, Railways, Civil Aviation, Forest authorities etc can be obtained faster.

Construction targets can be realistically fixed, which will help in judicious planning of materials flow, cash flow and manpower requirements.

Considerable time can be saved during construction of line, if selection of river crossing points, route along hill sections and power line crossings etc. are properly made.

1.3.3 Map Study: After drawing various feasible alternative routes within 10kms. of the Bee line on the survey of India topographical maps (1: 50000 scale), a comparative study is done on the basis of the following data.

Route length

Nos. and type of angle points in each proposal indicating the angle of each deviation as measured on the map.

Nature and no. of major crossings

Deviation in the line due to civil/military aerodromes and other industrial installations.

Approach to the line in general for construction

Reaches through protected or Reserve Forests
Continuous long stretches in paddy fields
Close parallelism with Telecom and Railway block circuits

1.3.4 Walkover Survey: Walkover survey is carried out in the alternate routes selected on the map. Walkover survey means going over the area covering the routes proposed and collecting the features observed other than those existing on the map. The following additional features are also checked.

- Power lines, communication lines
- Expanding villages and towns
- Rich gardens and plantations
- Reserve forests and high tree areas
- National parks and wildlife sanctuaries
- Archaeological monuments
- Aerodromes, Radar centers etc.
- Steep sloping terrain, areas prone to landslides, soil instability etc.
- Prohibited areas declared under statutory regulations.

Modern methods of route survey: Route survey can be carried out in any of the following modern methods.

- Electronic distance measuring technique (EDM). Accuracy in this method is up to 1PPM
- Total Station: Measures the distance and angle through measuring technique in one system.
- Global Positioning System (GPS)
- Remote Sensing Technique
- Air borne Terrain Mapping Technique.
- Remote sensing technique and terrain mapping techniques are techno economically suitable.

1.3.5 PRELIMINARY SURVEY: Most suited route proposed after conducting walkover survey, is further studied before taking up preliminary survey. The main objective of preliminary survey is to transfer the route to ground with such deviations as may be necessary as per field constraints. It includes fixing angle points of towers, route alignment, identification of major crossings, general classification of soils, measurement of route length etc with conventional instruments like Tapes and Theodolites. Bill of quantities is estimated based on these results and cost estimates are prepared. Preliminary survey does not include detailed soil investigations for locations along the route.

1.3.6 DETAILED SURVEY: After completing preliminary survey and approval of feasibility report, Administrative approval shall be obtained. After receipt of administrative approval/ instructions from construction wing at headquarters, the field construction unit (SE TLC) shall arrange to carry out detailed survey of the route. Detailed survey consists of precisely determining the no. and types of towers with extensions required if any, special towers required, no. and types of foundations, special foundations etc. Detailed survey includes taking of levels in different sections of the line, each section being the portion between two angle points. The levels are plotted on a graph sheet on a scale 1:200(vertical) and 1:2000(horizontal). These profiles are again examined for tower spotting.

1.3.7 Profiling

The complete survey along the route can also be carried out using modern surveying equipments viz. total stations, GPS, digital theodolite, long range scanners etc. Reference levels at every 20 meters along the route are to be recorded. R/L at other undulations along the route as well as in the route plan and other details enroute viz. crossings, buildings & structures, trees & other infrastructure Etc shall also be recorded. Areas along the route, which are not suitable for tower spotting, shall also be marked.

The complete profiling details shall be digitized and the data shall be prepared & stored in the format compatible to computer-aided tower spotting software.

A printed/plotted output of the digitized profiling shall be reviewed before taking up computer-aided tower spotting.

1.3.8 Tower Spotting Requirements: For spotting of towers on the profiles, 1) tower spotting requirements and 2) sag template are needed.

Tower spotting requirements include

1) Maximum value of sum of adjacent spans
2) Limitation of individual span on considerations of separation distance
3) Maximum permissible weight spans for different deviation angles
4) Whether or not vertical loads acting upward can be applied and
5) Normal values of wind span and weight span. These are derived from the tower designs.

While profiling & spotting the towers, the following shall be considered:

- **Span:** The number of consecutive spans between the section points shall not exceed 15 spans or 5 Km in plain terrain and 10 spans or 3 Km in hilly terrain. A section point shall comprise of tension point with B/ C / D or DB/ DC/ DD type.

- **Extension / Truncation:** Individual span shall be as near to the normal minimum design span as possible. If during tower spotting it is found that, due to undulations of the ground profile, the ground clearance becomes insufficient when using normal height towers, the height of such towers may be increased by the use of standard body or leg extensions designed for this purpose. In case of locations where the ground clearance is available, truncated towers may be employed. Including too many extensions in a particular reach may weaken the stability of the line in that particular reach.

- **Loading:** There shall not be any upward force on suspension towers under normal working conditions and the suspension towers shall support at least the minimum weight span as provided in the designs. In case uplift is unavoidable, it shall be examined if the same can be overcome by adding standard body extensions to the towers, failing which tension towers designed for the purpose shall be employed at such positions.

- **Railway Crossings:** Railway crossings shall be supported on Dead End Type Towers on either side depending on the merits of each case and shall be constructed in conformity with the specification laid down by the Railway Authorities. The angle of crossing shall be 90 degrees. However deviation to the extent of 30 degrees may be permitted under exceptionally difficult conditions.

The following are the important features of the prevailing regulations.

i) The maximum crossing span shall be 300m or 80% of the design span, whichever is lesser.
ii) The distance between the leg of the crossing tower and the edge of the nearest railway track shall be tower height + 6 metres.
iii) The minimum ground clearance above rail level of the lowest portion of any conductor under condition of maximum sag shall be maintained at 17.9 metres.

iv) The minimum clearance between the jib of a railway crane and the bottom conductors shall be 6.0m.

v) No crossing shall be located over a booster transformer, traction, switching station, traction sub-station or a track cabin location in an electrical area.

Minimum distance of the supporting structure for the crossing span from the centre of the nearest railway track shall normally be the height of the structure above ground level plus 6 metres.

1.3.9 Railway tracks are categorized as follows:

Cat A: Tracks electrified on 1500 V DC

Cat B: Tracks electrified at 25kV AC or likely to be electrified in near future

Cat C: Un-electrified tracks

Minimum clearances between the overhead line and railway track for Cat A and C

	BG (inside stn limits)(metres)	BG (outside stn limits) (metres)	MG or NG (inside stn limits)(metres)	MG or NG (outside stn limits)(metres)
Up to 11KV	10.0	7.6	8.6	6.3
Above 11KV – 33KV	10.0	7.6	8.8	6.4
Above 33KV – 66KV	10.3	7.9	9.1	6.7
Above 66 KV – 110KV	10.6	8.2	9.5	7.0
132 KV	10.9	8.5	9.8	7.3
220KV	11.2	8.8	10.0	7.6
400KV	13.41	10.97	12.19	9.76

Minimum clearances between the overhead line and railway track for Cat B for all gauges

	inside stn limits(metres)	outside stn limits(metres)
Unto 11kV	Only by cable	Only by cable
Above 11kV to 33KV	12.5	10.5
Above 33KV – 66KV	13.0	11.0

Above 66 KV – 110KV	13.7	11.7
132 KV	14.0	12.0
220KV	15.3	13.3
400KV	20.57	18.57

1.3.10 Highway Crossings:

Roads should be crossed preferably at right angles. Crossing towers should be located outside the road boundaries. Frequent crossing of the same road should be avoided. In such cases efforts shall be made to keep the route on the same side of the road. Minimum distance from the centre of nearest tower to road edge should be 1.5 times the tower height to have sufficient tower falling distance.

At all National Highways, tension towers shall be used. The crossing span shall not exceed 250 metres. The ground clearance at the roads under maximum temperature and still air shall be 12.2metres.

1.3.11 River Crossing:

In case of major river crossing in planes, tower shall be of suspension type using double suspension strings and the anchor towers on either side shall be dead end type.

Clearance required by the navigation authority shall be provided. For non-navigable rivers, clearance shall be reckoned with respect to the highest flood level.

1.3.12 Power Line crossings:

Rule87 of Indian Electricity rules 1956 states that a) When an overhead line crosses or is in proximity to another overhead line, guarding arrangements shall be provided so as to guard against the possibility of their coming into contact with each other.

a) No guarding is required when an EHV line crosses another EHV, High voltage, medium or low voltage line.

b) Where two lines cross, the crossing shall be made as nearly at right angles as the nature of case admits and as near the support of the line as practicable and the support of the lower voltage line shall be erected below the upper voltage line provided that the angle of crossing of power lines shall not be less than 60 degrees.

Where the proposed line is to cross another line of the same voltage or different voltage, angle tower with suitable extensions shall be used. In order to reduce the height of the crossing towers, it may be advantageous to remove the ground-wire of the line to be crossed (if this is possible and permitted by the owner of the line to be crossed).

Minimum clearance in metres between lines crossing each other:

		132kV	220kV	400kV	765kV
1	132 kV	3.05	4.58	5.49	7.94
2	220 kV	4.58	4.58	5.49	7.94
3	400kV	5.49	5.49	5.49	7.94
4	765kV	7.94	7.49	7.94	7.94

Where a proposed transmission line is to be taken parallel and in close proximity of existing power lines, adequate lateral clearance of minimum 300 metres may be provided to minimize induction effect to facilitate construction and maintenance in cross country reaches.

When locating terminal towers of proposed line near terminal tower of existing power line, it should be ensured that adequate electrical clearance between cross arms are available (minimum phase to phase clearance should be maintained).

Factors of safety of towers, clearances above ground of the lowest conductor, clearances from buildings for EHV lines, proximity to aerodromes, line crossings etc. are covered under the Indian Electricity Rules 1956.

Towers shall have a factor of safety of 1.5 based on the crippling load.

Clearance above ground of the lowest conductor of 33kV line shall not be less than 5.18 metres. Clearance shall raise by additional 0.3 metres for every 33kV or part thereof rise in line voltage.

Minimum clearance along or across any street shall not be less than 6.1 metres.

No conductor of an overhead line crossing a tramway or trolley-bus using trolley wires shall have less than3.05 metres clearance.

On the basis of maximum sag, vertical clearance above the highest part of the building immediately under a line shall not be less than 3.66 metres plus 0.3 metres for every additional 33kV or part thereof.

Horizontal clearance between the nearest conductor and any part of the building, on the basis of maximum deflection due to wind pressure, shall not be less than 1.83 metres plus 0.3 metres for every additional 33kVor part thereof.

1.3.13 Details enroute:

All topographical details, permanent features, such as trees, buildings etc., 13m for 132kV, 18m for 220kV, 26m for 400kV /400kVHVDC and 46m for 765 kV on either side of the alignment shall be detailed on the profile plan.

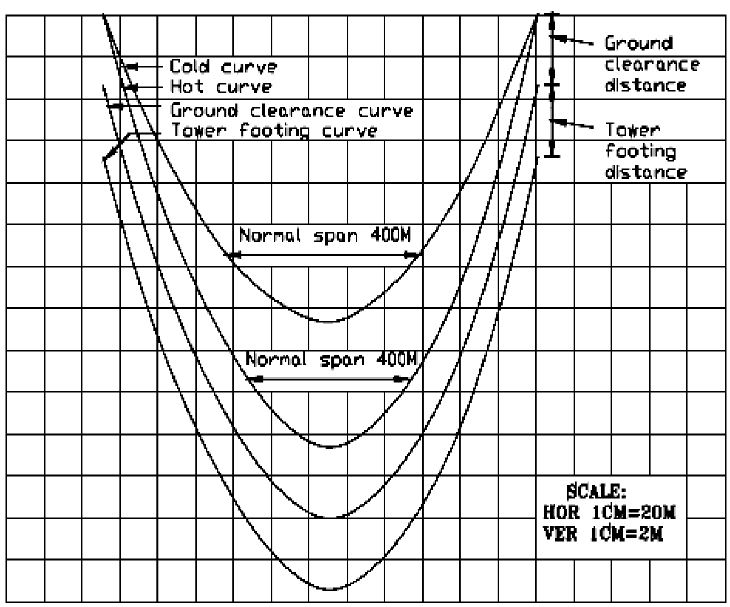
1.3.14 Sag Template

It is a very important tool for the surveyor by the help of which Tower spotting can be done. Depending upon the maximum specified permissible temperature of the conductor and zero wind condition the ground clearance is to be maintained by the line. Similarly under the specified minimum temperature of the conductor surface, with zero wind condition, the tower tensions should be within the specified limits. The sag template curves are first prepared on tracing paper and the blue print is taken out from the tracing. Their replicas on Acrylic sheets are prepared with the etching process. The Acrylic sheets are normally 2.5 to 3 mm thick.

The sag templates have the following curves etched on them.

- 'Cold or Uplift Curve' showing sag of conductor at specified minimum temperature and zero wind.
- 'Hot' or 'Maximum Sag Curve' showing maximum sag of conductor under zero wind and maximum temperature and sag tolerances are also allowed to take care of stringing error, conductor creep or snow incidences.
- Ground clearance Curve drawn parallel to hot curve and at a distance equal to specified minimum ground clearance.
- Tower footing Curve for normal tower drawn parallel to hot curve under ground clearance curve and separated by a distance equal to maximum sag at design span.

In erecting an overhead line all the spans cannot be kept equal to normal design span because of the profile of the ground and proper ground and object clearance considerations. A constant tension is calculated which will be uniform throughout the Section (from one tension tower to other tension tower), however the sags in individual spans will vary according to their respective spans. The 'Cold and Hot' Template Curves are plotted as parabola, to the same scale as the survey chart for the minimum and maximum sags for the normal span mentioned in the specification.



Application of Sag Template for Tower Spotting

The Sag Template is an important tool for correct spotting of the towers after the detailed survey work is completed. The following are the steps to be followed for correct application of sag template.

- The acrylic sag template is applied to the ground profile by moving the same horizontally while always ensuring that the vertical axis is held vertical with reference to graphed lines of the tracing paper below.
- The structure positions are marked where the tower footing curve just touches the profile, while the ground clearance curve is just clear and above the profile to the left or right of the centre line up to a distance equal to maximum cross area spread on either side.
- Besides normal ground clearance, the clearances between power conductor and objects like, other power or telecommunication lines, houses, trolley wires, roads, railway tracks, canal embankments etc., shall be checked.
- Extra clearance can be obtained either by reducing the span or providing extension to tower body, depending on which alternative is most economical.
- The weight span on either side of a tower can be easily obtained by marking the low points of sags (Null Point) in two adjacent spans and then reading the distance between the two.
- On inclined spans, null point may be outside the span. This indicates that the total weight of conductor is taken up by the higher tower and the lower tower is being pulled up by a force equal to the weight of conductor between lower support and the null point.
- Should the upward pull of the uphill span become greater than downward load of the next adjacent span, actual uplift will be caused and the conductor would tend to wing clear of the tower upwards.

The following may be adopted to check whether a tower is under uplift or not

- The Template is applied horizontally until the tops of alternate supports coincide with the Cold Curve.
- If the support is under uplift and has to be extended so as to be above it and in case requisite standard body extension do not suffice for doing this, tower which is designed to take uplift will have to be used.
- However, for the stability of the line it is not desirable to place a tower in such a position where it is always under permanent uplift condition.
- In case it becomes mandatory due to route compulsion, the cross-arms of the tower subjected to up lift shall be designed to take the extra upward pull.

- The intermediate spans shall be as near as possible to the normal design span.
- In case an individual span becomes too short on account of undulations in ground profiles, one or more line supports of the Section may be extended by inserting standard body extensions.
- Even if the line does not deviate for a long run, sections have to be provided after every 12 to 15 tangent towers. (i.e. 3 to 4 km. length).
- For this purpose a small angle tension tower designed for 15° should only be used. It is mandatory to afford better stability of the line against Transverse wind forces and to facilitate easy stringing. Besides 15° angle tension tower is most economical amongst the standard angle tension towers.

Use of computer for preparing sag template and the tower spotting

Before taking up the tower design on hand, Sag and Tension charts are required to be prepared. These charts indicate the values of sag and tension of conductor and the earth wire at Maximum temperature, minimum temperature and every-day temperature under 100%, 66% and 0% wind pressure. Normally, in plain terrain in India the maximum, minimum and every-day temperatures are considered as 75ºC, 0ºC and 32º C. These values may change in the region experiencing snow or Sub-Zero temperatures. If the conductor is required to carry large block of power, the maximum surface temperature of conductor can be taken up to 95ºC. For Earth wires the maximum temperature is taken as 53ºC

Based on the sag tension charts, the sag template curves can be plotted on the computer through a specific programme. The full scale print out of the curves is then used to prepare the Acrylic Sag Template by itching process.

The final output of detailed survey is in the form of tower schedule showing the type of tower with associated angle of deviation, span length, wind and weight spans, associated foundations along with its classifications, geological and geotechnical, data and any crossing involved in that span. The profile rolls and tower schedules finalized and approved shall be issued to contractor to proceed with check survey along the proposed alignment of the line.

Detailed survey also includes final alignment and pegging of line/direction/angle points at locations, trial pit excavation and detailed soil investigation where required. Further trees/shrub jungles and crops likely to come in the right of way clearance of the finalized line shall be enumerated during detailed survey to compute the extent of damages and compensation payable, so that payment of compensations are not delayed during construction preventing stalling of work. Soil resistivity readings are taken for every 1 kilo metre along the line in detailed survey.

1.3.15 Limitations of Conventional methods of Map study/ Surveying: Apart from taking considerable time, the conventional methods have the following limitations.

Topographical maps used for survey can be very old and do not contain recent changes in inhabitation pattern, vegetation coverage and water bodies etc.

Process of elimination is done at the ground itself which increases the number of angle locations and length of line.

Surveying staff do not have bird's eye view of the present ground condition. This may particularly result in large inaccuracies in estimation of quantities for civil works (benching and revetment) in terrains with large undulations.

There is every possibility of error in recording ground data and subsequent transfer on the route map.

1.3.16 Probable solutions for fast and reliable surveying: The following procedure at each stage of transmission line project will provide fast and reliable surveying solutions.

(a)Route planning and fixing of alignment: Data Input – Survey of India maps, Satellite data, Railway maps, land use maps, settlement maps etc are used as input for data base preparation.

GIS – Above inputs through GIS are used to update Survey of India topo sheets. Other specific maps may also be created.

Using computer run algorithms or linear programming techniques optimal transmission line route may be finalized.

On this output from GIS domain post field work is done and locational latitude and longitude of the deviation points are identified on ground using Geographical Position System (GPS)

Further in terrain having large undulations, stereoscopic satellite imageries may be used selectively to interpolate contours and digital terrain model can be used to select the route in hilly regions.

(b)Detailed survey: Aerial photography can be used as a reliable tool to record precise elevations and plan measurements of the selected route. Permission from Ministry of Defence is required for carrying out aerial photography. Flight has to be arranged on selected route. Photographs taken need to be transferred to studios for processing and detailed measurements. The same can later be verified on ground for authentication.

Once the ground profile in digital form is obtained, the estimation of various types of earth works involved viz. Benching; revetments etc can be made using software.

Appropriate techniques for obtaining soil conditions, subsoil conditions, water tables, treacherous terrain conditions etc for accurate estimation of civil works need to be explored.

When satellite imagery is used for preliminary survey there may be some error due to the shadow effect. In the above case it was found sometimes difficult to differentiate between forests and other greenery. Thus exact boundaries could not be demarcated.

Resolution plays an important part in interpreting satellite images. Power line crossings cannot be identified in the satellite imageries of 23.5m/4.88m resolution. Higher resolution may help reveal ground conditions more closely.

Ground profile and subsoil data cannot be accessed through satellite imageries.

Digitization of complete topographical maps rather select features would provide a complete replica in integrated environment.

Satellite data with 1 metre resolution will be preferable. However overall cost economics shall be worked out since this data will be costlier but will completely avoid field works.

1.3.17 Statutory Clearances in Construction:

Major statutory clearances in transmission line construction are

- Forest clearance
- PTCC clearance
- Clearances from Railways, Roadways, Navigation and Aviation Authorities
- CEA clearance
- Clearances from Local bodies and Defence authorities

Strict adherence to statutory provisions under various acts of centre and state is mandatory in the construction of Substations and transmission lines. Obtaining statutory clearances is a must for energizing newly constructed transmission system.

(a) Forest Clearance:

Forest conservation act came into existence on 25-10 1980, to protect forest lands from encroachments and to safeguard environment. Any diversion of forest land for non-forest purpose has to be approved by ministry of environment and forests (MOEF) under Central Govt. on compensation of loss of forest area / vegetation in the wake of diversion of forest land. Felling of trees in the forest land will be carried out only after approval of MOEF.

Section 2 of the act defines forest area as land covered under all reserved forests, protected forests or any other area recorded as forest in Govt's records irrespective of the ownership.

Reserved forests are natural forests having rich biodiversity. No activity is permitted in these forests without specific approval.

Protected forests are those which come up through plantation and regeneration. All activities are permitted in these forests unless something is specifically prohibited.

Dense forests are those where canopy density is more than 40%.

Open/Degraded forests are those where canopy density is less than 40%.

Plantations carried out under social forestry schemes or under compensatory afforestation schemes are covered under protected forest.

Steps in proposal formulation and approval under forest conservation act 1980:

Proposals for laying transmission line in a forest area to be submitted in a prescribed form given in FC Rules 2003 shall contain the following.

- Brief details like short narrative of project for which forest land is required.
- Total length of transmission line and the length passing through forest area.
- No. of transmission line towers and area covered by each tower, height of tower and the line.
- Towers to be erected in the forest area and right of way
- Extent of forest area to be diverted, legal status of forest land
- Whether the forest land needed for the purpose is minimum, whether no alternate alignment is possible.
- Whether forest land forms part of National park, wildlife sanctuary, Bio sphere reserve or forms part of the habitat of any endangered species of flora and fauna.

Where routing of transmission lines through forest areas cannot be avoided, these should be aligned in such a way that it involves least amount of tree cutting.

As far as possible, route alignment through forest areas should not have any line deviation.

Right of way requirements for different voltage lines on forest land are as follows:

Line voltage (kV)	Maximum right of way (metres)
11	7
33	15
66	18
110 – 132	22 - 27
220	35
400(DC - SC)	52
800	85
500 (HVDC)	52

Below each conductor, width clearance of 3mtrs. would be permitted for taking tension stringing equipment. Trees on such strips should be felled. After stringing work is completed, the natural regeneration will be allowed to come up. Felling/pollarding/pruning of trees will be done with the permission of the local forest officer, whenever necessary to maintain clearance. One outer strip shall be left clear to permit maintenance of transmission line.

In the remaining width the right of way up to a maximum of 85metres (for 800kV lines) trees will be felled or lopped to the extent required, for preventing electrical hazards by maintaining the following clearances:

Voltage (kV)	Minimum clearance between Conductors and trees (Mtrs.)
11	2.6
33	2.8

66	**3.4**
110 – 132	**3.7 – 4.0**
220	**4.6**
400	**5.5**

Sag and swing of the conductors are to be kept in view while working out minimum clearance mentioned above.

Where forest growth consists of coconut groves or similar tall trees, widths of right of way greater than those indicated above may be permitted in consultation with CEA.

Proposals for forest clearance:

Shall be submitted to Nodal officer in the prescribed proforma giving the above details. The Nodal officer will forward it to concerned Divisional Forest Officer to formulate the proposal.

Following the above, a joint inspection of Transco and forest authorities is carried out to assess the loss of vegetation. Enumeration of trees and shrubs is made species wise. These details form critical parameters for cost-benefit analysis to be done by forest authorities.

Transco shall give a certificate that they will provide cost of compensatory afforestation, net present value and royalty for timber and for operational cost for extraction of timber from project site.

Suitable degraded forest land / alternate land shall be identified for preparation of compensatory afforestation (CA) scheme. CA shall be done over equivalent area of non-forest land. The identified land shall be contiguous to or in proximity of reserved forests or protected forests. Where non forest land for CA is not available in the same district, non forest land anywhere in the state as near as possible to the site of diversion shall be identified.

Where non forest land is not available or available to a lesser extent than forest area being diverted, CA is carried out over degraded forest twice the area being diverted.

The proposal bearing the above details is then resubmitted by Divisional Forest Officer to the Nodal Officer through Conservator of Forests. Nodal officer after examining the proposal forwards it to Principal Chief Conservator of forests, and then to Secretary (Forests) of the state Government.

The State Government recommends the proposal to the concerned regional office of Ministry Of Environment and Forests (MOEF) if the area involved is 40 hectares or less and to MOEF, New Delhi if the area is more than 40 hectares for processing and approval.

Regional MOEF approves the proposal if the area is up to 5 hectares. In case of the area above 5ha and up to 40ha, Regional MOEF processes the case in the State Advisory Group (SAG) and recommends the proposal to MOEF New Delhi for minister's approval.

MOEF New Delhi directs the Regional MOEF to conduct inspection of the site, where the forest area involved is more than 100Ha. If the area in question is significantly rich in wild life, special recommendation of Chief Wildlife Warden of the state is sought. Proposals containing the above details are then submitted to Forest Advisory Committee (FAC) of MOEF for its views. The committee is headed by Director General of forests, with Addl.DG, Addl. Commissioner (Soil Conservation, Ministry of Agriculture), 3-non official experts one each in Mining, Civil Engg. and Development economics as Members. The committee after deliberations gives its views for approval or otherwise on the proposal. With these details proposal is submitted to the Minister of Environment and Forests. Approval of Minister marks the in principle or first stage clearance of proposal.

When the stipulated conditions like funds to the State Forest department for raising of CA are met, on such a certificate from the State Government, Govt. of India conveys its final or second stage approval.

(b) PTCC Clearance:

To solve the problems of inductive interference and to resolve any conflict of interest in regard to location and working of power and telecom line, Govt. of India constituted a central standing committee of coordination of power and telecom lines in May 1949 called Power & Telecom Coordination Committee. The committee comprises of members from Telecom, Railways, army, Ministry of Energy and State Transcos.

Due to proximity and parallelism of telecom and power lines, the performance of telecom lines is adversely affected. They are subject to dangerous induced voltages in the event of earth faults on power lines. To avoid induction, transmission line route is selected in such a way that line alignment remains away from telecom lines as far as possible.

PTCC clearance is required for crossing of any P&T line as per the laid down procedure.

On completion of preliminary survey, proposal is submitted in the prescribed forms accompanied with all the system data and route maps of transmission lines. All the telecom lines falling in the vicinity of the power line (8 kms on either side) are marked along with the computations of induced voltages.

Depending on the magnitude of induced voltage protective measures are taken for the affected telecom circuits. Protective measures to be taken for various induced voltage levels are given in the following table.

Induced voltage levels	Protective measures
Up to 430 V	No protection required
430 – 650 V	Adequate no. of Gas discharge (GD) to be Provided by Telecom authorities at their cost
650 – 2000 V	GD tubes to be provided by later entrant
More than 2000 V	Re- Engineering to be done

(c) **Proximity to Aerodromes:** Overhead lines shall be erected in the vicinity of Aerodromes only after the route of proposed line is approved by airport authorities.

Details such as flying tunnel limits, areas of aerodromes, landing strips etc. should be collected from the appropriate agencies.

As per the circular of Directorate of Air Routes and Aerodromes, overhead HT/LT lines shall not be permitted within 3.05kms of an airport. Beyond the radius of 3.05kms and up to 15.24kms from an airport (having runway of 5000 ft or more) construction is permitted subject to painting of all structures above 35 metres with day and night marking.

Advance action shall be taken by the SE/TLC In consultation with CE/construction, headquarters to obtain the statutory clearances from Power & Telecom Coordination Committee (PTCC) for new Transmission lines routing, permission from Railways for crossing of transmission lines over the railway tracks and from Civil. Aviation Authorities for Towers to ensure that there shall be no hold up of works for want of these clearances / permissions.

1.3.18 CHECK SURVEY FOR TOWERS:

Check survey shall be conducted to locate and peg mark the tower positions on ground conforming to the approved profile and tower schedule using GPS, Total Station, and Digital Theodolites etc. In the process, it is necessary to have the pit centres marked according to the excavation marking charts. The levels, up or down of each pit centre with respect to the centre of the tower location shall be recorded at intervals of 2 metre using Total station/GPS/ Digital Theodolites and digitized contour plans shall be made and recorded for determining the amount of earthwork required to meet the approved design parameters.

Changes in the preliminary tower schedule after detailed survey, if required, shall be carried out by the contractor and he shall thereafter submit a final tower schedule for the approval of owner. The tower schedule shall show position of all towers, type of towers, span length, type of foundation for each towers and the deviation at all angles as set out with other details.

1.3.19 RIGHT OF WAY, CUTTING / TRIMMING OF TREES, ETC.

Any lopping or trimming of tree branches obstructing the line of sight during survey shall be the responsibility of the contractor. Clearing of obstructions falling in the right-of-way as per IS: 5613 (Part 3/Section 2)-1985 and lopping or trimming of the portion of the trees falling within the minimum electrical clearance zone shall be the responsibility of the Purchaser

Clearance from ground, buildings, trees and telephone lines shall be provided in conformity with the Indian Electricity Rules, 1956 as amended up to date.

The contractor shall count, mark and put proper numbers with suitable quality of paint at his own cost on all the trees that are to be cut by the owner at the time of actual execution of the work as detailed below. Owner shall not pay any compensation for any loss or damage to the properties or for tree cutting due to contractor’s work.

To evaluate and tabulate the trees and bushes coming within right of way on either side of the central line alignment, the trees will be numbered and marked serially from angle point 1 onwards and the corresponding number will be painted on the stem of trees at a height of 1 metre from ground level. The trees list should contain the following:

a) Girth (circumferences) measured at a height of 1 meter from ground level.
b) Approximate height of the tree with an accuracy of + 2 metres.
c) Name of the type of the species/ tree.
d) The bushes and shrubs encountered under the r.o.w. for lines should also be evaluated with their type, height, girth and area in square meters, clearly indicating the growth in the tree/ bush statement.

On fixing of the line route after carrying out the detailed survey, a detailed enumeration of area of land and the number of trees with classification, likely to be affected in the corridor on construction of transmission lines, shall be assessed by the EE/TLC concerned. The details of extent of land, crop & trees likely getting affected, owner particulars, crop/tree, classification in the identified areas duly certified by local Revenue Authorities, etc, shall be prepared in the prescribed format by the EE/TLC and a provisional estimate shall be finalized for including in the technical estimate. At the time of taking up the excavation of foundations, tower erection, paving & stringing of line, the Crop/Tree Compensation Forms, as prescribed, shall be got filled up by the land owners and consolidated statements along with assessed tree compensation shall be furnished to Chief Engineer (Construction projects) at Headquarters, to facilitate processing the case for payment without delay and to avoid any hindrance to the construction programme on account of non-payment of crop compensation to the land owners in time.

1.3.20 Survey Report.

Complete bill of quantities (BOQ) of the transmission lines shall be furnished in the survey report.

Each angle point location shall be shown with detailed sketches showing existing close by permanent land marks such as specific tree(s), cattle sheds, homes, tube wells, temples, electric pole/ tower, telephone pole, canal, roads, railway lines etc. The relative distance of land marks from the angle points and their bearing shall be indicated in the sketch. These details shall be included in the survey report.

Information with regard to infrastructure details available enroute, identification and explanation of route constraints, etc shall also be furnished in the Survey report and shall inter-alia include the following:

- Information regarding infrastructural facilities available along the final route alignment like access to roads, railway stations, construction material sources (like quarry points for stone, sand and availability of construction water) labor, existing transport facilities, fuel availability etc., shall be furnished in the survey report.
- All observations which the contractor thinks would be useful to the construction of the transmission lines mentioned under scope of the work are to be reported.
- Suggestions regarding the number of convenient zones (line segments/ portion) in which the entire alignment can be divided keeping in view the convenience of owner are to be pointed.

- Working months available during various seasons along the final route alignment, with period, time of sowing & harvesting of different type of crops and the importance attached to the crops particularly in the context of way leave problems and compensation payable shall be stated by the contractor.
- Availability of labor of various categories and contractors of civil works shall be reported.
- Some portions of the line may require clearance from various authorities. The contractor shall indicate the portion of the line so affected, the nature of clearance required and the name of the concerned organizations such as local bodies, municipalities, P &T (name of circle), Inland navigation, Irrigation Department, Electricity Boards and Zonal Railways, Divisional Forest Authorities etc.
- All the requisite data for processing the case of statutory clearances such as PTCC, Forest and Railway shall be provided along with the report.
- The contractor shall also collect details pertaining to pollution levels envisaged along the transmission line.

1.3.21 Soil Resistivity: Soil resistivity along the alignment, shall preferably be measured in dry weather by four electrodes method keeping inter electrode spacing of 50 meters. For calculating soil resistivity, formula $2\pi ar$ (where a = 50 meters, r = megger reading in ohms, π=3.14) shall be adopted. Measurements shall be made at every 1km along the route. In case soil characteristics change within 1 km, the value shall also be measured at intermediate locations. The megger reading and soil characteristics shall also be indicated in the soil resistivity results.

1.4 Soil Investigation: Classification of foundation at each location shall be made after soil investigation. For each type of tower different types of foundations are to be designed suitable for different soils.

Soil investigation is made to ascertain the composition and type of soil. Various types of soils are given below.

1) Normal Soil: Vegetable or organic soil, turf, sand, ordinary gravel, clay, mud, black cotton soil, soft soil and loose morram.
2) Hard Soil: Hard gravel, hard morram, kankar, lime stone, and stone matrix.
3) Soft Rock: Decomposed rock, laterite or soft disintegrated rock which generally requires chiseling, wedging and hammering, besides the use of pickaxe or crowbar and spade.
4) Hard Rock: Hard rock is the one which has to be excavated by drilling and blasting.
   a) Any rock or boulder, of a volume of more than 3cu.m per each boulder, of the excavation for which blasting is required.
   b) Hard rock requiring blasting as described above but where blasting is prohibited for any reason, then excavation is carried out by chiseling, wedging or any other agreed method.

Detailed geo-technical investigation at specified number of tower locations need to be done to provide sufficiently accurate information, both general and specific about the substrata profile and relevant soil and rock parameters at site on the basis of which the foundation of transmission line towers can be classified and designed rationally

Detailed soil investigation shall be carried out at all important locations such as the crossing of railway lines, national highways, power lines, and location identified by the purchaser. Boring of trial holes or excavation of test pit to at least 3 metres depth or more is to be made depending upon the design depth of foundation proposed in the bid and bore log data including depth of the ground water with table shall be furnished. Data regarding variation of subsoil water table along the proposed line route shall also be ascertained.

Special care shall be taken for locations where marshy soils are encountered and Contractor in such cases shall ensure that specified numbers of vane shear tests are performed and the results correlated with other soil parameters.

Wherever possible, contractor shall obtain information and review existing local knowledge of neighbouring streams, water resources, abandoned under ground works, nearby quarries, unlined wells, excavations, records of test pits, boreholes, recent land fills, land slides etc., types of foundations adopted and the behaviour of existing structures, particularly those similar to the present project. Study of the general topography of the surrounding areas will often help in the delineation of different soil types.

1.4.1 CODES AND STANDARDS FOR GEOTECHNICAL INVESTIGATION

All work shall be carried out in accordance with the following Indian Standards and Codes

Indian Standards (IS)	Title	International and Internationally Recognised Standard/ Code
IS : 1080	**Codes of Practice for Design and Construction of Simple Spread Foundations.**	
IS: 3025	**Methods of Sampling and testing (Physical and Chemical) for Water used in Industry**	
IS : 1498	**Classification and Identification of Soils for General Engineering Purposes.**	**ASTM D 2487** **ASTM D 2488**
IS : 1888	**Method of load tests on soils**	
IS : 1892	**Code of Practice for Subsurface Investigation for Foundation.**	
IS : 1904	**Code of Practice for Design and Construction of Foundation in Soils: General Requirements**	
IS : 2131	**Method of Standard penetration test for Soils**	**ASTM D 1586**
IS : 2132	**Code of Practice for Thin Walled Tube Sampling of Soils**	**ASTM D 1587**
IS : 2720	**Method of Test for Soils (Relevant parts)**	**ASTM D 420**

IS : 2809	**Glossary of Terms and symbols relating to soil engineering**	**ASTM D 653**
IS : 2810	**Glossary of Terms and symbols relating to soil engineering**	
IS : 4078	**Code of practice for indexing and storage of drill cores.**	
IS : 4434	**Code of practice for In-situ Vane Shear test for soils**	**ASTM D 2573** **ASTM D 4648**
IS : 4453	**Code of Practice for exploration by pits, trenches, drifts and shafts**	
IS : 4464	**Code of practice for presentation of drilling information and core description in foundation investigation**	
IS : 4968	**Method for subsurface sounding for soils, dynamic method using cone and bentonite slurry**	
IS : 5313	**Guide for core drilling observation**	
IS : 6403	**Code of practice for determination of allowable bearing pressure on shallow foundation**	**ASTM D 194**
IS : 6926	**Code of practice for diamond core drilling for site investigation for river valley projects.**	
IS : 6935	**Method of determination of water level in a bore hole.**	
IS : 7422	**Symbols and abbreviations for use in geological maps. Sections and subsurface exploratory logs (relevant parts)**	
IS : 8009 (Part-1)	**Code of practice for calculation of settlements of foundations (shallow foundations subjected to Symmetrical vertical loads).**	
IS : 8764	**Method for determination of point load strength index of rocks**	
IS : 9143	**Method for determination of unconfined compressive strength of rock materials**	**ASTM D 2938**
IS : 9179	**Method of Preparation of rock Specimen for laboratory Testing**	**ASTM D 4543**
IS : 9259	**Specification for Liquid Limit Apparatus**	**ASTM D 4318**
IS : 9640	**Specification for Spilt Spoon Sampler**	**ASTM D 1586**
IS : 10050	**Method of Determination of Slake Durability Index of Rocks**	**ASTM D 4644**
IS : 11315	**Description of Discontinuities in Rock Mass – Core recovery and Rock Quality.**	
	CBI&P Manual on Transmission Line Towers – Chapter 10: Foundation	

1.4.1 Soil Investigation at Normal Locations: One bore hole of 150 mm dia shall be drilled at the center point of the tower. Standard penetration Test (S.P.T) shall be carried out at 1.50 m interval or change of strata up to the required depth of 2 1/2times below the depth of foundation below existing surface elevation or refusal whichever occurs earlier (By refusal it shall be mean that a standard penetration blow count 'N' of 100 is recorded for 30 cm penetration). Bore details and water table up to required depth below existing surface elevation or refusal whichever occurs earlier shall be furnished in the report.

1.4.2 Soil Investigation at Special Locations: At certain locations such as river banks, river beds or midstream of river and at other places, special soil investigation shall be carried out by drilling two holes each of 150 mm diameter at each tower location on the diagonally opposite legs of the tower, considering the base width of tower as 20m.

Standard penetration tests shall be carried out at every 3.0 m intervals or change of strata till refusal is met subject to maximum of 50 m below the existing surface elevation.

Undisturbed samples of soil shall be collected at every 5m intervals up to 15 mts and 3mts beyond 15 mts. or change of strata whichever occurs earlier.

In the hard rock the bore drilling shall be continued at least 5m to ascertain its sufficient thickness.

Samples collected through any of the above methods are tested for sieve analysis, liquid, plastic and shrinkage limits, specific gravity, chemical analysis, free swell index etc to establish bearing capacity and density of soil.

1.4.3 Preparation of Test Reports

The investigation report shall contain the following test results:

1. Grain size analysis
2. Nomenclature of soil
3. Atterbergs limit (Liquid and plastic limit only)
4. Tri-axial shear test results containing information about angle of internal friction and cohesion.
5. S.P.T results containing information about natural moisture content, Specific gravity and Bulk unit weight.
6. Consolidation test.
7. Unconfined compression test
8. Unconsolidated un-drained test.
9. Presence of carbonates, sulphates, nitrates and organic matters and any other chemicals harmful to the concrete foundation –obtained from chemical test on soil sample.
10. For rocky, soil core recovery and crushing strength of the rock shall be furnished.

11. The bearing capacities of soil at 3.5 m below the existing surface elevation for normal investigation and at a depth fixed considering the bore log data as mentioned in clause 11.13.3 below the existing surface elevation for special soil investigation shall be furnished considering approximate base width of foundation.

In addition to the above the following data also shall be furnished in the report of special soil investigation.

1. Scouring depth in case the locations area at the bank of river or at midstream duly collecting the Hydraulic particulars of the river from CWC or State authorities corresponding to the nearby station. However, the hydraulic data may be corrected / modified with respect to the topography / cross section of the river at that particular location.
2. Silting factor in case of midstream and river bank locations where submergence is envisaged.
3. Depth of fill, if any
4. Details of water table, water struck etc.
5. Compressibility of sub-soil stratification.
6. Settlement characteristics of the shallow foundations.

The above test results shall be summarized strata-wise as well as in a combined tabular form with all relevant graphs, charts, tables, diagrams and photographs, if any, shall be furnished in the test reports.

The test report shall include bore logs. Bore logs of each bore hole clearly identify the stratification and type of soil stratum with depth up to the refusal. The locations of water table shall be identified on the bore log. The value of SPT at depth where conducted and various laboratory tests conducted from samples collected at various depths shall be clearly shown against the particular stratum.

The report should contain specific recommendation for the type of foundation. In case the soil parameters obtained from the soil investigation report for a particular tower location differ from the ones considered during design, the Purchaser will develop a fresh design.

The type of foundations to be constructed at each tower site shall be based on the soil characteristics indicated on the route profile sheets and as determined by the contractor and approved by the Purchaser during the progress of the work. The Purchaser reserves the right to change the type of foundation at any location where conditions during the progress of work indicated the use of a different type of foundation.

The Purchaser will furnish the foundations designed for the soil conditions encountered in the excavations. If the soil conditions vary significantly between different excavations on one tower then foundations of different classes may be installed. The foundations for each tower in a straight section of the line shall be placed so that the longitudinal axis of the tower cross arm will be in a plane perpendicular to the transverse of the line. Unless otherwise directed by the purchaser, the foundations for each angle tower shall be placed in a manner so that the tower cross arms lie in a plane bisecting the interior angle formed by the intersection of the transverses of adjacent sections of the line. .

When determining the classification of the foundation at site the following procedure shall be followed.

i) The initial excavation shall be done to the dimensions of the immediate smaller foundation classification to that determined by the soil investigation.
ii) The base of the excavation shall be examined to determine the bearing capacity of the soil and the minimum foundation classification ascertained.
iii) The walls of the excavation shall be examined to determine the soil classification, angle of repose, and a suitable foundation classification selected to meet the soils encountered.
iv) The level of ground water or the expected level of ground water during the rainy season or standing water over the site shall also be considered when determining the foundation classification.

Characteristic values of different soils are as given below.

Type of Soil	Bearing strength Kg/Sq.Mtr	Weight of soil Kg/Cu.Mtr	Angle of Repose Degrees
Normal Dry soil	27350	1440	30
Soil in Wet Location	13675	940	15
Soft Rock (Dry Black cotton soil)	62500	1440	20
Hard Rock	125000		

Lateral Bearing Strength of Earth:

$$\text{Side Thrust Force (F)} = \frac{1}{2} \times \frac{W \times h2 \times B \times (1+\sin \Phi)}{(1 - \sin \Phi)}$$

where W= Weight of soil, B= 0.65, Φ = Angle of earth frustum.

1.4.4 Classification of Foundations: Similar but separate foundations are to be laid for the four legs of a lattice tower. For each type of tower different types of foundations are to be designed suitable for different soils.

Following types of foundations are adopted under normal conditions.

1) Inverted frustum with chimney and bottom concrete pad with or without steel reinforcement
2) Stepped pads with chimney, with or without steel reinforcement
3) Mass concreting of excavated pits of designed dimensions for rocky locations
4) Well foundations with anchor bolts laid in river bed locations
5) Pile foundations in locations where soils of poor bearing capacity are met with.

The foundation designs for various types of Foundations as given below shall be adopted in the construction of Transmission Lines and shall be based on the following instruction.

Sl. No.	Soil at the location of tower	Classification of foundation to be adopted.
1.	Where normal dry cohesive or non-cohesive soils are met	Dry
2(a).	Where sub-soil water is met at 1.50 meters or more below the ground level in normal soil	Wet
(b)	Where surface water could stand for long period with water penetration not exceeding 1.0 m below ground level (e.g. Paddy fields, Sugarcane fields)	
3(a).	Where sub-soil water is encountered between 0.75 meter and 1.50 meters depth below ground level.	Partially Submerged / Partially Black Cotton
(b)	Where top layer of Black Cotton soil extends up to 50% of the depth with normal soil thereafter	
Note – 1	Where soil is clayey type, not necessarily black in color, which shrinks when dry, swells when wet.	
4(a)	Where sub-soil water Table is within 0.75 m depth from ground level.	Fully Submerged – Black Cotton
(b)	Where top layer of Black Cotton soil exceeds 50% and extends up to full depth or is followed by normal soil.	
(c)	Where top layer is normal soil up to 50% of the depth but the lower layer is a Black Cotton soil	
Note – 2	In case of items 4(a), (b) & (c) above, the concerned Superintending Engineer (Civil) shall personally inspect and certify on soil classification and shall not delegate this responsibility to any sub-ordinate officers.	
5(a)	Where decomposed or fissured rock, hard gravel, kanker, limestone, laterite or any other soil of similar nature is met.	Fissured / soft rock
(b)	Where top layer of normal dry soil extends up to 85% of the depth followed by fissured rock without presence of water.	
6(a)	Where Hard rock is encountered at 1.5 m or less below ground level.	Hard Rock

(b)	Where Hard rock is encountered form 1.5 m to 2.5 m below Ground Level though Top layer is of normal soil	
(c)	Where chiseling, drilling and blasting is required for excavation.	
Note – 3	While classifying foundation of Wet, Partially Submerged / Partially Black Cotton, Fully Submerged / Black Cotton foundations mentioned above, the worst conditions may be considered and not necessarily the conditions prevailing at the time of inspection. For instance, there are areas where sub-soil water rises when canal water is let-out in the field raising sub-soil water to a considerable degree. Similarly the effect of monsoon or when the nearby reservoirs are full should be considered and not the conditions prevailing in open season or summer when work is carried out normally. In all such cases, the Chief Engineer (Civil) shall personally inspect and certify the requirement of higher classification on case to case basis.	
Note – 4	For critical locations of cut-point / Angle Towers, the classification of Tower Foundations may be at next higher type for ensuring safety of the transmission line that is likely to be subjected to variable forces from time to time on account of change in season and climatic conditions. This shall be decided by the concerned Superintending Engineer (Civil) on case to case basis on personal inspection.	
Note – 5	In case of highly collapsible & loose soils and river crossings, special design for foundations is to be made by Civil Engineering Wing for adoption on case to case basis.	
Note –6	At locations subjected to water logging, particularly in paddy fields, ponds, marshy areas, etc., the chimney of all stubs to be raised to 600 mm over the normal chimney being adopted in other cases. This shall be done after complete erection of towers as a separate item for identified locations.	

In addition to the above, depending on the site conditions more varieties of foundations may be introduced suitable for intermediate conditions under the above classifications to effect more economy.

In case of any deviation in classification of any foundation found necessary at the time of execution of the works in the earlier finalized classification, such deviation shall be permissible only with prior approval of the Chief Engineer of the respective TL & SS Zone based on Justification for such deviation up to 10% of the total number of locations ***I*** concrete volume of the line. Above such limit, the approval is to be accorded by the Committee of Technical Directors.

Vigilance wing shall test check the soil classification finalized by the detailed survey other than dry.

1.4.5 Design of Foundations:

Factor of safety to be adopted: 132kV, 220kV and 400kV lines – 1.1for normal conditions and 1.1 for broken wire condition based on limit load concept.

Nature of loads considered in designing foundations: Down thrust or compression for normal and broken wire condition, Uplift for normal and broken wire condition and Side thrust – Transverse / longitudinal for normal and broken wire condition.

The following characteristic values of concrete of 1:2:4 mix are adopted in the design of tower foundations.

1)	Weight of dry concrete	=	2400 kg / Cu.Mtr
2)	Weight of concrete in wet and Submersible location.	=	1400 kg / Cu.Mtr
3)	Bond strength between stub Angle and concrete	=	10 kg / sq. cm.
4)	Maximum stress in concrete	=	153 kg / sq. cm.
5)	Limit bond stress between concrete and reinforcement steel deformed bars in Tension	=	16 kg / sq. cm.
6)	The modular ratio m	=	19

1.5 Construction of Transmission Lines

Works below Ground level:

1.5.1 Setting of Stubs:

The stubs shall be set correctly at the exact locations and alignment and precisely at correct levels. Stubs shall be set in the presence of authorized representative of the purchaser available at site, for which adequate advance intimation shall be given to the purchaser by the contractor.

The concrete level shall be set with their tops 225 mm (minimum) above ground level and coping shall be of 75mm above the chimney.

The embedded end of the stub angle shall have a 150mm thick clear concrete cover over the top of lean concrete sub-base in case of dry foundations and a 200mm thick clear cover in case of wet, PS, and FS foundations.

The minimum length of stub encased in concrete below the ground level shall not be less than 1.5 m. However the stub shall extend up to the bottom of foundation having a clear concrete cover as specified above.

The depth of foundation below ground level shall be 3.5m. Except in hard rock foundation, the cutting of stub length is not allowed in any circumstances.

In any case the foundation should be 3.0m for each leg in original soil irrespective of the level difference between any two legs. The level difference up to 1.5m should be covered with extended stub along with chimney in addition to the standard length. The extended stub and chimney details will be furnished by Purchaser at the time of execution.

1.5.2 Excavation:

Earth excavation has to be done in all types of soils which can be excavated with pick axe & crow bars in all conditions such as dry, wet, slushy etc., and in hard rock requiring blasting including shoring, shuttering and dewatering wherever necessary covering initial lead and one extra lift. The contractor must satisfy himself about general conditions of transmission line route and ascertain the existing and future obstructions likely to come up during the execution of the contract to carry out the work. Excavation shall be as per approved drawing.

The grading near all excavations shall be controlled so that the surface of the ground will be properly sloped or diced to prevent surface water from running into the excavated areas during construction.

Excavation shall include blasting if required and the removal of all materials required to execute the work properly and shall be made with sufficient clearance to permit the placing, inspection and setting of forms and completion of all works for which the excavation was made.

Sides and bottoms of excavations shall be cut sharp and true. When machines are used for excavation, the last 300 mm before reaching the required level shall be excavated by hand or by such equipment that will leave the strata at the required final level, in its natural condition. The bottom of excavation shall be trimmed to the required level. Any extra excavation when carried below the prescribed level shall be brought to the prescribed level by filling with the lean concrete as specified at the contractor’s cost.

All excavations for installation of underground facilities, such as piping, trenches, ducts, etc. shall be open cut.

Excavations for foundations shall be carried to an adequate depth below the bottom of structural concrete and then be brought to the required level by sand filling and/or placing lean concrete of 1:4:8/1:3:6 mix with aggregate of 40 mm nominal size.

Where the excavation is to be carried out below the foundation level of an adjacent structure, precautions such as under pinning, shoring and strutting etc. shall be taken. No excavation shall be done unless such precautionary measures are carried out as per direction of Engineer-in-charge.

Loose, soft, in sand or in loose strata encountered in excavation at the required depth shall on Engineer-in-charge's instructions be excavated to a firm bed and the difference made up to the required level by filling with lean concrete PCC (1:4:8) conforming to IS: 456-2000. No foundation shall rest on filled up soil. In case filled up soil is encountered below the foundation, excavation shall be carried up to 500mm in original soil and the space between level of foundation and 500mm in natural soil shall be back filled with sand (if the space is up to 500mm) or PCC 1:4:8 (if the space is more than 500mm).

Foundation pits shall not be excavated to the full depth unless construction is imminent. The last fifteen (15) cm depth of the excavation shall not be removed until concreting work is imminent.

1.5.3 Shoring and Shuttering: Shoring and shuttering shall be done keeping in view the requirements given in IS: 3764 (latest). For excavations to be made in sandy soils or water bearing strata or in any other type of soil where there is every likelihood of pits collapsing, shoring and shuttering made out of timber planks or steel frames of adequate strength as per requirements shall necessarily be provided.

Where excavation required bracing, sheeting or shoring etc. the contractor shall submit to the purchaser the design and drawings showing arrangement and details of proposed installation for examination and approval, and shall not proceed until approved by the purchaser.

1.5.4 Excavation in Hard Rock: In case of excavation in hard rock requiring blasting, extreme care shall be taken with regard to storing, handling and use of explosives. Materials used for blasting such as explosives, detonators, fuses, tamping materials etc. shall be of approved make and of good quality. Proper storage of these materials shall be ensured.

The contractor shall familiarize himself with all applicable laws and regulations. Also reference to S.S.no.203 of APDSS shall be made.

Blasting operations shall be carried out under the supervision of competent and licensed person and trained workmen. Proper precautions for safety of persons and property shall be taken.

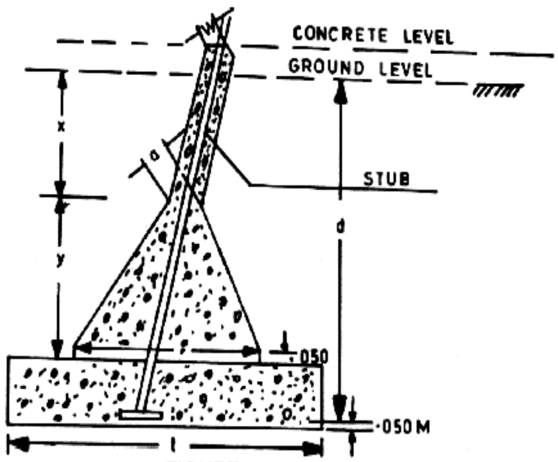
Where blasting is prohibited or not practicable, excavation shall be carried out by chiseling at no extra cost to the owner. The decision of the Engineer-in-Charge in this regard shall be final.

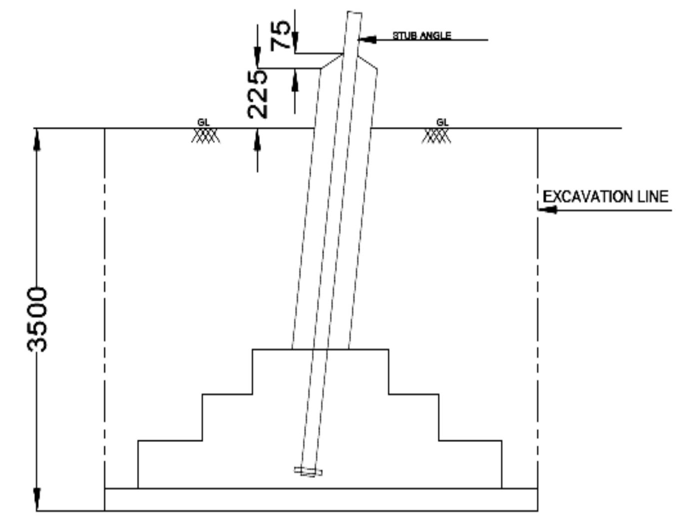
1.5.5 Excavation below Water Table: Wherever water table is met with during the excavation, the Contractor shall dewater and maintain the water table below the bottom of the excavation level during excavation, concreting and backfilling. The guidelines for de-watering during construction specified in IS: 9759 (latest) shall be followed. Dewatering shall be carried out either manually or by mechanical pumps or power driven pumps to facilitate excavation and casting of foundation. The pumps shall be suitable for handling muddy water. The pits shall be kept dewatered until 24 hours after concreting the foundations.

All excavated materials such as hard rock, boulders, bricks, dismantled concrete blocks, etc. shall be stacked separately as directed by the Engineer and shall be the property of the Purchaser.

Excavated material shall be placed beyond 1.5 meters from the edge of the pit or trench or half the depth of the pit or trench whichever is more or further away if directed by the Engineer. Excavation shall not be carried out below the foundation level of structure close by until required precautions have been taken.

1.5.6 Foundation in Normal Dry Location:





TYPICAL DRY,WET TYPE FOUNDATION

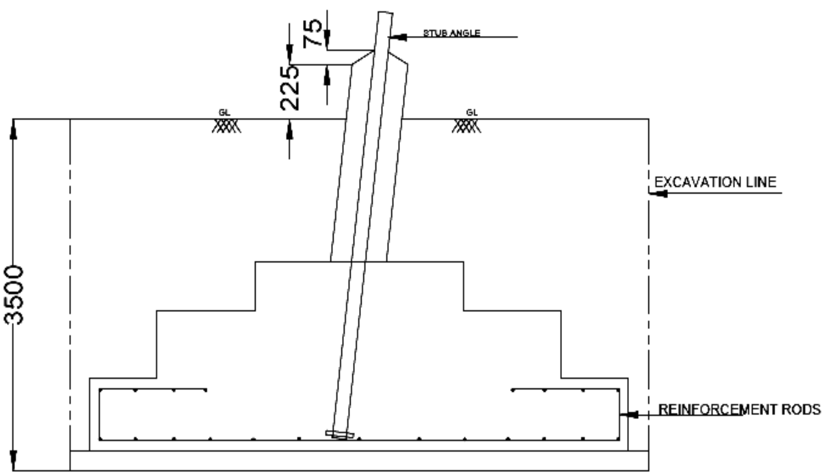
The maximum compression is obtained by applying the factor of safety to the value of compression due to Bending Moment Forces acting on the tower, dead weight of tower and power conductors and ground wire and weight of concrete. The bearing strength of the ground of area 'b' Sq. Mtr. should be more than the above maximum compression. The total uplift force is calculated based on the transverse and longitudinal forces. The minimum vertical loads due to conductors and ground wire and the dead weight of tower and weight of concrete are calculated per leg and deducted from the total uplift force to arrive at the net uplift. Counter weight for this uplift is provided by the weight of earth pyramid and concrete frustum. It is to be checked whether maximum uplift after applying factor of safety is fully compensated by the counter weight. The proposed foundation has to be checked for side thrust also. Based on the horizontal component of the stress in the stub, the maximum side thrust is calculated after applying the necessary factor of safety. The lateral bearing capacity of the soil is obtained by calculations based on the soil characteristics. This lateral bearing capacity of the soil should be equal to or more than the above maximum side thrust. The depth of the stub below ground level indicated as'd' is decided by the design of tower and hence cannot be altered. While choosing dimensions 'a' and 'w', care must be taken to ensure that the thickness of concrete all around the stub is not less than 100 mm.

1.5.7 Foundation in Wet Locations:

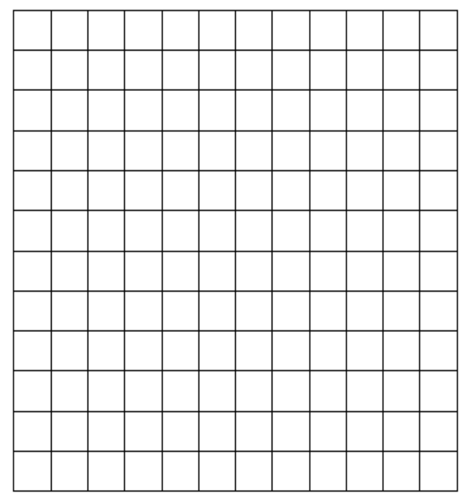
In case of wet foundation, the bearing strength of the soil is half of dry soil and the angle of internal resistance. In view of this an additional concrete slab with or without steel reinforcement as shown in fig, underneath the inverted frustum may be provided. However, the dimension 'x', 'y' and 'z' have to be chosen, keeping in view the fixed dimension d (depth of stub below ground level).

1.5.8 Foundation in Submersible Locations:

In case of fully submergible location steel reinforcement has to be provided in view of a large bottom concrete pad and as the over-hang of bottom concrete pad in too long to be contained under compression. The dimensions t and z are determined based on the soil characteristics and the design values of compression and uplift.



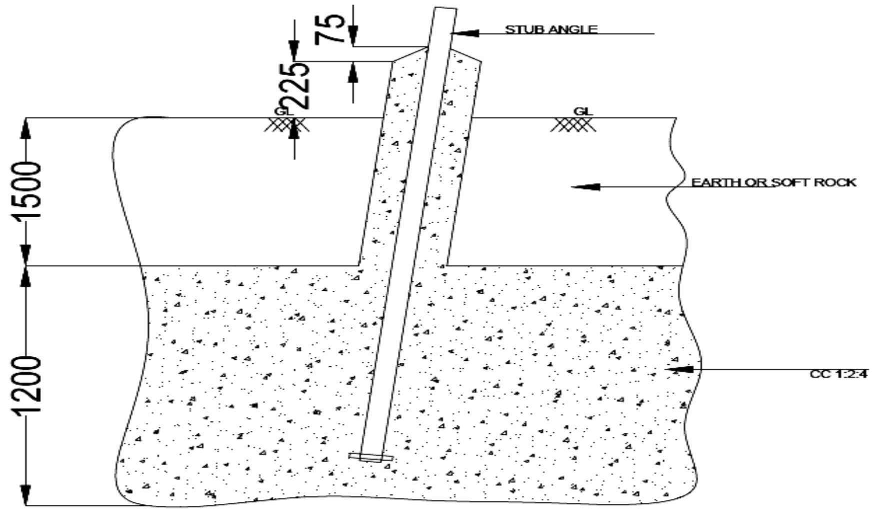
TYPICAL PS, FS TYPE FOUNDATION



REINFORCEMENT PLAN

1.5.9 Foundation in Rocky Locations

In view of tremendous bearing strength of rock and bond strength between stub angle and concrete, special type of foundation is to be designed providing for preparing a much smaller pit and mass concreting after stub setting. The base width and depth in the hard rock have to be decided based on the design values of compression and uplift. The excavation in the hard rock is to be done by drilling, blasting and chiseling. Dimensions of the pit shall be limited to base width and depth within hard rock portion. After stub setting the pit in the hard rock and chimney shall be filled with concrete of 1:2:4 Mix as shown in the figure. Depending upon how deep below ground level, the rock is met with; the stub angle may have to be cut to limit the depth of stub below ground level to (C-0.050) mtrs. It may be noted that necessary holes have to be provided at the bottom of the stub angle to fix the cleat. The remaining portion of the pit above the hard rock level shall be backfilled with the excavated rock bits and earth properly rammed to form a homogeneous earth pyramid. The dimension of the surface width at the hard rock portion may be kept slightly less than the designed base width at the bottom of hard rock to ensure rigidity of concrete block. The dimension of chimney portion may normally be taken the same as those of wet foundations.



HARD ROCK FOUNDATION

1.5.10 Backfilling:

After completion of foundation work and prior to backfilling, all forms, temporary shoring, timber etc. shall be removed and the excavation cleaned of all trash, debris and perishable materials. Backfilling shall begin only with the approval of the purchaser.

Backfilling of excavation in trenches around foundations and elsewhere shall be with one of following materials, as directed by the Engineer-in-charge in each location.

- Ordinary soil
- Selected earth from soil heap or from borrowed area.
- Hard core.
- Sand filling
- Lean concrete. The material shall be free from fobbing roots, hard lumps and any other foreign organic materials

Excavation shall be cleaned of all trash, debris and perishable materials before backfilling.

Backfill shall not be dropped directly upon or against structure or facility where there is danger of displacement or damage. Backfill shall be placed in horizontal layers not exceeding 150 mm in thickness. Each layer shall be compacted with proper moisture content and with such equipment as may be required to obtain a density equal to or greater than 94% of maximum as determined by the IS:2720 and IS:4701. For cohesive soils each layer shall be wetted, or dried by aeration, to a moisture content of 3 to 5 per cent above optimum. Trucks or heavy equipment for depositing or compacting backfill shall not be used within 1.5 meters of building walls, or other facilities which may be damaged by their weight or operation. Pushing of earth for back filling shall not be adopted under any circumstances. Backfill adjacent to pipes shall be hand placed, free of stones, concrete etc. compact uniformly on both sides of the pipe and where practicable, to a depth of 300 mm over the top of pipes.

Black cotton soil shall not be used for backfilling around the structure .Cushion of sand be laid. Over this 75 mm thick layer of stone aggregate, with stone size uniformly. This shall then be compacted by light roller (by 2 ton roller and 4 to 5 passes) or any other means. After compacting, sand shall be uniformly spread and water shall be sprayed over it to ensure that the voids are filled with sand. Water shall be spread in such a manner that bulking in sand does not take place. This process will be repeated till the filling reaches the desired level. When it reaches the finished level, surface shall be flooded with water for 24 hrs, allowed to dry and then rammed and consolidated to avoid any settlement at a later stage.

1.5.11 Formwork:

Formwork shall be as per IS: 456-2000 and shall be composed of steel and/or best quality shuttering wood of non-absorbent type timber. The timber shall be free from knots and shall be of medium grain as far as possible.

Formwork shall be composed of steel and/or best quality shuttering wood of non-absorbent type. Timber shall be free from significant knots and shall be of medium grain as far as possible and hard woods shall be used as caps and wedges under or over posts. Plywood or equivalent shall be used where specified to obtain smooth surfaces, for exposed, concrete work. Struts shall generally be mild steel tubes, and strong Sal wood is 150 mm in diameter or above. Materials used for the form work inclusive of the supports and centering shall be capable of withstanding the working load and remain undistorted throughout the period it is left in service.

The centering shall be true and rigid and thoroughly braced both horizontally and diagonally. The form work shall be strong enough to withstand the effects of vibration, without appreciable deflection, bulging, distortion or loosening of its components. The joints in the formwork shall be sufficiently tight to prevent any leakage or mortar. The formwork shall have a smooth uniform surface free form honeycombs, air bubbles, bulges, fins and other blemishes. To achieve the desired rigidity, the bolts, space blocks, the wires and clamps shall be used but they must in no way impair the strength of concrete or leave stains or marks on the finished surface.

For exposed interior and exterior concrete surfaces of beams, columns and walls, plywood or other approved forms, thoroughly cleaned and tied together with approved corrosion-resistant devices shall be used. The temporary openings shall be so formed that they can be conveniently closed when required and must not leave any mark on the concrete.

Cleaning & Treatment of Forms: All parts of the forms shall be thoroughly cleaned of old concrete, wood shavings, saw dust, dirt and dust sticking to them before they are fixed in position. All rubbish, loose concrete, chippings, shavings, sawdust etc. shall be scrupulously removed from the interior of the forms before concrete is poured. Compressed air jet and/or water jet along with wire brushes, brooms etc. shall be used for cleaning.

The inside surface of the formwork shall be treated with approved non-staining oil or other compound before it is placed in position. Care shall be taken that oil or other compound does not come in contact with reinforcing steel or construction joint surfaces and shall be non-staining and non- injurious to concrete. They shall not be allowed to accumulate at the bottom of the formwork. The oiling of the formwork will be inspected just prior to placement of concrete and redone wherever necessary.

Reuse of Forms: Formwork may be reused, provided that it is true, un-warped, thoroughly clean and without broken or damaged edges and equal in use in every respect to a new lumber. All form lumber shall have the contact surfaces re-oiled or recoated with an approved composition prior to usage.

Classification: Generally, the 'ordinary' class formwork shall be used unless otherwise directed by the Engineer.

a) Ordinary: These shall be used in places where ordinary surface finish is required and shall be composed of steel and/or approved good quality partially seasoned timber.

b) Plywood: These shall be used in exposed surfaces, where a specially good finish is required and shall be made of approved brand of heavy quality plywood to produce a perfectly uniform and smooth surface conforming to the shape described in the drawing with required grain texture on the concrete.

c) Ornamental: These shall be used where ornamental and curved surface are required and shall be made of selected best quality well seasoned timbers or of plywood, which can be shaped correctly.

1.5.12 Reinforcement:

The steel bars used for reinforcement may be of 6mm to 32 mm dia as per the design requirement. Mild steel round bars, cold twisted and deformed bars as medium tensile or high yield strength steel confirming to IS:432 and IS:1786-1979, plain hard drawn steel wire fabric etc will be used as reinforcement.

Requirements for a concrete cover over steel reinforcement, projection of bars for bending with future extensions, mesh reinforcement and other items to connection with proper placing shall be strictly adhered to. All steel for reinforcement shall be free from loose scales, oil, grease, paint or other harmful matters immediately before placing the concrete.

Reinforcing steel shall be bent in accordance with the procedure specified in IS: 2502 or as approved by the Engineer. Bends and shapes shall comply strictly with the dimensions corresponding to the approved Bar Bending Schedules. No reinforcement shall be bent when already in position in the work. Bars shall not be straightened in a manner that will injure the material. Re-bending bars shall be bent by machine or other approved means producing a gradual and even motion. All the bars shall be cold bent unless otherwise approved.

The radius of the bend shall not be less than 4x bar diameter for plain mild steel or 6 x bar diameter for deformed bars.

Welding: Normal bond laps in reinforcement may be placed by lap or butt-welding reinforcement bars, if asked by the Engineer, under certain conditions. The work should be done with suitable safeguards in accordance with relevant Indian Standards & IS: 2751 for welding of mild steel bars used in reinforced concrete construction as per IS: 2751 and IS: 456. Welded mesh fabrics conforming to IS: 1566 may also be used if specified in the Schedule of items and drawings.

Laps and anchorage lengths of reinforcing bars shall be in accordance with IS: 456, unless otherwise specified. If the bars in a lap are not of the same diameter, the smaller will guide the lap length. The laps shall be staggered as far as practicable and as directed by the Engineer and not more than 50% of the bars shall be lapped at a particular section. Arrangements for placing concrete shall be such that reinforcement in position does not have to bear extra load and get disturbed.

Covers for Reinforcement: Care should be taken to ensure that projecting ends of ties and other embedded metal do not encroach into the concrete cover. Where concrete blocks are used for ensuring the cover and positioning reinforcement with suitable binding wire, they shall be made of mortar not leaner than 1 (one) part cement to 2 (two) parts sand by volume and cured in a pond for at least 14 (fourteen) days. Their strength shall correspond to the strength of concrete proposed for the structure. Where such cover blocks are used, all cover, spacers shall be secured firmly so that they are not disturbed during vibration.

Tolerances: Reinforcement shall be placed within the following tolerances as specified in Clause 12.3.1 of IS: 456-2000:

(a) For effective depth 200 mm or less + 10mm

(b) For effective depth more than 200 mm + 15 mm

The cover shall in no case be reduced by more than one third of specified cover or 5 mm whichever is less.

1.5.13 Foundation Concrete:

Cement, Coarse and Fine Aggregates, Water, Admixture used if any and reinforcement steel etc. used in forming, mixing, placing, finishing, curing and testing of plain and reinforced concrete for foundation work for transmission line towers shall meet the requirements stipulated in relevant standards mentioned under specifications for works. The contractor shall furnish all labour, equipment and materials required for complete performance of the work in accordance with the drawings and as described herein

i) Preliminary Tests

A test conducted in laboratory on the trial mix of concrete produced in a laboratory with the objective of:

Designing of a concrete mix before the actual concreting operation starts;

Determining the adjustments required in the design mix when there is a change in the materials used during the execution of work;

Verifying the strength of the concrete mix.

ii) Work Tests

A test conducted in the field or in a laboratory on the specimen made on the works, out of the concrete being used on the works.

Design mix concrete shall be used on all concrete works, except where specified otherwise. Work shall not commence until the Purchaser has approved the control/design concrete mix. The contractor shall allow sufficient time for all the obligations and tests etc. to be carried out prior to approval.

NOTE: Mix design shall take account of any chemicals harmful to concrete found to be present during soil investigation.

Concrete Mix Review:

The source and quality of concrete materials and concrete proportions proposed for the work shall be submitted to the Engineer for review before the concrete work is started. Complete certified reports prepared by an independent testing laboratory and covering the materials and proportions shall be submitted. Review of these reports will be for general acceptability only and continued compliance with all contract provisions only will be required. The Engineer shall have the option to witness the preparation of the trial mixes, testing etc.

Reports on admixture shall include the classification, brand, manufacturer and active chemical ingredient. All admixtures, conforming to relevant IS Codes, shall be the products of one manufacturer approved by the Engineer.

Reports on the fine aggregates shall include the sources, type, gradation, deleterious substance, soundness and the results of all tests required to verify compliance IS: 383.

Reports on the coarse aggregates shall include the source, type, gradation, deleterious substances, soundness, abrasion loss and the results of all tests required to comply with IS:383.

Using concrete materials acceptable to the purchaser: A concrete mix shall be designed and tested for each size and gradation of aggregates and for consistency intended for use on the work. Design quantities and test results of each mix shall be submitted for review. Acceptable mixes shall be subjected to field adjustments as necessary to meet the requirements of these specifications. Should the contractor wish to use alternative sources for sand and aggregate the additional design mixes must be supplied.

The report for each concrete mix submitted for review shall include the following information:

(a) Slump on which the design is based.

(b) Total litres of water per cubic meter.

(c) Water-cement ratio.

(d) Ratio of fine to coarse aggregates.

(e) Weight (surface dry) of each aggregate per cubic meter.

(f) Quantity of each admixture.

(g) Air content, if any.

(h) Compressive strength based on 7 days and 28 day’s compression test.

(i) Time of initial set.

(j) Time of final set.

(k) Weight of cement used in the mix.

Concrete test specimens shall be made cured and tested in conformity with IS: 516. These tests shall be conducted at approved laboratory. Calibration certificates for the test equipment shall be available on demand. The mould and materials for cubes and cylinders shall be supplied by the contractor who shall also arrange to transport the cubes/ cylinders to laboratory at his own cost. The cost of the testing shall also be borne by the contractor.

Concrete Mixing:

Concrete mixing shall conform to IS: 456-2000. Concrete shall only be mixed in a mechanical mixer. Mixing by hand is strictly prohibited. On sites where access is very difficult then "one bag" mixers capable of being dismantled and carried in shall be employed.

The proportion of fine and coarse aggregates, cement and water shall be as determined by the mix design in case of controlled concrete. The quantities of fine and course aggregates shall be determined by weight. The engineer may allow the quantity of aggregates to be determined by equivalent volume basis after the relationship between the weight and volume is well established by trial and the same will be verified frequently. The quantity of cement shall always be determined by weight. The water shall be measured accurately after giving proper allowance for surface water present in the aggregates for which regular check shall be made for bulking in the case of volume batching in accordance with IS:2386 (Part-III).

Detailed procedure and precautions to be observed in mixing, conveyance of concrete, depositing, temperature at the time of placing and compaction of concrete is available in pages 96 to 100 (substation construction concreting)

Contractor shall keep an accurate record of the date on which the concrete is cast for each part of work and date on which the forms are removed.

To secure maximum density and eliminate formation of air pockets, the concrete shall be thoroughly vibrated and worked around all reinforcements, embedded facilities and into corners of forms during and immediately after placing. Unless other methods are authorized by the Purchaser, mechanical vibrators conforming to IS: 2505, IS: 2506, IS: 2514 and IS: 4656 shall be used for this purpose, the type and operation of which is subject to the approval of the purchaser.

The placing of concrete shall be in a continuous operation with no interruption in each location. Concrete shall be handled from the place of mixing to the place of final deposit as rapidly as practicable by methods, which will prevent segregation.

Concrete shall normally be placed in continuous horizontal layers. Construction joints in foundations shall not be permitted. Concrete shall be compacted to the maximum practicable density during the placement and thoroughly worked around the reinforcement if any and around the embedded stubs and into the corners of the formwork, with vibrators or any other means approved by the purchaser.

Repairs of imperfection in concrete shall be completed within 24 hours after the removal of forms. Repair of concrete shall be performed only in the presence of the purchaser or his representative. All exposed corners shall be slightly rounded or chamfered. Concrete in the top of foundations shall be sloped to provide drainage away from stub angles.

1.5.14 Curing: The concrete after setting for 24 hours shall be cured by keeping the concrete wet continuously for a period of 14 days after laying. The pit may be backfilled with selected earth sprinkled with necessary amount of water and well consolidated in layers not exceeding 200mm after a minimum period of 24 hours and there after both the back filled earth and exposed chimney top shall be kept wet for the remainder of the prescribed time of 14 days. The uncovered concrete chimney above the back filled earth shall be kept wet by providing empty gunny bags dipped in water fully wrapped around the concrete chimney for curing and ensuring that the bags kept wet by the frequent pouring of water on them.

For curing the foundations below ground level, after backfilling, 150mm high earthen embankment along the sides of excavation pits shall be made and sufficient water shall be poured in the backfilled pits so that standing water may remain above the backfilled earth.

In high temperature and low humidity areas, more frequent sprinkling shall be done.

In cold weather at or below freezing temperature, concrete shall be insulated with layer of straw or similar material covered with a waterproof sheet material to help retention of the original heat of concrete plus heat of hydration. Curing shall be carried out for longer periods to the satisfaction of purchaser, to ensure that the concrete attains the strength and quality.

The stubs of foundations constructed in fully submerged soil shall be painted after installation with black bituminous paint overlapping the steel / concrete interface from 150 mm below the top of concrete to 500 mm above.

1.5.15 Sampling and Testing: Samples of concrete shall be taken at the direction of the Engineer in the field in accordance with IS: 1199 'Methods of Sampling & Analysis of concrete'. The testing shall be carried out as per IS: 456 and other relevant codes.

The samples shall be tested for strength and consistency at any approved laboratory in accordance with IS: 516. These tests shall be conducted at approved laboratory or at the contractor's premises under the supervision of the Purchaser's representative. Calibration certificates for the test equipment shall be available on demand. The mould and materials for cubes and cylinders shall be supplied by the contractor who shall also arrange to transport the cubes/ cylinders to laboratory at his own cost. The cost of the testing shall also be borne by the contractor.

The number of samples to be taken for testing and verifying concrete strength shall be in accordance with IS: 456 but shall be a minimum of four (4) cubes per foundation and as per the directions of purchaser.

Samples shall be cured under laboratory conditions except when in the opinion of the purchaser extreme weather conditions may prevail at which time the purchaser may require additional cubes cured under job conditions.

If the strength of the cubes for any portion of the concrete work falls below the specified compressive strength, the criteria for acceptance of the portion of the work shall be as stipulated in IS: 456.

If the concrete falls below the specified compressive strength then the contractor shall:

i) Analyze the actual loads on the foundation to determine its adequate strength. If acceptable, this shall require a payment to the purchaser for the reduced quality.

ii) Propose modifications to bring the strength of the foundation to a level acceptable to the purchaser. All modifications shall be at the contractor's expense.

iii) Break out and replace the foundation as per the Purchasers instruction at the contractor's expense.

The purchaser shall also reserve the right to reject whole or any part of the work. In case of acceptance of such works, the standard deviations shall be worked out, and examined by the purchaser and if he is satisfied only then such works can be accepted at the reduced rates. Furthermore, the purchaser shall have the right to order a change in the mix or the water cement ratio for the remaining portion of the foundations at no extra cost to the purchaser.

1.5.16 Concreting of Foundation:

The contractor shall inform the purchaser or his authorized representative sufficiently in advance about the programme of concreting the location.

1.5.17 Protection of Tower Foundation: The work shall include all necessary stone revetment, concreting and earth filling above ground level. Special measures for protection of foundations shall be taken in respect of locations close to/in nallah, river-beds, etc. by providing suitable crate of galvanized wire netting and meshing packed with boulders. The top seal cover of the revetment work shall be done with PCC 1:3:6 nominal mix. The contractor shall furnish recommendations for providing protection at such locations.

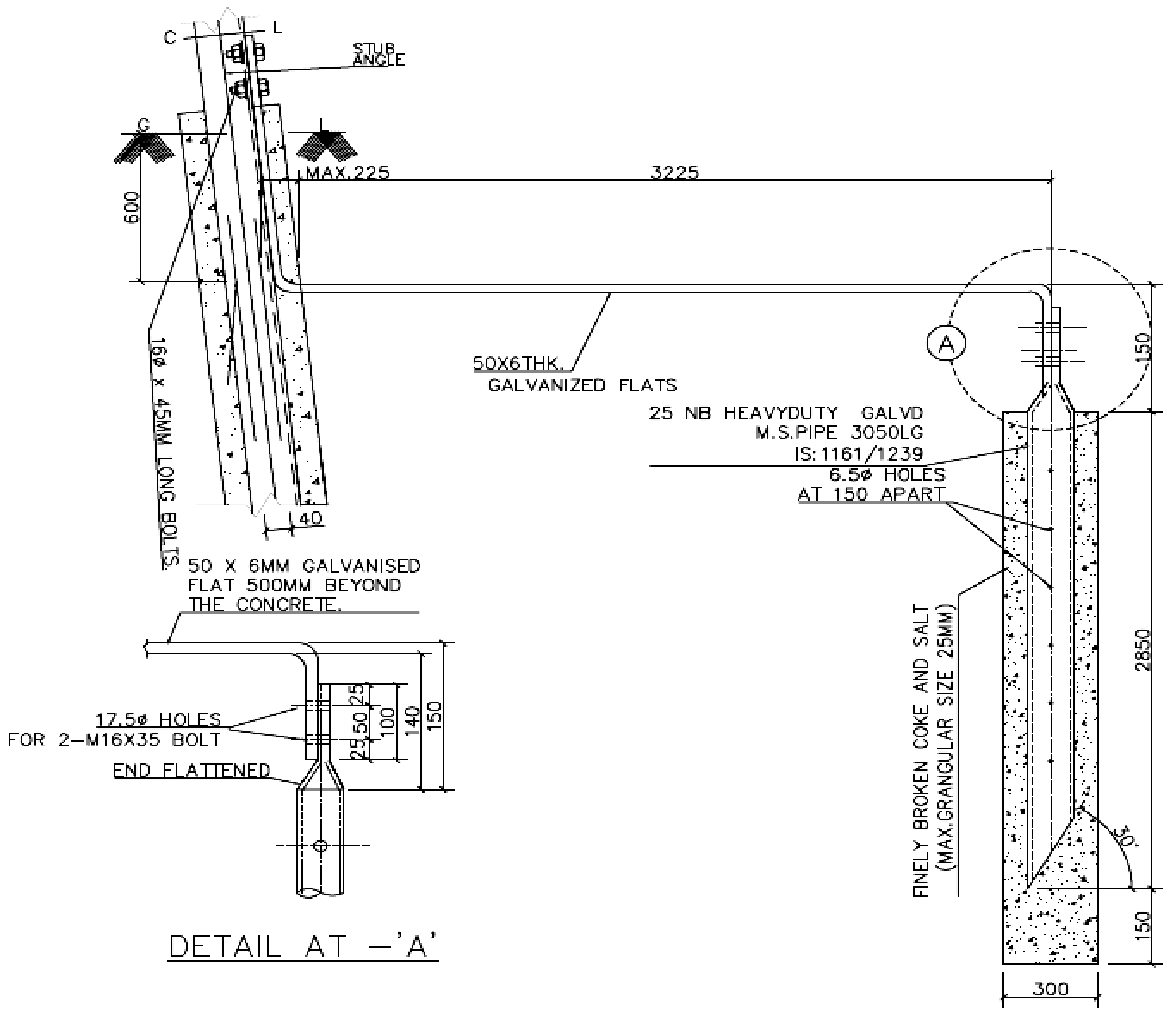
Where the ground surface is irregular the foundation shall be finished off in a substantial and permanent way by forming a plinth by side cutting and building a suitable random stone revetment or in case of rock foundation by building up with concrete as desired by the purchaser. The number of retaining walls and breast walls en-route transmission line shall be intimated by the contractor for obtaining the decision of the purchaser before taking up erection.

1.5.18 T & P Required:

i)	Concrete mixers	2 Nos.
ii)	Needle vibrators	4 Nos.
iii)	Cube moulds	8 Nos.
iv)	Water tankers	2 Nos.
v)	Compaction rammers	2 Nos.
vi)	Template supporting jacks	20 Nos.
vii)	IS Sieves (all sizes)	1 set.
viii)	Vernier calipers & screw gauge	1 set.
ix)	Steel ladders	2 Nos.
x)	Dewatering pumps	3 Nos.

1.5.19 Earthing:

Each tower shall be earthed after the foundation has been cast. The installation of earthing sets shall be in accordance with relevant standard specifications. The galvanized steel pipe sets shall be installed in the ground near the towers and connected to the tower legs by means of galvanized steel flat as shown in Drawing. The grounding shall be effected by making about 350mm dia and 3600mm deep pit at a distance of not less than 3650mm diagonally away from the stubs and filling in the pits with finely broken coke having grain sizes not more than 25mm thick. Coke shall be maintained up to a distance of 150mm from the pipe on all sides. The top edge of the pipe shall be at least 600mm below the ground level. The steel strip shall be buried not less than 600mm depth from the ground level.



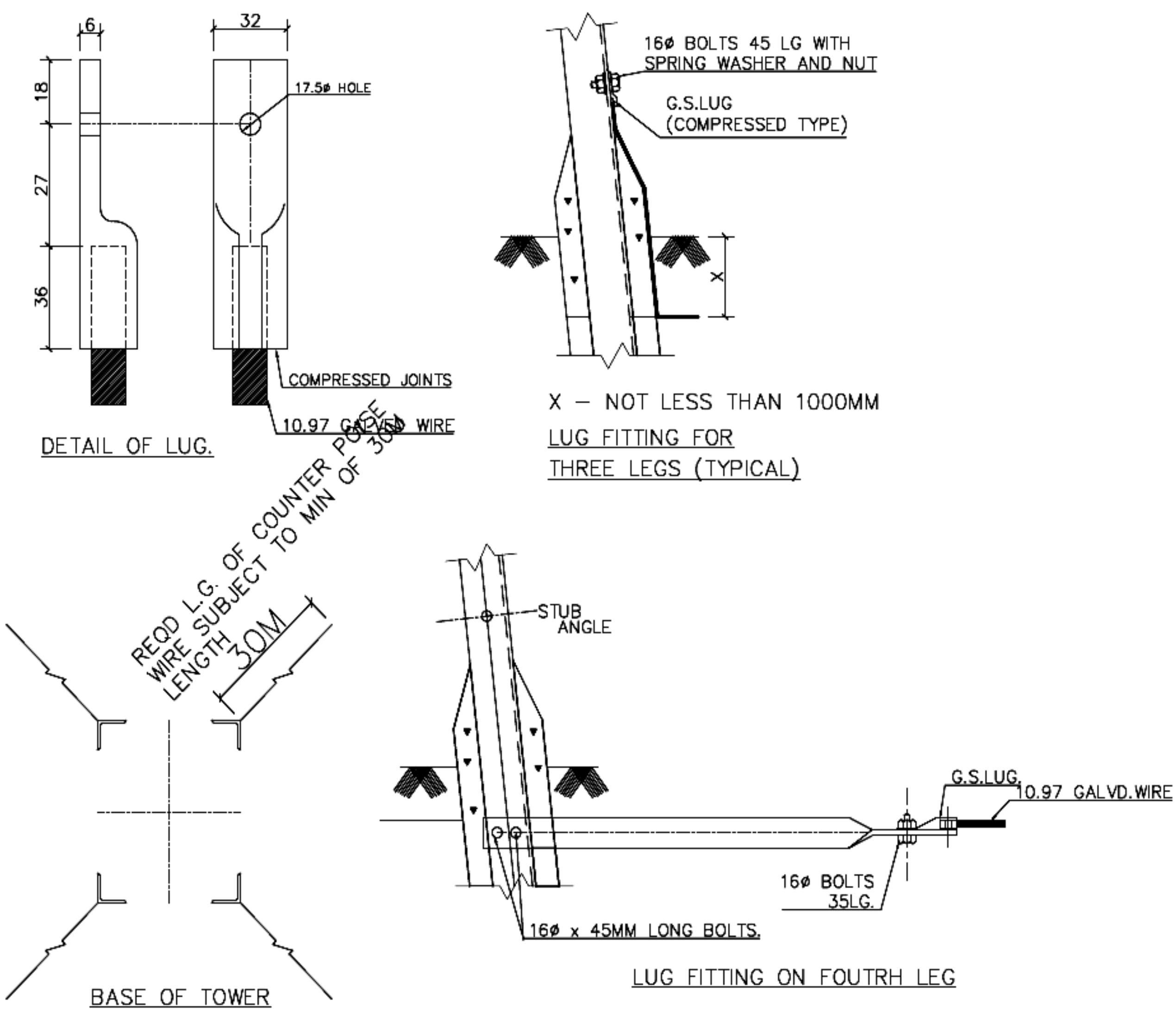
PIPE TYPE EARTHING ARRANGEMENT

Tower Footing Resistance: The tower footing resistance of all towers shall be measured in dry weather after their erection and before the stringing of earth wire. Tower footing resistance shall not exceed 10 ohms. In case the resistance exceeds the specified values, multiple pipe earthing or counterpoise earthing shall be adopted in accordance with the following procedure, but without interfering with the foundation concrete even though the earth strip/counterpoise lead remains exposed at the tower end.

The connections in such case shall be made with the existing lattice member holes on the leg just above the chimney top.

Multiple Pipe Earthing: Where tower foundation resistance exceeds 10 ohms, the desired earthing resistance shall be obtained by installing additional pipe earthing sets. The distance between the electrodes in such cases shall preferably be not less than twice the length of electrode.

Counterpoise Earth: Counterpoise earth consists of four lengths of galvanized steel stranded wires, each fitted with a lug for connection to the tower leg at one end. The wires are connected to each of the legs and taken radially away from the tower and embedded horizontally 600mm below ground level. The length of each wire is normally limited to 30m but may be increased if the resistance requirements are not met. Galvanized steel stranded wire preferably of the same size of the overhead ground wire may be used for this purpose. A typical example of counterpoise type earthing to tower is given in the drawing below.



COUNTER POISE EARTHING ARRANGEMENT

Where a tower stands on rock, efforts shall be made to obtain a good ground by carrying a length of galvanized steel flat from the tower legs to earthing pipe driven in damp soil at the shortest possible distance from the tower. The connecting flat shall be buried in a groove cut in the rock surface and adequately protected from damage.

The contractor shall measure and record the resistance of each tower to earth after erection and before installing the earth wire and submit the same to the purchaser. He shall provide adequate notice to the Purchaser so the Purchaser can witness the measurements if he so wishes. The measurements shall be made during the dry season.

All towers are to be earthed properly before stringing operation is taken up.

1.5.20 Tree/Crop Compensation Right-of-way, Cutting of trees etc:

Payment of compensation for damaged crops or fruit bearing trees shall be initially made by the contractor, which will be reimbursed by APTRANSCO later on. The compensation so payable in respect of damaged crops shall be based on the assessment of MRO. In respect of the trees, compensation so payable is the lowest of the rates fixed by the Horticulture/NABARD/MRO. The contractor shall take up the payment of compensation amount only after written approval by the Project Manager (Executive Engineer). The payment shall be made in the presence of representatives of SE (TLC), Accounts and Vigilance wings of APTRANSCO. The Superintending Engineer/ TLC shall finalize the compensation claims.

The contractor shall take all possible steps to see that standing crops etc. are not damaged during execution of works. When such damage is inevitable, the compensation will be borne by the APTRANSCO to the extent of land required for laying of foundation, provided the damage is with prior concurrence of the Executive Engineer. The contractor shall bear the compensation for damages caused without prior concurrence of the Executive Engineer concerned. Any extra land required by the contractor temporarily for dumping of the construction material and consequent damage to the crops etc. shall be the responsibility of the contractor.

In the event of any obstruction being encountered from the local villagers /authorities, the contractor shall immediately notify the Executive Engineer who shall take such steps as may be necessary to clear the obstruction. The contractor or his representative or gangs shall not adopt antagonistic attitude towards the village authorities with whom they may come into contact, but shall immediately report to the Executive Engineer any case of obstruction which cannot be settled amicably. No trees shall be cut until the APRTANSCO has made necessary arrangement with the authorities concerned and permission is given to the contractor to fell such trees. APTRANSCO shall arrange to remove the obstacles as soon as possible. At times however, it may not be possible for the APTRANSCO to arrange right-of-way for laying foundations or erecting the towers or stringing the line. At all such times, the contractor shall shift his gangs to other locations, to maintain continuity of work.

APTRANSCO will arrange the right-of-way along the transmission line route. Any avoidable or deliberate damage done to standing crop or private property by the erection contractor's persons shall be compensated by the erection contractor without affecting the work.

APTRANSCO will acquire only such piece of land as is actually required for each tower foundation. Any extra land required by the erection contractor temporarily for dumping of the construction material and consequent damage to crops etc. shall be arranged by the erection contractor at his expenses. Arranging access roads / right-of-way for transport of material from road side to work sites also shall be done by the erection contractor with the consent of the property owners and any compensation in that respect will be his responsibility. The erection contractor shall take all reasonable steps for preventing damage to crops during execution of the contract work.

Clearing of obstructions falling in the right-of-way as per IS: 5613 (part-2, section2)-1985 and lopping or trimming of the portion of the trees falling within the minimum electrical clearance zone shall be the responsibility of the purchaser. However, any lopping or trimming of tree branches obstructing the line of sight during check survey shall be the responsibility of the erection contractor.

1.5.21 Tower Erection :

The towers shall be erected on the foundations not less than 14 days after concreting or till such time the concrete has acquired sufficient strength. The towers are erected as per the erection drawings furnished by the manufacturers to facilitate erection. For the convenience of assembling the tower parts during erection operations, each member is marked in the factory to correspond with a number shown in the erection drawing. Any damage to the steel and injuring of galvanizing shall be avoided. No member shall be subjected to any undue over stress, during erection

Method of Erection: There are four main methods of erection of steel transmission towers

(i) Build-up method or piecemeal method.
(ii) Section method
(iii) Ground assembly method
(iv) Helicopter method.

Build up Method: This method is normally adopted for erection of 66 kV, 132 kV, 220 kV and 400 kV transmission line towers due to the following advantages:

- Tower materials can be supplied to site in knocked down condition, which facilitates easier and cheaper transportation.
- It does not require any heavy machinery such as cranes etc. Tower erection activity can be done in any kind of terrain and mostly throughout the year.
- Availability of workmen at cheap rates.

This method consists of erecting the towers, member by member. The tower members are kept on ground serially according to erection sequence to avoid search or time loss. The erection progresses from the bottom upwards. The four main corner leg members of the first sections of each corner leg are bolted together at the ground and erected.

The cross braces of the first section which are already assembled on the ground are raised one by one as a unit and bolted to the already erected corner leg angles. First section of the tower thus built and horizontal stunts (belt members) if any, are bolted in position. For assembling the second section of the tower, two gin poles are placed one each on the top of diagonally opposite corner legs. These two poles are used, for raising parts of second section. The leg members and braces of this section are then hoisted and assembled. The gin poles are then shifted to the corner leg members on the top of second section to raise the parts of third section of the tower in position for assembly. Gin poles are thus moved up as the tower is assembled. This process is continued till the complete tower is erected. Cross-arm members are assembled on the ground and raised up and fixed to the main body of the tower. For heavier towers, a small boom is rigged on one of the tower legs for hoisting purposes. The members/sections are hoisted either manually or by winch machines operated from the ground. For smaller base towers/vertical configuration towers one gin pole is used instead of two gin poles. In order to maintain speed and efficiency, a small assembly party goes ahead of the main erection gang and its purpose is to sort out the tower members, keeping the members in correct position on the ground and assembling the panels on the ground, which can be erected as a complete unit.

Section Method: In the section method, major sections of the tower are assembled on the ground and the same are erected as units. Either a mobile crane or a gin pole is used. The gin pole used is approximately 10m long and is held in place by means of guys by the side of the tower to be erected. The two opposite sides of the tower section of the tower are assembled on the ground. Each assembled side is then lifted clear of the ground with the gin or derrick and is lowered into position on bolts to stubs or anchor bolts.

One side is held in place with props while the other side is being erected. The two opposite sides are then laced together with cross members and diagonals: and the assembled section is lined up, made square to the line. After completing the first section, gin pole is set on the top of the first section. The gin rests on a strut of the tower immediately below the leg joint. The gin pole then has to be properly guyed into position.

The first face of the second section is raised. To raise the second face of this section it is necessary to slide the foot of the gin on the strut of the opposite face of the tower. After the two opposite faces are raised, the lacing on the other two sides is bolted up. The last lift raises the top of the towers. After the tower top is placed and all side lacings have been bolted up all the guys are thrown off except one, which is used to lower the gin pole. Sometimes whole one face of the tower is assembled on the ground, hoisted and supported in position. The opposite face is similarly assembled and hoisted and then the bracing angles connecting these two faces are fitted.

Ground Assembly Method: This method consists of assembling the tower on ground, and erecting it as a complete unit. The complete tower is assembled in horizontal position on even ground. The tower is assembled along the direction of the line to allow the cross arms to be fitted. On sloping ground, however, elaborate packing of the low side is essential before assembly commences. After the assembly is complete, the tower is picked up from the ground with the help of a crane and carried to its location, and set on its foundations. For this method of erection, a level piece of ground close to footing is chosen from the tower assembly. This method is not useful when the towers are large and heavy and the foundations are located in arable land where building and erecting complete towers would cause damage to large areas or in hilly terrain where the assembly of complete tower on sloping ground may not be possible and it may be difficult to get crane into position to raise the complete tower.

This method may not be feasible at many locations, because of prohibitive cost of mobile crane, and non-availability of good approach roads to tower locations.

Helicopter Method: In the helicopter method, the transmission tower is erected in section. For example bottom section is first lifted on to the stubs and then the upper section is lifted and bolted to the first section and the process is repeated till the complete tower is erected. Sometimes a completely assembled tower is raised with the help of helicopter. Helicopters are also used for lifting completely assembled towers with guys from the marshalling yards where these are fabricated and then transported one by one to line locations. Helicopter hovers over the line location while the tower is securely guyed. The ground crew men connect and tighten the tower guys. As soon as the guy wires are adequately tensioned the helicopter disengages and moves away. This method is adopted where approach is very difficult or to speed up the construction of the transmission line.

The contractor shall be entirely responsible for correct erection for all towers as per the approved drawings and their correct setting on the alignment finally approved by the purchaser. The towers must be truly vertical after erection, the permitted tolerance in verticality being 1 in 360 of the tower height. No straining will be permitted to make the towers vertical.

A reasonable amount of drifting as permissible in IS:5613 (Part 3, section-2)-1989 shall be allowed in assembling, but reaming for correction of mismatched holes due to shop errors will not be permitted. If any shop errors are discovered, the contractor shall notify the purchaser, who will decide whether the errors may be corrected in the field or members returned to tower fabricator for correction or replacement. All galvanized surfaces damaged as a result of correction shall be made good to the satisfaction of the department.

The contractor shall give complete details of the erection procedures. Before starting erection of an upper section, the lower section shall be completely braced and all bolts provided in accordance with approved drawings.

Tower shall be fitted with number plate, danger plate, phase plates, circuit plates and anti-climbing device as described. After complete erection of tower, all blank holes, if any, are to be filled by Bolts and nuts of correct size. Suspension towers shall be fitted with Bird guards

Tightening and Punching of Bolts and Nuts: The number of bolts required for joining two or more members of a tower are worked out based on the maximum values of compression and tension i.e. after applying factors of safety obtaining in the member to be joined to the main member. Normally for E.H.T transmission line towers, the bolts of 16 mm dia are used. The bolts of different lengths will be required depending upon the thickness of the members to be joined. The dia of the bolt holes to be provided to the tower members shall be 17.5 mm. The centre of the bolt hole shall be away by not less than 20 mm from the rolled edge and 23 mm from the sheared edge. The bolts and nuts shall be hot dip galvanized and shall confirm to IS 12427 of 1988. The bolts and nuts are to be used with electro galvanized spring washers of 3mm thickness. For design purpose, the maximum bearing strength of the bolts of property class 5.6 quality is taken as 6320 Kg/cm^2 and shear strength 3l60/Kglcm^2

All nuts shall be tightened properly using correct size torque wrenches. Before tightening, it will be ensured that filler washers and plates are placed in relevant gaps between members, bolts of proper size and length are inserted and one spring washer used under each nut, and in case of step bolts, spring washers have been placed under the outer nuts. The tightening shall progressively be carried out from the top downwards, care being taken that all bolts at every level are tightened simultaneously. The threads of bolts projecting outside of the nuts shall be punched at three positions on the diameter to ensure that the nuts are not loosened in course of time. If during tightening a nut is found to be slipping or running over the bolt threads, the bolt together with the nut shall be replaced.

All the bolts projected outside the nuts shall be welded with the nuts at two diametrically opposite places. The length of each welding shall be at least 10mm. The welding shall be provided from ground level up to bottom cross arm level. After welding cold galvanized paint (zinc rich paint) having at least 90% (per cent) zinc content shall be applied to the welded portion. At least two coats of the paint shall be applied.

Alternately use of epoxy resin adhesive which can serve the purpose of locking the nuts permanently with the bolts and nuts to prevent pilferage of the tower members may be considered.

All the inter contact surfaces especially in coastal and highly polluted areas at the joint shall be painted with zinc rich paint to avoid rust formation, before assembling the tower.

1.5.22 Stringing of Conductors and Earth Wire

Insulator Hoisting: Suspension insulator strings shall be used on suspension towers and tension insulator strings on angle and dead end towers, the strings shall be fixed generally on the tower just prior to the stringing of conductors. Damaged insulators and fittings shall not be used on the assemblies. Before hoisting, all insulators shall be cleaned in a manner that will not spoil, injure or scratch the surface of the insulator, but in no case shall any oil be used for the purpose. Security clips shall be in position for the insulators before hoisting. Corona control rings in case of 400kV lines only shall be fitted. Arcing horns or guard rings, if required, shall be placed along the line on suspension, and facing upwards on tension insulator string assemblies.

Insulation resistance value of each insulator shall be measured with a suitable Megger and those insulators with a value of 50Mega ohms only shall be used.

The installation of string assemblies shall also include the installation of armor rod sets at suspension locations.

Handling of Conductor and Ground Wire:

__Running out the Conductors:__ Before commencement of stringing, the contractor shall submit stringing charts for the conductor and earth wire for various temperatures corresponding to ruling spans on the basis of the data given and also on the data obtained from the detailed survey. The contractor shall provide a drum schedule, based upon the tower schedule and line profile, to show efficient use of the conductor for the Purchasers approval.

While paving out the conductors, care shall be taken to see that the conductors do not touch and rub against the ground or objects that could cause scratches or damage to the strands. The conductor shall be run, out of the drums from the top in order to avoid damage due to chafing. Immediately after paving out, the conductor shall be raised at the supports to the levels of the clamp and placed into the running blocks.

The conductor shall be continuously observed for loose or broken strands or any other damage. When approaching the end of a drum length, at least three coils shall be left when the stringing operations are to be stopped. These coils are to be removed carefully, and if another length is required to be run, a joint shall be made as per the recommendations of the conductor accessory manufacturers. The contractor shall use running out blocks suitable for joint protectors to ensure that the joints remain straight during tension stringing.

Adequate steps shall be taken to prevent clashing of sub-conductors from the process of paving out to the installations of the spacers/spacer dampers. Care shall be taken that both sub-conductor of a bundle are from the same conductor supplier and preferably from the same batch so that creep behavior of the sub-conductor remains identical. During sagging, care shall be taken to eliminate differential sag in the sub-conductor as far as possible. However, in no case sag mismatch shall be more than 25mm. Conductor splices shall be so made that they do not crack or get damaged in the stringing operation.

The sequence of paving out shall be from top downwards, i.e., the ground wire shall be run first, followed by the conductors in succession alternating across the tower between phases.
Unbalance of loads on towers shall be avoided as far as possible.

The proposed transmission line may run parallel for certain distance with the existing 400kV, 220kV or 132kV lines which may remain energized during the stringing period. As a result there is a possibility of dangerous voltage build-up due to electromagnetic and electrostatic coupling in the pulling wire conductors and ground wires. It shall be the contractor's responsibility to take adequate safety precautions to protect his employees and others from this potential danger. Running grounds and earthing of running blocks at each tower shall be installed as a minimum requirement.

Wherever towers are not designed for one side stringing, proper guying arrangement shall be made by the contractor during stringing to avoid unbalanced loads on towers. The sagging and landing of the phase conductors and ground wires shall be done in pairs i.e. both top phases or both middle phases etc.

<u>Traveler/Running Blocks</u>: Installation of travelers, including finger lines where used, requires consideration of traveler attachment methods and the need for and location of traveler grounds and uplift rollers. For single conductor vertical insulator assemblies, the travelers are normally connected directly to the insulator, and with 'vee` string insulator assemblies, to the yoke plate. For most bundled conductor lines, the travelers are connected to the yoke plate. With post type insulators, the travelers are connected to the end of the insulators. Where travelers are installed to string through tension towers, the travelers are normally connected directly to the tower. If substantial line angles are involved, two travelers in tandem may be required to reduce the bending radius of the conductor the load on each traveler, or both.

Where bundled conductor travelers are used at line angle locations of over 5 degrees, it is advisable to change to individual single conductor travelers after the passage of the running board to facilitate accurate sagging.

The groove of the running blocks shall be of such a design that the seat is semicircular and larger than the diameter of the conductor, ground wire and it does not slip over or rub against the sides. The grooves shall be lined with hard rubber or neoprene to avoid damage to conductor and shall be mounted on properly lubricated bearings.

The running blocks shall be suspended in a manner to suit the design of the cross-arm. All running blocks, especially those at the tensioning end shall be fitted on the cross arms with jute cloth wrapped over the steel work and under the slings to avoid damage to the slings as well as to the protective surface finish of the steel work. **Normally, suspension towers shall not be used even for temporary termination. In case small or medium angle towers are used even for temporary terminations, these shall be well guyed and steps be taken by the contractor to avoid damage.** Guying proposals along with necessary calculations shall be submitted, for approval, by the contractor to the Purchaser.

Use of traveling grounds and choice of locations must be based on the degree of exposure to electrical hazards. When such hazards exist, as a minimum, traveler grounds should be installed at the first and last tower between tensioner and puller. When stringing in proximity to energized lines, additional grounds shall be installed as required, but at a maximum distance not exceeding 3 km. Additionally, grounds shall be installed within a reasonable distance on each side of an energized crossing, preferably on the adjacent structure.

Travelers with grounds are usually sensitive to direction and care must be exercised in hanging the travelers. Usually the grounds are connected to the pulling end. Each traveler with grounds must be connected with temporary grounding sets to provide an electrical connection between the traveler and earth, or to some conducting medium that is at earth potential. Personnel should never be in series, with a ground lead. Traveler grounds should have a suitable grounding stub located in an accessible position to enable placing and removing the ground clamps, with hot sticks when necessary. Traveler grounds also help protect the sheave linings.

Repairs to Conductors: Repairs to conductors, if necessary, shall be carried out during the paving out operations, with repair sleeves. Repairing of conductor surface shall be done only in case of minor damage, scratch marks or not more than 2 broken strands in the outer layer etc. keeping in view both electrical and mechanical safe requirements. The final conductor surface shall be clean, smooth and shall be without any projections, sharp points, cuts, abrasions etc. If the damage is greater than above or extends to the successive layers then a mid-span joint shall be used.

Crossings: Derricks and scaffolding shall be used where roads, rivers, channels, telecommunication or overhead power lines, railways lines, fences or walls have to be crossed during stringing operations. It shall be seen that normal services are not interrupted or damage caused to property. Shutdown shall be obtained when working at crossing of overhead power lines. The contractor shall be entirely responsible for the proper handling of the conductor, ground wire and accessories in the field.

Paving out Earth wire: Normally earth wire drums are mounted on a turn-table. Pulling machine/tractor is employed to pull the earth wire. Earth wire running blocks are hoisted on the towers prior to taking up of this operation. The earth wire while paving out passes through the earth wire running bocks. Earth wire splices shall be made in such a way that they do not crack or get damaged in the stringing operations. It should be noted that no earth wire joints are allowed within 30 m from the tension or suspension clamp fittings.

Paving out Conductor: Slack Layout or Direct Installation Method: Using this method, the conductor is paved out over the ground rollers by means of a pulling vehicle or the reel carried along the line on a vehicle. The conductor reels are positioned on reel stands or jack either placed on the ground or mounted on a transporting vehicle. These stands are designed to support reel on a shaft permitting it to rotate as the conductor is pulled out. Usually a braking device is provided to prevent over-running and backlash.

When the conductor is paved out past a tower pulling is stopped and the conductor is placed in travelers attached to the structure before proceeding to the next structure.

This method is generally applicable to the construction of new lines in cases where maintenance of conductor surface condition in not critical and where terrain is easily accessible to a puling vehicle. The method is not usually economically applicable in urban locations where hazards exist from traffic or where there is danger of contact with energized circuits, nor it is practical in mountainous regions inaccessible to pulling vehicles.

Major equipment required to perform slack stringing includes reels stands, pulling vehicles and a splicing cart.

Tension Stringing Method: Multi-conductor lines shall generally be strung with the help of tension stringing equipment. Using this method, the conductor is kept under tension during the stringing process. Normally, this method is used to keep the conductor clear of the ground and obstacles which might cause conductor surface damage and clear of energized circuits. It requires pulling of a light pilot line through the travelers, which in turn is used to pull in a heavier pulling line. The pulling line is then used to pull in the conductors from the reel stands using specially designed tensioners and pullers.

For lighter conductors, a lightweight pulling line may be used in place of pilot line to directly pull in the conductor. A helicopter or ground vehicle can be used to pull or lay out a pilot line or pulling line. Where a helicopter is used to pull out a line, synthetic rope is normally used to attach the line to the helicopter and prevent the pulling or pilot line from flipping into the rotor blades upon release. The tension method of stringing is applicable where it is desired to keep the conductor off the ground to minimize surface damage or in areas where frequent crossings are encountered. The amount of right of way travel by heavy equipment is also reduced. Usually, this method provides the most economical means of stringing conductor. The helicopter use is particularly advantageous in rugged or poorly accessible terrain.

Major equipment required for tension stringing includes reel stands, tensioners, puller, reel winder, pilot line winder, splicing cart and helicopter or pulling vehicle.

While running out the conductors, care shall be taken such that the conductors do not touch and rub against the ground or objects, which could cause scratches or damage to the strands. The conductor shall not be over-strained during erection. The conductor shall be run out of the drums from the top in order to avoid damage due to chafing.

Wherever required, jointing of conductor during paving out will be carried out.

Jointing: All the joints on the conductor and ground wire shall be of compression type, in accordance with the recommendations of the manufacturer for which all necessary tools and equipment like compressors dies, etc. shall have to be arranged by the contractor. Each part of the joint shall be cleaned by wire brush to make it rust or dirt free and shall properly be greased with anti-corrosive compound, if required and as recommended by the supplier before the final compression is done with the compressors.

All joints or splices shall be made at least 15 metres away from the structures. No joints or splices shall be made in the span crossing over main roads, railways and rivers or in the span adjacent to a tension tower. No joints in the conductor or earth wire shall be permitted without the approval of the Purchaser. Not more than one joint per sub-conductor shall be allowed in a span. The compression type fitting used shall be self-centering type or care shall be taken to mark the conductor to indicate when the fitting is sitting on the conductor properly. During compression or splicing operations the conductor shall be handled in such a manner as to prevent lateral or vertical bearing against the dies. After pressing the joint, the aluminum sleeve shall have all corners rounded; burrs and sharp edges removed and smoothened. The compression of the joints shall be as per manufacturer's instructions.

During stringing of conductor, to avoid any damage to the joint, the contractor shall use a suitable protector with mid span compression joints in case joints are to be passed over pulley blocks/aerial rollers. The size of the groove of the pulley shall be such that the joint along with protector can be passed over it smoothly. The arrangement to be adopted shall be explained in the bid.

1.5.22.1 Stringing Procedure:

Site Selection: The selection of pull, tension, anchor and splicing sites must consider accessibility, location of deadmen, length of conductor to be strung, available conductor and line lengths, puller capacity, including placement of pullers, tensioners and conductor anchor locations, placement of reel stands, pilot line winders, reel winders and the ability to provide an adequate grounding system.

Equipment Locations: The locations of the puller, tensioners and intermediate anchor sites must be selected so that the structures are not overloaded. A pulling line slope of three horizontal to one vertical from the traveler to the site is considered good practice. It is also necessary that the puller be so positioned that the pulling line enters the machine at the smallest horizontal angle thereby minimizing the possibility of damaging the line. When a bull wheel type puller is employed, the reel winder to recover the pulling line is located at the pulling site. The pilot line winder is located at the tensioner site.

The arrangement of the tensioner and reel stands should be such that the lateral angle between the conductor as it approaches the bull wheel and the plane of rotation of the wheel is not large enough to cause the conductor to rub on the sides of the groove. For example, bird caging problems were eliminated in large conductor by using a maximum fleet angle of 1.5 degree from the plane normal to the conductor reel axis and a back tension of approximately 4500 N. problems of bird caging are normally more acute in the case of large conductors having three or more aluminum layers.

Anchors: Anchors are normally required for holding equipment in place and snubbing conductors against tensions imposed. The type of anchor is dependent upon the soil conditions and stringing and sagging tensions. Portable equipment as well as ground type anchors are often used for this purpose. Slack should be removed from all anchor lines prior to loading to minimize the possibility of equipment movement or impact loads to the anchors.

Equipment Grounding: Adequate grounding must be established at all sites. The methods required and equipment used will be determined by the degree of exposure to electrical hazards and the soil conditions at the site. All equipment, conductors, anchors and structures with in the work area must be bonded together and to the ground source.

Installation of conductor: Once the rope pulling lines have been installed prior to pulling in any conductor or conductive type pulling lines, a running ground must be installed between the reel stand or tensioner for conductor, or puller for pulling line, and the first tower. This ground must be bonded to the ground previously established at the site.

Pulling lines are usually pulled in under tension. The pulling line is then connected to a single conductor through swivel link, or to bundle conductors through swivel links and a running board.

Swivel links should not be used on a three strand synthetic pulling line. Pulling lines may be synthetic fibre or wire rope. When wire rope is used, it is recommended that swaged type or braided type be used since it has fewer tendencies to rotate under load, which minimizes spinning problems.

A ball bearing swivel link is usually used for the connections between conductors, pulling lines and running boards. Swivel links must have sufficient rated working load to withstand loads placed on them during tension stringing. They should also be compatible with the travelers being used so that they can pass through without spreading or damaging the sheaves. These special line stringing swivel links are clevis type and compatible with woven wire grips and swaged steel pulling lines. It is recommended that swivel links not be passed over bull wheels under significant tension since they may by weakened or damaged due to bending.

When reeving the bull wheels of a tensioner with the conductor entering and leaving the wheel from the top facing in the direction of pull, the conductor should enter from the left and leave from the right for right hand lay (standard for aluminum conductor) and enter from the right and leave from the left for left-hand lay (standard for ground wire). The procedure eliminates the tendency of loosening of outer layer strands while conductor passes around the bull wheel.

It is recommended that conductor of only one manufacturer is used in a given pull, and preferably in any given ruling span. This precaution helps in minimizing the possibility of difference in sag characteristics of conductor significantly.

Attachment of the conductor to the pulling line, running board or to another reel of conductor to be pulled successively is accomplished by the use of woven wire grips. These grips should be compatible strength wise and sized as close as possible for the conductor or pulling line on which they are used. Overall diameter of the grip over the conductor or rope should be small enough to pass over the sheaves without damage to the sheave or its lining and the grip must also be capable of mating with a proper size swivel link.

Metal bands should be installed over the grip to prevent it from accidentally coming off and dropping the conductor. The open end of the grip should be secured with two bands. This should then be wrapped with tape to prevent accidentally stripping the grip of the conductor if the end were to snag or catch. This is particularly important when these grips are used on pulling lines or between lengths of conductor when more than one reel is strung. The grips will then pass through the travelers backwards and if the ends are not banded and taped, they may slip off.

Pulling speed is an important factor in achieving a smooth stringing operation. Speeds of 3-4 km/hour usually provide a smooth passage of the running board or connecting hardware, or both, over the travelers, whereas slower speeds may cause significant swinging of the traveler and insulator hardware assemblies. Higher speeds create a potential hazard of greater damage in case of a malfunction.

The maximum tension imposed on a conductor during stringing operations should not exceed than necessary to clear obstructions on the ground. The clearance should be confirmed by observation. In general, stringing tension about one-half of the sagging tension is a good criterion. If greater tensions are required, consideration must be given to any possible pre-stressing of conductors that may result, based on the tension and time involved. Consideration must also be given to the fact that when long lengths of conductor are strung, the tension at the pulling end may exceed the tension at the tensioner by a significant amount. Difference in tension is caused by the length of conductor strung, number and performance of travelers, differences in elevation of supporting structures, etc.

Light and steady back tension should be maintained on the conductor reels at all times sufficient to prevent over run in case of sudden stop. It must also be sufficient to cause the conductor to lie snugly in the first groove of the bull wheel and to prevent slack in the conductor between bull wheels. It may be necessary periodically to loosen the brake on the reel stand, as the conductor is paved off. As the reel empties, the moment arm available to overcome the brake drag is reduced, and the tension therefore rises. This may cause the conductor to wedge into the underlying layers on the reel.

The reel should be positioned so that it will rotate in the same direction as the bull wheels. Loosening of the stranding that often occurs between the reel and the bull wheels of the tensioner is caused to a great extent by coil memory in the conductor. As the conductor is unwound from the reel and straightens out, the outer strands become loose, a condition that is particularly noticeable in a large diameter conductor and can be best observed at the point at which it leaves the reel. As the conductor enters the bull wheel groove, the pressure of contact tends to push the loose outer strands back towards the reel where the looseness accumulates, leading to the condition commonly known as bird caging. If this condition is not controlled, the strands can get damaged to the extent that the damaged area of conductor must be removed. This problem can be remedied by allowing enough distance between the reel and tensioner to permit the strand looseness to distribute along the intervening length of conductor and simultaneously maintaining enough back tension on the reel. Stretch the core and inner strands to sufficiently tighten the outer strands.

The maximum time conductors may safely remain in the travelers depends on wind induced vibration or other motion of the conductors. Wind blown sand can severely damage conductors in a few hours if clearance is less than about 3 m over loose sand with little vegetation. Damage from vibration at sagging tensions is quite possible and, when required, dampers should be installed promptly. However, at lower tensions generally used for initial stringing, damage to conductors or sheave bearings, or both, is not likely to occur from vibration. Even for travelers having lined sheaves with root diameters 20 times the conductor diameter, it is important to complete conductor stringing, sagging, plumb marking, clipping, spacing and damping operations as soon as possible to prevent conductor damage from weather, particularly wind. Conductor should not be strung if adverse weather is predicted before the entire sequence can be completed.

Sub-conductor oscillation may occur in bundled conductor lines and tie-down methods involving temporary spacers, or other means may be required to prevent conductor surface damage prior to installation of spacers. Temporarily positioning of one sub-conductor above another to prevent conductor clashing is undesirable since different tension history will produce sub-conductor mismatch unless the tensions are low and duration short enough so that creep is not a factor. Conductor clashing can mar the strands and produce silvers, which can result in radio noise generation.

If a bull wheel type puller is utilized, the pulling line must be recovered during the pulling operation on a separate piece of equipment. This function is usually performed by a reel winder, which is placed behind the puller in an arrangement similar to the reel stand at the tension site. These coils shall be removed carefully and if another length is required to be run out, a joint shall be made according to the recommendation of the manufacturers. Drum battens shall be removed just prior to moving drums on drum stands.

The conductors, joints and clamp shall be erected in such a manner that no bird caging, over-tensioning of individual wires of layers or other deformation or damage to the conductors shall occur. Clamps for hauling devices shall, under erection conditions, allow no relative movement of strands or layers of the conductors.

Scaffolding shall be used where roads, rivers, channel telecommunication or overhead power lines, railway lines, fences or walls have to be crossed during stringing operations. It shall be seen that normal services are not interrupted or damage caused to property. Shut-down shall be obtained when working at crossing of overhead power lines.

The sequence of running out shall be from top to downwards i.e. the earth wire shall be run out first, followed by the conductors in succession. In case of horizontal configuration tower, middle conductor shall be strung before stringing of outer conductors is taken-up.

1.5.22.2 Sagging Operation: The conductors shall be pulled up to the desired sag as per sag board fixed with reference to initial stringing chart on tower and left in running block for at least one hour after which the sag shall be re-checked and adjusted, if necessary, before transferring the conductors from the running blocks to the suspension clamps. The conductors shall be clamped within 36 hours of sagging in. Thermometer should be used at site for identifying tension and sag, accordingly fixing the sag boards on tower.

The sag will be checked in the first and the last span of the section in case of sections up to eight spans and in one intermediate span also for sections with more than eight spans. The sag shall also be checked when the conductors have been drawn up and transferred from running blocks to the insulator clamps.

The running blocks attached to the suspension string, when suspended from the tower shall be so adjusted that the conductors on running blocks will be at the same height as the suspension clamp to which it is to be secured.

At sharp vertical downward angles, the sags and tensions shall be checked on both sides of the angles, the conductor and earth wire shall be checked on the running block for equality of tension on both sides. The suspension insulator assemblies shall normally assume vertical positions when the conductor is clamped.
Tensioning and sagging operations shall be carried out in calm weather when rapid changes in temperatures are not likely to occur. In areas where calm weather is not prevalent during working season, the contractor shall recommend the precautions to be taken during final tensioning and sagging of conductor.

1.5.22.3 Final Sagging of Conductor and Earth wire:

The tensioning and sagging shall be done in accordance with the approved initial stringing charts before the conductors and ground wire are finally attached to the towers through the ground wire clamps for the ground wire and insulator strings for the conductor.

Provision for ground undulations, errors in stringing and compensation for creep in conductors shall be considered at the time of stringing of conductors and as per approved stringing charts developed by the Contractor.

No pre-stressing/over-tensioning of the ground wire shall be done.

The adjustment of sub-conductor sag by means of sag adjustment devices provided in the insulator string shall not be permitted at the time of stringing of the conductors. The sag adjustment plates shall be kept in fully open position at the time of stringing of the conductor.

The final sagging of the Conductor shall be done by sagging winches.

After being rough sagged, the conductor/earth wire shall not be allowed to hang in the stringing blocks for more than 96 hours before being pulled to the specified sag.

The sag will be checked in the first and last span of the Section in case of Sections up to eight spans and in one intermediate span also for sections with more than eight spans. The sag shall also be checked when the conductors have been drawn up and transported from running blocks to the insulator clamps.

The running blocks, which are suspended from the transmission structure for sagging, shall be so adjusted that the conductors on running blocks will be at the same height as the suspension clamp to which it is to be secured.

At sharp vertical angles, the sags and tensions shall be checked on both sides of the angle, the conductor and earth wire shall be checked on the running blocks for quality of tension on both sides. The suspension insulator assembly will normally assume vertical positions when the conductor is clamped.

Tensioning and sagging operations shall be carried out in normal weather when rapid changes in temperatures are not likely to occur. Sag board and dynamometers shall be employed for measuring sag and tension respectively.

The dynamometers employed shall be periodically checked and calibrated with a standard dynamometer.

Attempts to sag conductor on excessively windy day should be avoided since serious error can result due to conductor uplift caused by wind pressure on the conductor.
Once a section has been sagged, the sub-conductors of the bundle should be checked for evenness. Unevenness, if any, shall be rectified as far as possible with the help of sag adjuster.

The travelers which are used to string conductor are not frictionless and therefore, can cause problems during a sagging operation. If one or more of the travelers becomes jammed, sagging can become very difficult. A traveler which swings in the directions of the pull may be an indication of a defective traveler. Should unexplainable sagging difficulties occur, the traveler should be checked. Tensions applied to the conductor to overcome sticky or jammed travelers can cause sudden abrupt movement of the conductor in the sagging spans and quickly cause change of sag, particularly, if the conductor is already tensioned to the required value.

During sagging care shall be taken to eliminate differential sags in the sub-conductor as far as possible. However, in no case sag mismatch of more than 25 mm shall be allowed.

INITIAL STRINGING CHARTS FOR CONDUCTOR

LINE : 400 KV DC line

SECTION DETAILS :

SECTION FROM : LOC9 SECTION TO : LOC 15 EQUIVALENT SPAN : 346.9

LIMITING CONDITION : 32 DEG. C WITH NIL WIND

TEMPARATURE : 32.0 DEG.C WIND PRESSURE : 0.0 KG/M2 ICE THICKNESS : 0.00 CM TENSION : 3652.1 KG

TEMPARATURE	TENSION	360.0	360.0	360.0	340.0	330.0	326.0
LOCATION NO.		LOC9	LOC10	LOC11	LOC12	LOC13	LOC14	LOC15
0.0(-26.0)	5172.8	6.276	6.276	6.276	5.598	5.274	5.147
2.0(-24.0)	5100.7	6.365	6.365	6.365	5.677	5.348	5.219
4.0(-22.0)	5030.3	6.454	6.454	6.454	5.757	5.423	5.292
6.0(-20.0)	4961.5	6.543	6.543	6.543	5.836	5.498	5.366
8.0(-18.0)	4894.4	6.633	6.633	6.633	5.917	5.574	5.439
10.0(-16.0)	4828.8	6.723	6.723	6.723	5.997	5.649	5.513
12.0(-14.0)	4764.8	6.813	6.813	6.813	6.077	5.725	5.587
14.0(-12.0)	4702.3	6.904	6.904	6.904	6.158	5.801	5.661
16.0(-10.0)	4641.4	6.995	6.995	6.995	6.239	5.877	5.736
18.0(-8.0)	4581.9	7.085	7.085	7.085	6.320	5.954	5.810
20.0(-6.0)	4523.8	7.176	7.176	7.176	6.401	6.030	5.885
22.0(-4.0)	4467.2	7.267	7.267	7.267	6.482	6.107	5.959
24.0(-2.0)	4411.9	7.358	7.358	7.358	6.564	6.183	6.034
26.0(0.0)	4358.0	7.449	7.449	7.449	6.645	6.260	6.109
28.0(2.0)	4305.4	7.540	7.540	7.540	6.726	6.336	6.183
30.0(4.0)	4254.1	7.631	7.631	7.631	6.807	6.413	6.258
32.0(6.0)	4204.0	7.722	7.722	7.722	6.888	6.489	6.333
34.0(8.0)	4155.1	7.813	7.813	7.813	6.969	6.565	6.407
36.0(10.0)	4107.4	7.904	7.904	7.904	7.050	6.641	6.481
38.0(12.0)	4060.9	7.995	7.995	7.995	7.131	6.718	6.556
40.0(14.0)	4015.5	8.085	8.085	8.085	7.212	6.794	6.630
42.0(16.0)	3971.1	8.175	8.175	8.175	7.292	6.869	6.704
44.0(18.0)	3927.9	8.265	8.265	8.265	7.372	6.945	6.778
46.0(20.0)	3885.6	8.355	8.355	8.355	7.453	7.021	6.851
48.0(22.0)	3844.4	8.445	8.445	8.445	7.533	7.096	6.925
50.0(24.0)	3804.1	8.534	8.534	8.534	7.612	7.171	6.998
52.0(26.0)	3764.8	8.623	8.623	8.623	7.692	7.246	7.071
54.0(28.0)	3726.3	8.712	8.712	8.712	7.771	7.321	7.144
56.0(30.0)	3688.8	8.801	8.801	8.801	7.850	7.395	7.217
58.0(32.0)	3652.1	8.889	8.889	8.889	7.929	7.469	7.289
60.0(34.0)	3616.3	8.977	8.977	8.977	8.008	7.543	7.362
62.0(36.0)	3581.3	9.065	9.065	9.065	8.086	7.617	7.434
64.0(38.0)	3547.1	9.153	9.153	9.153	8.164	7.691	7.505
66.0(40.0)	3513.6	9.240	9.240	9.240	8.242	7.764	7.577
68.0(42.0)	3480.9	9.327	9.327	9.327	8.319	7.837	7.648
70.0(44.0)	3448.9	9.413	9.413	9.413	8.396	7.910	7.719
72.0(46.0)	3417.6	9.499	9.499	9.499	8.473	7.982	7.790
74.0(48.0)	3387.0	9.585	9.585	9.585	8.550	8.054	7.860
75.0(49.0)	3371.9	9.628	9.628	9.628	8.588	8.090	7.895
77.0(51.0)	3342.3	9.713	9.713	9.713	8.664	8.162	7.965
79.0(53.0)	3313.3	9.798	9.798	9.798	8.740	8.233	8.035
81.0(55.0)	3284.9	9.883	9.883	9.883	8.815	8.304	8.104
83.0(57.0)	3257.1	9.967	9.967	9.967	8.891	8.375	8.173
85.0(59.0)	3229.9	10.051	10.051	10.051	8.965	8.446	8.242

NOTES : 1. ALL LOADS ARE IN KG AND SAG IN METRES.
2. BRACKETED TEMPARATURES ARE VALUES AFTER CONSIDERING CREEP.

FINAL STRINGING CHARTS FOR CONDUCTOR

TEMPARATURE	TENSION	360.0	360.0	360.0	340.0	330.0	326.0
LOCATION NO.		LOC9	LOC10	LOC11	LOC12	LOC13	LOC14	LOC15
0.0	4358.0	7.449	7.449	7.449	6.645	6.260	6.109
2.0	4305.4	7.540	7.540	7.540	6.726	6.336	6.183
4.0	4254.1	7.631	7.631	7.631	6.807	6.413	6.258
6.0	4204.0	7.722	7.722	7.722	6.888	6.489	6.333
8.0	4155.1	7.813	7.813	7.813	6.969	6.565	6.407
10.0	4107.4	7.904	7.904	7.904	7.050	6.641	6.481
12.0	4060.9	7.995	7.995	7.995	7.131	6.718	6.556
14.0	4015.5	8.085	8.085	8.085	7.212	6.794	6.630
16.0	3971.1	8.175	8.175	8.175	7.292	6.869	6.704
18.0	3927.9	8.265	8.265	8.265	7.372	6.945	6.778
20.0	3885.6	8.355	8.355	8.355	7.453	7.021	6.851
22.0	3844.4	8.445	8.445	8.445	7.533	7.096	6.925
24.0	3804.1	8.534	8.534	8.534	7.612	7.171	6.998
26.0	3764.8	8.623	8.623	8.623	7.692	7.246	7.071
28.0	3726.3	8.712	8.712	8.712	7.771	7.321	7.144
30.0	3688.8	8.801	8.801	8.801	7.850	7.395	7.217
32.0	3652.1	8.889	8.889	8.889	7.929	7.469	7.289
34.0	3616.3	8.977	8.977	8.977	8.008	7.543	7.362
36.0	3581.3	9.065	9.065	9.065	8.086	7.617	7.434
38.0	3547.1	9.153	9.153	9.153	8.164	7.691	7.505
40.0	3513.6	9.240	9.240	9.240	8.242	7.764	7.577
42.0	3480.9	9.327	9.327	9.327	8.319	7.837	7.648
44.0	3448.9	9.413	9.413	9.413	8.396	7.910	7.719
46.0	3417.6	9.499	9.499	9.499	8.473	7.982	7.790
48.0	3387.0	9.585	9.585	9.585	8.550	8.054	7.860
50.0	3357.0	9.671	9.671	9.671	8.626	8.126	7.930
52.0	3327.7	9.756	9.756	9.756	8.702	8.198	8.000
54.0	3299.0	9.841	9.841	9.841	8.778	8.269	8.070
56.0	3271.0	9.925	9.925	9.925	8.853	8.340	8.139
58.0	3243.5	10.009	10.009	10.009	8.928	8.411	8.208
60.0	3216.5	10.093	10.093	10.093	9.003	8.481	8.277
62.0	3190.2	10.177	10.177	10.177	9.077	8.551	8.345
64.0	3164.3	10.260	10.260	10.260	9.151	8.621	8.413
66.0	3139.0	10.342	10.342	10.342	9.225	8.690	8.481
68.0	3114.2	10.425	10.425	10.425	9.299	8.760	8.549
70.0	3089.9	10.507	10.507	10.507	9.372	8.829	8.616
72.0	3066.0	10.588	10.588	10.588	9.445	8.897	8.683
74.0	3042.7	10.670	10.670	10.670	9.517	8.966	8.750
75.0	3031.2	10.710	10.710	10.710	9.553	9.000	8.783
77.0	3008.5	10.791	10.791	10.791	9.625	9.068	8.849
79.0	2986.2	10.872	10.872	10.872	9.697	9.135	8.915
81.0	2964.4	10.952	10.952	10.952	9.769	9.202	8.981
83.0	2942.9	11.031	11.031	11.031	9.840	9.269	9.046
85.0	2921.9	11.111	11.111	11.111	9.911	9.336	9.111

1.5.22.4 Clipping in/clamping in of conductors

Conductor shall be fitted with the armor rods at suspension point and with vibration dampers at suspension and tension points.

The jumpers at the section and angle towers shall be formed to parabolic shape to ensure maximum clearance requirements. Pilot suspension insulator string shall be used, where required by the existing tower design.

Fasteners in all fittings and accessories shall be secured in position. The security clip shall be properly opened and strung into position.

The clipping portion of the conductor stringing operation involves the work following sagging and plumb marking of the conductors. This entails removing the conductors from the travelers and placing them in their permanent suspension clamps attached to the insulator assemblies.

When clipping is being done, care must be exercised to ascertain that the conductors are grounded prior to clipping despite the fact that the lines being clipped are not attached to any electrical source. This involves placing a local ground upon the conductor at the location of work.

After the conductors have been marked, the erection crew will lift the weight of the conductors, allowing the travelers to be removed and the suspension clamps, and amour rod, if any used, to be placed on the conductors. Lifting is normally done by use of a hoist suspended from the structure and a conductor-lifting hook, which is designed so as not to notch or severely bend the conductors. After placing the suspension clamps on the conductor, the hooks are lowered thereby placing the weight of the conductor on the suspension clamp and completing the assembly. Where bundle conductors are used, the multiple conductors may be lifted simultaneously by using a yoke arrangement supporting the hooks and a single hoist or other lifting means.

1.5.22.5 Installation of Spacers

Following the clipping operations for bundled conductor line, spacers must be installed. This is done by pacing the erection crew on the conductors in the 'conductor car' normally known as spacer cycle to ride from structure. Depending on the length of line and the equipment available, cars may be hand powered, towed by persons on the ground or in adjacent structures with ropes, or powered by a small engine on the car itself. Care must be exercised to ensure that the concentrated load of the man, car and equipment does not increase the sag appreciably to cause a hazard from obstructions over which the car will pass. The installation of the spacers on the conductor varies with the type and manufacturer of the spacer and is normally done as per the manufacture's recommendations.

The load of the man, car and equipment should be equally distributed to all sub-conductors of the phase. This is particularly important at the time each spacer is attached. Number of spacers per span and the spacing are provided as per the approved spacer placement chart.

1.5.22.6 Installation of Vibration Dampers/Spacer Dampers: Vibration Dampers/Spacer Dampers are normally placed on the conductors immediately following clipping to prevent any possible wind vibration damage to the conductors, which at critical tensions and wind conditions can occur in a matter of a few hours.

The number of dampers/ spacer dampers and spacing are provided as per the design requirement and instructions of the manufactures.

1.5.22.7 Jumpering: The jumpers at the section and angle towers shall be formed to parabolic shape to ensure maximum clearance requirement. Pilot suspension insulator string shall be used, if found necessary, to restrict the jumper swings to the design values. Clearance between conductors and ground and between jumpers and the tower steel work shall be checked during erection and before handing over the line.

Ground undulation: A provision of 150 mm shall be made to account for any undulations in the ground in final still air sag at maximum

1.5.22.8 HOT-LINE STRINGING OF E.H.V. LINES

General: Hot line stringing means stringing of second circuit on the same tower with first circuit electrically & mechanically loaded.

Hot-line stringing is done in this country only up to 220 KV. The advantage of stringing second circuit at a later date (with hot-line method) is saving initial capital investment in the form of conductors, insulators hardware etc. besides, with provision of Double circuit towers from the beginning saves way leave problems as a separate corridor is not required for second circuit.

Precautions: Being a specialized job hot-line works call for special precautions. All the crewmembers shall be provided with rubber shoes and hand-gloves for use during stringing without fail.

All the drums of conductor and pilot wires shall be solidly earthed. All the tension locations, where the conductor ends are terminated, shall be solidly earthed.

In addition to above, during final sagging and clipping operation, standard earthing rods are used for connecting each conductor to the tower body.

Operations**:** Arrangement for earthing the conductor drums and pilot wire drums is made at both the ends of the section under stringing. The hoisting of insulators, clamping of pilot wire and the conductor and rough sagging of conductor is done as per normal stringing method.

Before marking and clipping the dead ends, each phase conductor is solidly earthed in two separated sets: - one set is earthed by means of droppers and earthing rods and second set is by earthing of conductor end to tower body.

While removing the second set of earthing, the conductor end is removed first and the tower end later. Similarly in case of the first set the cable is disconnected from conductor end first and the rod end later.

Similarly, before clipping the conductor on the suspension towers, each conductor on both the sides of the clamp is earthed to tower body. After the clipping is over, the earthing cable is first removed from the conductor end later from the tower end.

In order to limit the parallelism and induced voltages, it is advisable to do the jumpering work at the end. While doing the jumpering work also the earthing cables are required to be provided.

Earthing: Solid earthings are provided by driving one or more G.I. SPIKES in the soil as done in pipe type of earthing. If required, more pipes are driven at the same place. In any case the soil resistance should not be more than 5 ohms.

In case of rocky soils, counterpoise type earthing system is used. The length of the wires is decided by trial & error till the earth resistance is lowered to 5 ohms or less.

For earthing a flexible copper cable having 10 sq.mm area (20 Ampere capacity) is used. The cable is generally armoured type for rough use. Proper clamps/connectors are used to connect the cable to the conductor and to the earth.

1.5.23 TOWER ACCESSORIES:

Bird Guards: These are fixed to the cross-arms of tangent towers to prevent birds from perching over the insulator strings. If such provision is not made, the droplets may foul continuously with the insulator string resulting in breakdown of insulation. The bird guard is made of 18 gauge M.S sheet.

Anti-Climbing Devices: These devices are provided to towers at a height of about 3.00 Mtrs. from ground at vulnerable places such as road crossings, near villages and other inhabited places. These anti climbing devices prevent persons from reaching the live power conductors or their vicinity. The anti climbing devices are made of M.S angle and barbed steel wire.

Danger Plates: 16 gauge M.S. sheet of size 200 x 325 Mtr. is used as Danger Plate. The word 'DANGER' in English and Local Language shall be inscribed on the Plate. Danger sign depicting of a skull above two bones is painted on the Danger Plate. The voltage at which the EHV line is charged is also indicated on the plate. Provision is made in the danger plate to fix it on the tower leg with 16mm bolts.

Number Plates: Each tower in any transmission line is allotted a number in a serial order commencing from one terminal tower and ending with the terminal tower on the other end. The number plate is made of 16 gauge sheet of 100 x 150 Mtr. Size. The number is enameled in Red on white enameled background. The number plate is fixed to the tower body at about 4 Mtrs ground level.

Phase Plates: Each angle tower is provided with a set of three circular discs of 0.100 mtr. dia each enameled in Red, Yellow and Blue. These phase plates are fixed to the towers at a height of about 4 mtr, above ground.

1.6 FIELD QUALITY PLAN

1. Check Survey

i) Verification of line deviation angle and bisection for proper location of towers.
ii) Verification of meeting statutory clearances.
iii) Check spans on either side of the tower location.
iv) Mark distances and angles from angle point at 3 conspicuous places to identify the angle point location in case of displacement of angle point peg.
v) At peg marks GPS marking should be done. This ensures correct position of peg even if it is removed, as the longitudes and latitudes are recorded.

2. Soil Investigation

i) Soil Penetration Test (SPT) to be performed at all angle points, at locations where soil strata changes, railway and national/state road crossings, power line crossings and special locations.
ii) Perform soil investigation for every KM of soil. Investigation is done by way of ERM method, time is saved and soil investigation can be done without disturbing standing crops.

3. Pit Marking

i) Mark position of all the four pits on the ground as per pit marking drawing for standard type of foundation and note levels of the center of each leg pit w.r.t center peg of the tower.
ii) Assess volume of bench cutting or use of hill side extension revetment if required and take approval of the Superintending Engineer /Chief Engineer.

4. Foundation Classification

i) One of the foundation pits to be used as a trial pit and excavated as per normal soil dry type foundation.
ii) Observe following for classification
   - Type of cultivation surrounding tower and whether encasement of stub required due to surface water.
   - Type of strata and depth of each layer.
   - Water table/level.
   - Maximum water table in the near by village well.

iii) Check and record soil classification and foundation classification as per relevant clauses of the agreement and excavate pit as per approved drawing for the type of foundation classification.

5. Form Work

Verify form work dimensions, rigidity, adequacy of tightness to prevent loss of cement water from concrete, ensure form surfaces in contact with concrete wetted and sprayed with fine sand/treated with black oil or waste oil/mould releasing agent every time before use.

6. Stub setting and Stub setting template

i) Recheck the depth of the pits w.r.t center peg level and pit dimensions as per approved foundation classification.
ii) Check under cutting as per approved drawing.
iii) Position fully assembled and bolt tightened stub setting template with supporting jacks placed on firm ground and level the template.
iv) Check placing a green concrete block of thickness equal to the clearance between the stub end and concrete to mitigate settling of template.
v) Check height of template above the center peg level.

7. Reinforcement

i) Check reinforcement dimensions as per bar bending schedule. Tie reinforcement at alternative crossing points with suitable binding wire.
ii) Verify using chair and gitties to ensure proper spacing in two layers reinforcement and minimum cover of 50 mm on the bars respectively.
iii) Before commencement of concreting ensure sufficient quantity of chairs and gitties are fabricated and made available at stores for use at locations.

8. Concrete Mixing

i. Ensure using coarse aggregate (metal) and fine aggregate (sand) as per IS-383.
ii. Check coarse aggregate for flakiness, soft stone and laminar shape.
iii. Check cement for approved brand.
iv Ensure proper mixing of concrete as per the guide lines.
v After mixing and before placing the concrete in the foundation pit, take samples for checking compressive strength and slump test of concrete.
vi Where ever it is not possible to work with manual methods engage ready mix concrete with prior approval from AP Transco, on case to case basis.

9. Placing of Concrete

i) Check providing lean concrete (M 10) base 100 mm thick at bottom of the excavated pit before placing reinforcement.
ii) Use pointing/poking rod and vibrator for compaction of concrete ensuring vibrator head does not come in contact with steel, hardened concrete etc.,

10. Stripping of Form Work

Ensure stripping formwork after about 24 hrs and check for any damage, honey combing and do necessary rectification.

11. Back Filling

i) Ensure back filling on foundation in layers and ensure proper consolidation.
ii) Ensure all top soils to be placed at the surface in case of towers located on cultivated land.
iii) Excess earth available over and above ground level (after consolidation) should be transported away from the site.

12. Curing

Ensure proper curing by keeping adequate quantity of water and storing arrangement available at site.

13. Earthing of Tower

i) Ensure tower footing resistance not to exceed 10 Ohms.
ii) Use pipe earthing or counter poise earthing as per approved drawings to ensure minimum tower footing resistance.

1.6.1 A Field Quality Assurance plan indicating the components to be checked, sampling basis, standards and testing agency is furnished below.

Sl. No	Component operation and description of test	Sampling plan with basis	Reference
1. Detailed Survey and Alignment			
a)	**Field survey/Walk over survey**	**100%**	**Technical specification Geographical Map, Route alignment, Route Plan & Measurement Schedules**
(b)	**Plotting of Route**	**100%**	**Technical specification, Field book, Geographical Map, Route alignment, Route plan**
(c)	**Profiling**	**100%**	**Technical specification, Field book, Graph sheets, approved route alignment.**
(d)	**Tower Spotting**	**100%**	**Technical specification, Approved Tower spotting data & Sag Template, Field Book, approved route alignment**
(e)	**Tower Schedule**	**100%**	**Technical specification, Approved Route alignment & route profile tower schedule, sag template, tower spotting data**

Note: Testing/checking is to be done by contractor. Counter checking is to be done by AEE/EE/SE, construction. Tower schedule should be counter checked by EE/SE and approved.			
2. (a)	**Check Survey Bisection of Angle/Accuracy of Alignment**	**100%**	**Technical specification IS: 5613, and other relevant standards. Approved Route Map & Route Profiles, Tower/line Schedule and Sag Template etc.**
(b)	**Check for profile levels and electrical clearances**	**100%**	**- do -**
(c)	**Check for span marking and lengths**	**100%**	**Technical specs IS: 5613 and other relevant standards, Apprd. Profile drgs. Tower schedule, tower spotting data.**
(d)	**Check for tower type& position as per site condition**	**100%**	**- do -**
(e)	**Estimation of benching &Revetment volumes (as per site conditions)**	**100% (To be done by contractor)**	**Technical specification IS: 5613 and other relevant standards Apprd. Tower leg location counters, approved profile**
(f)	**Final Profile & tower schedule**	**100%**	**Modified profile drawing and amended tower schedule**
Note: Testing/checking is to be done by contractor. Counter checking is to be done by AEE/EE/SE, construction. Span marking, tower type as per the site condition and final profile & tower schedule should be counter checked by EE/SE and approved. Benching should be checked by EE, Construction and Revetment by SE, Construction.			
3. Soil Investigation			
A	**At Normal location Bore log/Trial Pit for obtaining details/types of soil encountered. Including gradation of samples at specified levels, ground water levels etc. (at center of tower)**	**At locations as indicated by APTRANSCO**	**Technical specification IS:1498, 1892, 2720, 4464, 6935, SP-36 & and other relevant standards**
B	**Soil Resistivity**	**One Location in a stretch of 2 to 3 Km or at locations approved by APTransco**	**IS:2131, IS 2720 and Technical Specifications**
C	**Tests on soil samples Visual and Engineering classifications**	**- do -**	**Technical specification IS:5613, IS:1498 and other relevant specifications**
D	**Tests on Rock Visual classifications**	**At locations as indicated by APTRANSCO**	**Technical specification IS:2131, 2720, 4078, 4474, 1498, 5613and other relevant standards**
Note: To be done by contractor on his own or through APTRANSCO's approved agency, and to be cross checked by AEE/EE/SE, construction and approved.			

4	**Selection of Site for Material Storage**	**100% (To be done by contractor and to be counter checked by AEE/EE/SE, construction)**	**Technical specification, utility/industry storage document Wooden sleepers, wooden planks, tarpaulin, steel sheets, bricks, Barbed wire for fencing etc site shall be free from termites**
5. Checking of foundation materials			
A	**<u>Cement</u>**	**Supply source to be approved by AP Transco**	
(i)	**Fineness**	**For each source MTC shall be furnished for every lot of 200 MTs and part thereof**	**APTRANSCO Technical specification IS:269, 456, 1489, 4031, 8112, 12269 and other relevant standards**
(ii)	**Compressive Strength**	**- do -**	**- do -**
(iii)	**Initial & Final setting time**	**- do -**	**- do -**
iv)	**Soundness**	**- do -**	**- do -**
(v)	**Chemical composition of Cement**	**- do -**	**APTRANSCO Technical specification IS:269, 456, 1489, 4031, 8112, 12269 and other relevant standards**
B.	**<u>Coarse Aggregates</u>**	**One sample per lot of 200Cum or part per each source for each size**	
(i)	**Determination of Particle size (sieve analysis)**	**One sample per lot of 200Cum or part per each source**	**Technical specification IS :383, IS:2386 and other relevant standards**
(ii)	**Flakiness Index**	**- do -**	**Technical specification IS :383, IS:2386 and other relevant standards**
(iii)	**Crushing Valve**	**- do -**	**Technical specn, IS :383, IS:2386 and other relevant standards**
(iv)	**Specific gravity**	**- do -**	**- do -**
v)	**Bulk Density**	**- do -**	**- do -**
vi)	**Absorption Value**	**- do -**	**- do -**
vii)	**Moisture Content**	**- do -**	**- do -**
viii)	**Presence of deleterious materials**	**- do -**	**- do -**
C.	**<u>Fine Aggregates</u>**	**One sample per lot of 200Cum or part per each source**	
(i)	**Gradation/ Determination of Particle Size (Sieve analysis)**	**- do -**	**Technical specification IS :236, 383, 456, 2386, 2430, 4031 and other relevant standards**
(ii)	**Specific gravity and density**	**- do -**	**Technical specification IS :236, 383, 456, 2386, 2430, 4031 and other relevant standards**
iii)	**Moisture Content**	**- do -**	**- do -**
iv)	**Absorption Value**	**- do -**	**-do -**
v)	**Bulk Density**	**- do -**	**- do -**
vi)	**Presence of deleterious materials**	**- do -**	**- do -**

D. Water			
(i)	**Suitability (Potable water is considered suitable for concreting)**	**One sample for source**	**Technical specification IS 456, IS:3025 and other relevant standards**
(ii)	**Cleanliness (Visual Check)**	**100%**	**- do -**
iii)	**P.H. Value**	**One sample per source**	**- do - Min-6 and Max-8**
E. Reinforcement Steel			
(i)	**Identification & Size**	**Random**	**Technical specification and approved drawings & IS 432, 1139 & 1786 and other relevant standards**
(ii)	**(a)Strength (Tensile test, Yield stress/proof stress)** **(b) percentage elongation**	**For steel as per IS 1786 under 10mm one sample per each 25 MT or part thereof 10mm-16mm one sample per each 35 MT or part thereof. Over 16 mm 1 sample per each 45 MT or part thereof.**	**- do -**
iv)	**(a) Bend Rebend Test** **(b) Reverse bend test for HDS wires**		**Technical specification IS: 432, 1139, 1786 2502 and other relevant standards**
v)	**Chemical analysis test**	**One sample per source**	**IS:432, IS:1139, IS:1786 and specification**
F. Earthing Materials			
(i)	**Visual identification**	**100% (to be done by contractor and counter checked by CE, Construction)**	**Technical specification IS: 5613 and other relevant standards**
(ii)	**Bill of material & installation**	**100%(by contractor and counter checked byEE/SE,Construction**	**Technical specification approved drawings & IS 5613**
Note: Cement, coarse and fine aggregates, reinforcement steel and water are to be tested as above by contractor at manufacturer's works or an approved test lab by APTRANSCO. To be reviewed by AEE/EE/SE, Construction and approved.			
6. (A) Before Excavation			
(i)	**(a) Checking of pegs condition as per line Alignment** **(b) Checking of pit marking as per drawing** **(c) Trial pit** **(d) Classification of soil** **(e) Pit marking** **(f) Pit levels w.r.t. centre peg levels** **(g) Depth of pits as per centre peg level (estimate)**	**100% Every Location**	**Approved line alignment/profiles Tech. Specification. IS 4091, 5613, CBI & P Publication No.268 and other relevant standards** **Excavation and foundation drawings**

(ii)	**Benching**	**Where required**	**Technical specification IS 5613, approved Foundation leg contour Profiles and other relevant standards**
(B)	**Excavation**		
(i)	**a)Dimensional conformity b)verticality and squareness of each pit c)Verification of classification of soil type and type of foundation**	**Each Location**	**Technical specifications IS:3764, 408, 4091 &5613, SP:16 and other relevant standards Approved excavation Drgs./ Specification**
(ii)	**a)Shoring and Strutting (Check durability strength & soundness of staging, fonts adequacy and specific levels) b)Dewatering (where required)**	**As required**	**Technical specification applicable state/ local body safety regulations. IS:456 and other relevant standards**
C)	**Stub and Template**		
(i)	**a)Identification & Assembly b)Stub setting c)Template level width&Diagonal d)ground clearance e)Stub clearance f)Tightening of bolts nuts for template, stubs and cleats**	**100% Every Location**	**Technical specification IS: 5613. Approved drawings of stub template and foundation drawing**
D)	**Shuttering (Form work) Fixing of form boxes check for identification dimensions parallelization and squareness and equidistance from stubs**	**100% in all collapsible location**	**Technical specification IS 456 and other relevant standards approved drawings**
Note: To be checked by contractor and counter checked by AE/AEE, construction and approved. Soil classification, shuttering works to be jointly inspected by contractor and AE/AEE.			
E) **(i)**	**Concreting** **Control Concrete mix design**	**100%**	**Technical specification IS 456 and other relevant standards & approved drawings**
(ii)	**Identification of material and water supply sources**	**100%**	**Technical specification IS 383,456 IS:3025, 3550 and other relevant standards**
(iii)	**Determination of characteristics of aggregates, cement, water etc.**	**100%**	**Technical specification IS 269,383,456, 3125, 3550 and other relevant standards**
(iv)	**Preparation of mix and taking of samples for strength (7days, 14 days & 28 days) and slump report**	**100%**	**Technical specification IS 456 and other relevant standards**

<table>
<tr><td>(v)</td><td>Review of controlled concrete mix report
a) Mixing of concrete
b) padding/lean concrete base</td><td>100%
100%</td><td>Technical specification IS 456 and other relevant standards</td></tr>
<tr><td></td><td>c) Reinforcement placing fixing as per bar bending schedule 2. Check for proper cover spacers and chairs. 3. Check whether lapping of bars is tied properly.</td><td>100%</td><td>Technical specification IS:2502 and other relevant standards and approved drawing</td></tr>
<tr><td></td><td>d) Fixing of form boxes check for identification, dimensions parallelization and squareness and equidistance from stubs
e) Placing of concrete and ramming
f) Fixing of chimney column width, length, check square and parallelism and equidistance from stub
g) Placing concrete, poking & ramming</td><td>100%</td><td>Technical specification IS 456, IS:5613 and other relevant standards approved drawings</td></tr>
<tr><td colspan="4">Note: Control concrete mix design& identification of material and water supply source s to be jointly inspected by contractor and AE/AEE. Tests shall be conducted by contractor at APTRANSCO’s approved test laboratory. Test results to be checked and approved by AE/AEE/EE, Construction. All other checks to be done by contractor and counter checked by AE/AEE and approved.</td></tr>
<tr><td>F)</td><td>Box removal check for dimensional conformity and workmanship</td><td>100%</td><td>Technical specification IS 456, and other relevant standards approved Drawings.</td></tr>
<tr><td colspan="4">Note: To be jointly checked by contractor and AE/AEE and approved.
Reinforcement rods should not be exposed. Boxes should be opened after 24 hours.</td></tr>
<tr><td>G)</td><td>Backfilling</td><td>100% all Locations</td><td>Technical Specification,
IS: 5613, and other relevant standards
Boulder size 80 mm (Max)</td></tr>
<tr><td colspan="4">Note: To be done by contractor and counter checked by AE/AEE/EE.
Boulders of size more than 80mm should not be allowed for backfilling. Sufficient water should be poured and rammed for every 200mm layer of earth. 100mm height earthen bund along with the side of excavation for filling water</td></tr>
<tr><td>H)</td><td>Coping and Curing</td><td>100%</td><td>Technical Specification, IS:5613, and other relevant standards and approved drawing</td></tr>
</table>

Note: To be done by contractor and counter checked by AE/AEE and approved. At locations in the paddy fields or in the low lying areas, the chimney is to be extended as per AP Transco Approved drawing. The corner reinforcement rods 200 mm below the final chimney level to be left un concerted and the extensions of chimney for this portion and coping shall be done after tower erection. Curing should be continued for minimum 15 days.			
I)	**Laying of Earthing (Pipe or Counterpoise type). (Based on measurement of soil resistivity/ tower footing resistance)**	**100% all Locations**	**Technical specification IS 3403**
Note: Earthing type to be decided by APTRANSCO. Work to be jointly inspected by contractor and AE/AEE and approved.			
J)	**<u>Concrete Cubes Testing</u> i) Strength under compression ii)Slump test iii)Unit weight of concrete**	**100% one sample for each location (One sample consists of min 4 test cubes for 28 days strength**	**Technical specification. IS 456, 516, 1199 and other relevant standards**
Note: Testing to be done by contractor at approved laboratory by APTRANSCO standard cube moulds, to be checked by AE/AEE/EE. Cubes must be tested within a week of 20 days curing period and test results should be approved by APTRANSCO before tower erection.			
K)	**<u>Bricks</u> a)Absorption strength b)Compressive strength c)Efflorescence**	**After 24 hours immersion immersion in cold water - do - - do -**	**IS:3495-1966 Not more than 20% by weight Not less than 40Kg/cm² Not more than "Moderate"**
Note: Testing to be done at APTRANSCO's approved laboratory, to be checked by AEE/EE/SE.			
L)	**<u>Earth work and Compaction control:</u> Degree of compaction**	**1test per 2000sq.mm. area**	**IS:2720 (Part-28)**
M)	**<u>Roads</u>**		
1.	**<u>Water Bound Macadam</u> a)Aggregate impact value**	**1 test per 250 Cum**	**IS: 2386 (Part-4)**
	b)Grading of aggregate and screening	**2 tests per 250 Cum**	**IS: 2386 (Part-1)**
	c)Flakiness index and elongation index	**1 test per 250 Cum**	**IS: 2386 (Part-1)**
	d)Atterberg limits of blinding material	**1 test per 50 Cum**	**IS: 2720 (Part-5)**
	e)Water absorption	**1 test per source**	**IS: 2386 (Part-30)**
	f)Thickness	**Regularly**	**………..**
2.	**<u>Bituminous Macadam/ Fix Seal Surfacing</u> a)Quality of binder b)Temperature of binder c)Aggregate impact value**	**1test per lot or per 10 tonnes. Regularly 1test per 250 Cum**	**IS:73/217/8887 Appendix – 10.6 IS:2386 (Part-4)**

	d)Flakiness index e)Stripping of aggregate f)Water absorption g)Grading of aggregates h)Binder content i)Density of compacted layer (for Bituminous Macadam) j)Soundness(Magnesium and Sodium Sulphate) (for Fix Seal Surfacing) k)Thickness(Fix Seal Surfacing)	2tests per 250 Cum 1 test per source 1 test per source 1 test per 100Cum 2 tests per day 1 testper1000Sqmarea 1 test per source Regularly	IS:2386 (Part-1) IS:6241 – 1971 IS:2386 (Part-3) IS:2386 (Part-1) IRC Specification, Appendix-10.8 IRC Specification IS:2386 (Part-5) --
3	<u>Granular and Sub-Base</u> a)Gradation/Determination of particle size (Sieve analysis) b)Atterburg limits c)Density of compacted layer	2 tests per 500 Cum 2 tests per 500 Cum 1 set of test per 2000Sq.m	IS:2720 (Part-4) IS:2720 (Part-5) IS:2720 (Part-28)
Note: To be tested by contractor at APTRANSCO approved testing laboratory, to be checked by EE/SE. Test results to be reviewed and approved by APTRANSCO. Item M (f) to be checked by AE/AEE.			
7)	Tower Erection		
A)	<u>Materials checking</u> i)Checking of tower members for damage, cleanliness, galvanizing and stacking ii)Checking of GI bolts nuts, step bolts, D-shackles, U-bolts, spring washers& accessories iii)Dimensional check	100% 100% Random	Technical specifications, IS:5613& other relevant standards and approved drawings
Note: To be done by contractor and counter checked by AE/AEE/EE and approved.			
B)	<u>Erection of Super structure</u> i)Checking of leg members/ bracing/redundant size&proper placement ii)Tightness of bolts, identification, cleanliness galvanizing iii)Punching of tightened bolts iv)Checking of assembly and verticality v)Tack welding vi)Tower footing resistance measurement before & after earthing	Random 100% each location - do - - do - 100% each location -do- -do-	Technical specifications,IS:5613 & other relevant standards and approved drawings. (Tightening of bolts nuts with torque wrenches)

	vii)Fixing of Danger plates, Number plates&Phase plates, Circuit plates (a)Visual check (b) Dimensional check		
Note: To be jointly inspected by contractor and AE/AEE. **Before starting erection of upper section ensure that (i) the lower section is completely braced and all bolts provided in accordance with approved drawing. Support guys at main panels are used during erection to avoid member deformations. Approval by APTransco.** **Verticality shall not exceed 1: 360** **Tack welding diametrically opposite, length of each welding at least 10mm, 2 coats of Zinc rich paint on welded portion**			
8	Line Stringing		
a)	Stringing (Sag Tension) chart	100%	TechnicalSpecification,IS:5613, Sag Tension calculations and stringing chart approved by APTransco
b)	Checking of insulators identification, cleanliness, packing glazing, cracks and white spots, security clips	100%	TechnicalSpecificationIS:731,5613, IEC 383 and other relevant standards, approved sag tension calculation and stringing chart
c)	Measurement of IR Value	100% (Shall be more than 50MΩ)	Technical Specification, IS:5613, and other relevant standards
d)	i) Checking of insulators hardware fittings and conductor & ground wire accessories – identification, cleanliness & packing, any mechanical damage& measurement of dimensions before and after making joint ii) checking mechanical strength	100% Random	Technical Specification, IS: 2121,2486,5613 and other relevant standards and approved drawings
Note: Item (a) should be checked by contractor and cross checked by AE/AEE/EE and approved. Remaining items to be jointly checked/tested by contractor and AE/AEE/EE. No approval is necessary. **Mech. Strength not to be less than 95% of UTS of conductor**			
e)	Checking of conductor and earth wire		
	i)Drum schedule approval ii)Identification, cleanliness & packing iii)Damage of conductor & earth wire stranding iv)Drum rubbing against ground/any metal part	100% 100% 100% 100%	Technical specification Approved Tower schedules, IS:1778,5613 & other relevant standards and other approved drawings
f)	Conductor/Earth wire stringing		
	i)Initial conductor position ii)Check for temperature iii)Final conductor position:	Entire route -do-	

	(a)Dimensional continuity **(b)Joints in conductor &earth wire** **iv)Jumpering (pre-formed)** **v)Tension stringing(if any).** **Installation of pilot string on D/DD tower**	**-do-** **-do-** **-do-** **-do-**	**Technical specification IS:5613 & other relevant standards and approved SAG & Tension charts**
Note: To be jointly inspected by contractor and AE/AEE/EE and approved. **Use of TSE, Sagging winch, Hydraulic Dynamometer, Metal enclosed thermometer and other tools etc. shall be ensured. Item (iii) shall be considering creep and no bend curve in the joint.** **Minimum clearance to be maintained at 2.1 mtrs. for 220kV and 1.54 mtrs. for 132kV.**			
9	**Final Checking**		
(a)	**i) Check for Backfilling** **ii) Removing any stored material near to the tower** **iii) Store extra back fill within the base of the tower** **iv) Checking of prospective revetment with weep holes and stone packing of weep holes.**	**100%**	**Specifications, IS:5613 and other relevant standards and approved Drgs.**
(b)	**Check for ACD & all tower accessories**	**Entire Route**	**- do -**
(c)	**Check for Tightening, punching and tack welding of bolts**	**- do -**	**- do-**
(d)	**Check for Final ground and electrical clearances**	**- do -**	**- do-**
(e)	**Check for effectiveness of Earthing**	**- do -**	**- do-**
(f)	**Meggering of the Line**	**100%**	**- do-**
(g)	**Conductor continuity Test**	**- do -**	**- do-**
(h)	**Measurement of line resistance**	**- do -**	**- do-**
(i)	**Phase sequence**	**- do -**	**- do-**
Note: To be jointly checked by contractor and EE/SE and approved. **All excess material should be cleared away as indicated in the specification**			

Testing and Commissioning of the line should be done by TRANSCO testing agency as per the procedure given in chapter-IV.

Post Commissioning checks such as check for visual corona at insulator, hardware, conductor accessories etc. at identified locations shall be done by APTRANSCO.

Note:
Route Plan, approved profiles, approved tower schedule sag template etc will be made available by the purchaser if the detailed survey is already carried out by the Purchaser

Contractor must ascertain TRANSCO's clearance before receipt of material i.e., Tower parts, Conductors, Hardware fitting accessories, insulators earthwire etc. at site.

APTRANSCO site office Engineers/Field quality Engineers should witness/review specified tests.

T & P of the erection contractor shall be inspected at site by the APTRANSCO before their use.

1.6.2 <u>Check list of works at various stages:</u>

Note: Checks made at each stage by both the contractor and the Transco engineer should be recorded in prescribed forms. Both contractor's authorized representative and Transco's representative shall sign the format after examining the checks and ensuring correctness of results. Next stage works shall be taken up only after clearance of previous stage works.

<u>Sample format:</u>

Name of line: Name of contractor:
Location No.: Type of tower:
Approved Drawing No.:

Details of checks <u>Ok. /NotOk.</u> <u>Yes/No</u> <u>Values of results (qty/ unit)</u>
i)
ii)
iii)

Certificate: - Cleared for ------

For contractor For APTRANSCO
Signature: ……… Signature: ………
(Name, Designation, Date) (Name, Designation, Date)

1.6.3 Checks to be conducted at each stage:

1. CHECK SURVEY

Approved detailed survey profile drg.Nos.: ---- Reference level: ------
Peg Marked Suspension Locations w.r.t Detailed Survey Profile :
Alignment of Location w.r.t previous and next location :
Whether Location of center peg/position of various landmarks are matching as per profile
Whether there are any new features on ground, w.r.t. profiles necessitating realignment / shifting :
Span on both sides of location As per profile (Metres) Actual (Metres)
Preceding span/Succeeding span (Loc.No):

Angle of deviation and bisection at tower loc: As per profile Actual

a) Angle of deviation

b) Bisection

After ensuring correct results clearance for pit marking should be given.

2. PIT MARKING

Approved Pit Marking Drg. Nos: ----- Angle of Bisection:

Position of pegs in line/longitudinal and transverse direction:

Position of leg pegs w.r.t center peg of tower:

Position of all four pits is on leveled ground and safe:

Dimensions of pit marking are per drgs. :

Whether Benching/Revetment required : Yes/No. If yes, then whether contour maps/Revetment drgs.prepared; Calculated volume (cu.m); whether approved by designated authority.

To be cleared for excavation, after satisfactory checks.

3. FOUNDATION CLASSIFICATION

Strata wise pit details:

i) Strata depth and predominant soil at each pit : pit A/1, pit B/2, pit C/3, pit D/4
(Note: Classification may also be given on one pit excavation basis for normal dry soil foundation dimension.)

ii) Sub-soil water table details as on date pit wise: pits A/1, B/2, C/3, and D/4.

iii) Water table in near by well as on date: …… mtrs.

iv) Maximum sub-soil water table during monsoon after local enquiry: …mtrs

v) Surface water table on ground in monsoon and its duration: …..mtrs for …..days

vi) Type of cultivation: Paddy fields / Cultivated land/ Barren land
Whether encasement of stubs required due to surface water: Yes/No
If yes, height of encasement above ground level: ……. mtrs.

vii) Whether soil investigation (SPT) carried out at this loc. or nearby loc.

viii) If this loc. strata details are comparable with above soil investigation report or any other loc. of this line. Loc. No…………

ix) Details of soil investigation report:-

a) Strata depth b) Subsoil water table: ……….mtrs.

c) Ultimate Bearing capacity: …..mtrs. d) Angle of Repose (Φ): ….degrees

x) Foundation classification proposed by contractor:
As perSPT/Trial pit - As per Actual

Contractor shall furnish Remarks/ Reason for the proposed classification in writing to the project designated authority (EE/SE/CE, Civil) who shall visit the site and verify the details and approve suitable classification and communicate in writing

4. STUB SETTING

i) Approved drg.Nos: a) Stub setting template ………..……
b) Pit dimension ………..……
c) Stub assembly ………..……

ii) Pit Dimensions.
- a) Depth of pits From Ref. Level Ground Level
  Pit A ….. Pit B ……. Pit C ……. Pit D ……..
- b) Whether Pit dimensions are as per approved foundation classification
- c) Whether excavated soil is kept 2m away from pit edge
- d) Whether under cutting done in case of partially dry, dry Fissured rocks & mixed dry

iii) Alignment of template.
- a) Tangent Tower
  a.a) In the direction of line Yes/No
- b) Angle Tower
  b.a) Angle of deviation (Φ) ….degrees
  b.b) Alignment of template on bisection Yes/No

iv) Diagonals of template
AC…….m BD…….m

STUB SETTING ON BISECTION

v) Check level of template by dumpy/water level

vi) Height of template above ground level: …….Cms.

vii) Clearance between lowest part of stub and P.C.C. (to be not less than 15cms in dry and 20cms in wet foundation or as specified in the drawing)
LegA - ….cm. LegB - ….cm. LegC - ….cm. LegD - ….cm

viii) Whether Jacks placed on firmground:

ix) Whether Template supports/jacks positioning causing any danger to collapse of pit:

x) Whether green concrete blocks placed below stubs to avoid displacement of stub. (only for Prop setting):

xi) Whether all members of template are fixed as per drg. and fully tightened:

xii) Checking of stubs
- a) Stub dimensions are as per type of tower: Yes /No
- b) All plates/cleats fixed with required no. of Nut/bolts and are fully tightened: Yes /No
- c) Is earth flat fixed (for tower earthing): Yes /No
  Stub setting to be cleared after conducting above checks.

5. CONSTRUCTION MATERIALS

(A) CEMENT

i) Manufacturer's name (Whether approved brand): (Ramco/Pennar/Raasi etc.):

ii) Quantity required - …… Quantity available at location - ……..

iii) Quality – Stacking, Organic/foreign material, Lumps:

iv) Protective covering found :

v) Condition of cement bags :

iv) No. of cement bags leaking: ------------

(B) COARSE & FINE AGGREGATE

i) Proper Stacking of aggregates:
ii) Size of Coarse aggregate 20 mm (80 to 85%) 10 mm (15 to 20%)
iii) Fine aggregate /sand 4.75 mm conforming to Grade Zone – I sand.
iv) Quantity required - ……. Quantity available at location - …….
v) Source of receipt : (whether approved)
vi) Presence of Organic material and foreign material- if yes, ensure cleaning
vii) Coarse aggregate- check for Flakiness, soft slice and laminar shape:
viii) Fine aggregate/Sand- Check for Lumps and silt and if yes, sieve available for cleaning:

(C) Dimensions of measuring box (30cm x 30cm x 39cms height): Ok/Not Ok

(D) Proportion of concrete mix by volume derived from controlled design mix by weight:

Grade of Cement	**Quantity of Coarse aggregate**	**Quantity of Fine aggregate**	**Quantity of cement**	**Quantity of water**
M - 15	**6 boxes**	**3 boxes**	**1 bag**	**34.1 litres**
M - 20	**4 boxes**	**2 boxes**	**1 bag**	**28 litres**

Volume proportioning of material by boxes to be verified and conformed after finalization of controlled design mix by weight.

(E) Quality and quantity of water as per specifications: Ok/ Not Ok

(F) Reinforcement Steel: Quality and quantity as per approved drawings/Specifications:

Diameter	**Qty.required**	**Qty.available**	**Approved source**	**Quality o.k./not o.k.**
6mm				
8mm				
12mm				
16mm				
22mm				
32mm				
....mm				

i) Approved reinforcement bending schedule Drawing No…………………
ii) Cleanliness of reinforcement bars from rust, mill deposit etc.:
iv) Binding wire availability:
v) Adequate fabricated chairs and gitties for supporting of reinforcement bars availability:

(G) Form boxes: a) Whether dimensions are as per approved designs
b) Whether oiling of inner wall of form boxes done or not

Check for availability of tools such as Level instruments, Theodolites, Sieves of different sizes, Screw gauge,Slump cone, Cubes casting etc. and their proper working.
After the checks, the materials and T&P may be cleared for lean concreting.

(H) Lean Concreting:

a) All Pits free from all Foreign Materials
b) All Pits free from standing water (Dewatering continued in advance by Pumps / Buckets)
c) Mix ratio 1:3:6 with 40 mm metal
d) Concrete mixing by mixer as per specification
e) Mixer running time (mixing Time 2 ½ minutes)
f) De-watering to be done
g) Lean concreting to be done up to specified level and in all the four pits
h) No. of cement bags consumed - As per design/ Actual

(I) In case of excess excavation/filling done by lean concrete and no loose soil is permitted for filling, Volume of excess lean concrete - …

After checking lean concreting work as above pits shall be cleared for installation of reinforcement and form boxes.

6. INSTALLATION OF REINFORCEMENT STEEL & FORM BOXES

i) Apprd.Drg.Nos. ------------
ii) a) Quality/Qty. of reinforcement steel as per specification:
   b) Bending /Placing as per approved drg:
   c) Required no. of chairs approved (Min dia-12mm, Max spacing-500mm):
   d) Binding done as per specifications:
   e) Any undue stress or bending of steel bars:
   f) Whether Steel is clean and free from loose rust or any other foreign materials.
   g) Position of bars with respect to stub as per drawing:
iii) Form Boxes:-
   a) Dimensions as per approved drawing:
   b) Placing with respect to stub as per approved drawing:
iv) Clear cover of 50 mm (or as per specification)
   After the checks clearance may be given for foundation casting.

7. MIXING, PLACING AND COMPACTION OF CONCRETE

i) Approved Drawing Nos. ---------
ii) Mix Ratio
   a) For Pyramid/base with 20 mm metal with specified ratio:
   b) For chimney with 20 mm metal with specified ratio:
   c) Water to cement ratio as per specification:
iii) Mixing done by Mixer (Running time 2 ½ minutes)
iv) Use of poking rod for compacting:
v) Use of vibrator for compacting:
vi) Whether checking of template levels & its diagonals at regular intervals
vii) Casting of legs done in continuity:
viii) No. of cement bags consumed: As per drg: …. Actual: …..
ix) Removal of stub template, shoring & shuttering and stripping of form work after 24 hours of concreting, observe for any damage and attend rectification:
x) Back filling and compaction of backfilled as per specn:
xi) Curing of backfilled earth & chimney carried out for a minimum period of 14 days

after concreting as per specn:

a) Availability of water pump with storing arrangement for curing purpose ------

b) Date of start of curing --------

c) Date of completion of curing --------

xiii) Cubes, last sent for testing as per approved FQP :

xiv) All the surplus materials removed from site:

After conducting these checks, foundation may be cleared for tower erection subject to fulfillment of Part (I) before tower erection and Part (II) in due course as follows.

Part-I: Setting period (28 days) is allowed as per specification
Part-II: (i) Revetment benching proposal status …………
(ii) Revetment benching likely execution date ………..

CONCRETE CUBE TEST REPORT

Name of work : Agreement No. :
Sample No. : Identification Mark :
Portion of Work or Qty. representing sample:
Date & Time of casting : Proportion of Mix :
Duration of Curing at site and
Site temperature before transportation to test Lab and Temperature at
7 days 28 days :

1. Due date of test ……………….. ……………
2. Actual date of testing ……………….. ……………
3. Delay in testing ……………….. ……………
4. Actual Average compressive strength ……………….. …………….
5. Is average compressive strength equal to or
more than specified compressive strength : Yes/No

(Signature of Executing Agency) **(Signature of APTransco official)**
Date…………………………. Date………………………….

WATER TEST REPORT

Name of line…………………………….. Source of water supply…………….
Sample Indent Mark………………..
Name of Executing Agency…………….. Date…………………….
Name & address of Test Lab ………………………………………………
Test Report Reference No. ……….

Sl. No.	Description	Requirement/ Tested as per	Permissible limits
1	**Water**	**potable**	**----**
2	**Neutralization 100ml H2O**	**IS:3025**	
3	**PH value**	**IS:456**	**Not less than 6**
4	**Solids** **a) organic** **b) Inorganic** **c) Sulphate SO3** **d) Chlorides**	**IS:3025**	**200 mg/litre** **3000 mg/litre** **400 mg/litre** **2000 mg/l for non-reinforced concrete**

	e) Suspended matter		**2000 mg/l for reinforced concrete**
5	**Compressive strength (20 days) for three 150mm concrete cubes made with proposed water vis-à-vis similar cubes made with distilled water**	**IS:516**	**90%**
6	**(a)Initial setting time for test cube made with proposed water (b)variation in initial setting time for test cube made with proposed water and distilled water**	**IS:4031**	**Not less than 30 minutes 30 minutes**

Note: Values from the latest revisions/amendments of relevant IS codes may be considered.

Signature of Local Official Signature of Erection Agency
Date: Date:

Sample is approved for concreting.

Signature of APTRANSCO Official
Date:

Registers for Construction materials such as cement, coarse and fine aggregates and reinforcement steel and concrete cube test reports shall be maintained, for recording the details of samples collected and tests conducted as per field quality assurance plan, joint reports for collection of samples in case of site testing.
Particulars of quantity of materials received, batch no./lot no, manufacturer's test reports and results of tests conducted etc. shall also be entered and authenticated.

1.6.4 List of items to be checked:

TOWER ERECTION :

1. Setting period of foundation is allowed for at least 14 days (preferably 28 days) as per specification
2. All tested tools and plants and safety equipments in working conditions are available at site
3. All tower members, Nuts, bolts are available at site without any damage, bent or rusting and kept on ground serially according to erection sequence
4. Benching /revetment, if any, completed. If not, then program of completion
5. Whether shutdown of power line, if required, is arranged
6. Whether required no. of safety helmets, safety belts & safety shoes are being used.
7. First section is completely braced and all plane diagonals are placed in proper position
8. Guying of tower provided as per approved drawings and norms. Guying to be terminated on firm ground.
9. All nuts/bolts, flat/spring washers are provided as per approved drawings

10. All bolts to have the nuts facing outside for horizontal or near horizontal bolt connections and downwards for vertical bolt connections
11. All the inner contact surfaces at joints painted with zinc rich paint (as per Technical Specification)
12. Subsequent section are erected only after complete erection and bracing of previous section
13. Any undue stress, bending or damage of member during erection noticed
14. Filling of holes or cutting of members during erection observed
15. Any heavy hammering of bolt causing damage of threads noticed
16. Any substitute of tower member erected, if, yes, member nos.
17. Tightening is done progressively from top to bottom
18. All bolts at same level on all the four faces tightened simultaneously starting from leg to face on right side by four individuals
19. Slipping/running over nuts/bolts are replaced by new ones
20. Threaded portion of bolts projected outside of nut is not less than 3 mm and not more than 8 mm
21. Punching of threads projected outside is done at three positions on dia
22. Half round Tack welding of bolts nuts at two diametrically opposite places upto the bottom cross arm and each weld length at least 10mm

22 Zinc rich (at least 90% zinc content) on the tack welds on the nuts

23. Verticality of tower (1 in 360) is checked with help of Theodolite for both longitudinal & transverse direction. This is within specified limits
24. Details of missing member, nut, bolts, etc.
25. Mention the tower footing resistance value:

After satisfactory completion of above checks, a certificate to the effect that Tower erection is complete in all respects and footing resistance is within permissible limit is to be given duly signed by both Contractor and Transco's representatives.

TOWER ACCESSORIES

1. GI bolts and nuts fully tightened and placed as per approved drawing.
   a) Number Plate
   b) Phase Plates (set of 3 per circuit)
   c) Danger Plates
   d) Circuit Plate (2 Nos.)
   e) Name plate
   f) Bird guards (Suspension tower only)
   g) Earthing bond (One on suspension tower and two on tension towers) (37/7/0.417 mm Stranded Tinned Copper)
   h) Step bolts with spring washers 450 mm spaced on diagonally opposite leg provided 3.5m above the ground level to top of the tower

   i) Step bolt holes available up to 3.5m above ground level.
2. Anti-climbing device including barbed wire, cleats, Barbed wire fixing galvanized MS member with fully tightened bolts.
3. Aviation signals/Paints as per requirement/specification provided where required.

After satisfactory completion of above checks, a certificate to the effect of satisfactory completion to be given by both contractor and Transco's representatives.

PIPE TYPE EARTHING

1) Earthing on leg A/1
2) GI Pipe (25mm dia, 3m long) Flat (50x6 mm, 5m Long) with nuts and bolts fully tightened and placed as per approved drawing.
3) Placement of Flat along with stub and bending of flat inside the form box as per approved drawing.
4) Burying of Flat 650mm below ground
5) Bore hole (300 mm dia) and depth (3000 mm)
6) Gap (150 mm) between the GI pipe bottom end and bottom of the bore hole
7) Finely broken coke (grain size not more than 25 mm) and salt (proportion10:1) filled in bore hole around the pipe.
8) Mix of Bentonite powder in 1:6 ratio
9) Back filling done
10) Earthing resistance measurement (less than 10 Ohms) and if higher value is observed , then whether additional earthing pipe installed.
12) Repeat earthing resistance measurement (to be less than 10 ohms)

COUNTERPOISE EARTHING

1) Earthing provided on all the four legs
2) GSS earth wire 7/3.15, 25m long), MS rod (20 mm dia, 6mtrs long) with nuts and bolts fully tightened and placed as per approved drawing.
3) Burying of GSS earthwire 1000 mm below ground
4) MS rod (20mm dia, 600 mm length) at the end of earthwire.
5) Back filling done
6) Earthing resistance measurement (not less than 10 ohms). If higher value is observed then whether additional counter poise installed
7) Repeat earthing resistance measurement (should be less than 10 ohms)

After conducting above checks a certificate on Footing resistance should be furnished by Contractor and Transco's representatives.

STRINGING

A) General:

Approved Tension Stringing Chart:- Approved Drum Schedule:-

1) Back filling of soil and revetment/ benching wherever required is done.
2) Towers are tightened properly and all the members, nut/bolts are provided.
3) Tress in the ROW removed to facilitate smooth stringing
4) Are all line materials, tested and calibrated T &P safety equipments and relevant drawings available for stringing.

5) Whether Shutdown of Power line/Railway block if required, is arranged.
6) Necessary Protection/scaffolding / warning signals provided for Railway/Power line/P&T line/Road crossing.
7) Towers vulnerable for one side load are guyed properly.

B) Paving out Earth wire:

1) Whether all safety measures are ensured in carrying out the Work.
2) All pulleys fixed on towers for paving out are moving freely.
3) Effective communication exists through walkie-talkie and through persons with red flags on towers.
4) Earthwire is being constantly checked as it is unwound, Damaged portion, if any, is removed.
5) Necessary arrangement have been provided to avoid rubbing of earthwire against hard ground.

C) Paving out Conductor:

1) Check for ensuring all safety measures.
2) Conductor drums are placed properly to avoid bird caging.
3) Sequence of paving out is such that unbalancing of load on tower is avoided
4) Travelers fixed on towers are moving freely
5) Effective communication exists through Walkie-Talkie and through persons with red flags on towers.
6) Conductor is checked continuously as it is unwound from drum. Damaged portion if any, is removed/repaired.
7) Proper arrangements made to avoid rubbing of conductor on ground/hard surfaces.

D) Final Sagging & Tensioning of Earth wire & Conductor

1) Sag Board is fixed correctly after taking into account length of suspension clamp/ Record on the details such as Make, type/ batch No, date of manufacture of fittings in case of Earthwire and Suspension insulator string in case of conductor.
2) Sag/Tension is measured correctly at prevailing temperature and details recorded.
3) Minimum Ground Clearance, clearance over Power line/Railway Line/River crossing/Telecom/Road are as per specification.

E) Dead Ending

1) Subsequent to final sagging, dead end work is done marking the length of conductor corresponding to single/double tension string for conductor and dead end clamp for ground wire.
2) Corresponding to dead end clamp drawing, the aluminum strands over the steel core are cut and steel portion and aluminum portion of dead end clamp is compressed as applicable to conductor and only steel clamps for ground wire.
3) Clipping offsets marked with felt tip marker and not with sharp instruments that may cause dent in conductor strands.
4) For power line crossing section precautions taken before clipping:-
   i) The existing power line conductors are grounded.
   ii) No person in series with the potential electric circuit.

5) Prior to installation/removing dead end jumper on structure, earthing is done on both sides of the work and connected to structure.
6) Suspension clamps and dampers installed with in 36 hours after final connection to structure
7) Center of the body (cushion) and clamp body of AGS clamp coincide with the armor rods, marked point on the conductor.
8) Difference in length between the longest and shortest rod when applied not to exceed 13 mm.

F) Conductor Fittings and Attachments

1) Spacers and dampers fixed with in 24 hours of conductor clamping as per Manufacturer's recommendations.
2) a) Whether spacer cars/cycles are fixed with meter counters for measuring intra spacing of spacers/ spacer dampers during placement and if no,
   b) How the distance between spacers/spacer dampers is measured.
3) Vibration dampers for ground wire installed as per manufacturer's recommendations within 24 hours of clipping.
4) Span marker on ground wire, if required, installed on ground wire after clamping and fixing of vibration dampers on the ground wire

G) Tower Hardware

1) Tower Hardware viz. phase plates, number plates, circuit plates, copper earthing bond, phase plates and danger plate fixed are as per approved drawing.
2) Anti-climbing devices fixed are as per approved drawing.
3) Step bolts with 2 Nos. nuts and one spring washer fixed as per approved drawing.

After satisfactory checks from A to G indicated above a certificate on satisfactory completion of stringing in all respects should be furnished duly signed by both Contractor and Transco's representatives.
Record on the details such as Make, type/ batch No, date of manufacture, quantity required and utilized at each location circuit wise, phase wise and wire wise and those checks mentioned against each, for the following materials should be maintained duly signed by both Contractor and Transco's representatives. Record for each of the materials may be maintained separately.

(A)

1.Earth wire/Conductor: Drum No, length, length paved out and paved between location Nos. may also be furnished.

2. Compression type Mid-span joint for earth wire/Conductor and repair sleeve for conductor:

a) Mid-span joint has been provided at least 50 feet away from tower.
b) There is no mid-span joint over Railway/River/Main Road crossing.
c) Not more than one mid-span joint provided in one span for each earth wire/conductor

d) Repair sleeve shall be used if number of damaged strands is not more than 2 strands in outer layer of the conductor. No repair sleeve shall be used in case of ground wire. If damage is in more than the permissible strands, the damaged portion shall be removed and mid span joint provided.
e) Dimensions are recorded.

3. Insulators:

a) Quantity required as per specification, quantity used at each location phase wise and conductor and jumper wise should be recorded.
b) I.R.values of each insulator measured to be recorded (use 5kV megger) Insulators are cleaned with soft cloth. Check for proper glazing, no crack, scratch or white spots on surface and proper fitting of "R" clips
c) Insulators are hoisted without causing any damage

4. Hardware Fitting:

a) Type of fitting - I/V Single/Double, Suspension/Tension.
b) No. of fittings used at each location circuit wise, phase wise for conductor and jumper to be recorded
c) All nuts/bolts properly tightened.
d) All Components of fittings have been provided as per approved drawings. Dimensions and galvanizing are OK. Fitting is cleaned and there is no damage to any component.
e) All spilt pins properly provided.
f) In case of Tension fittings, dimensions before and after compression recorded

5. Suspension/Tension Clamps for Earth Wire:

a) All components of clamps have been provided as per approved drawings. Dimensions and galvanizing are OK. Clamp is cleaned and there is not damage to any component.
b) All Nuts & bolts have been properly tightened, to 5 Kg m torque.
c) Split pins have been properly fixed.
d) In case of tension clamp, dimensions before and after compression recorded

6. Vibration Dampers (V.D.) for Earth wire and Conductor:

a) All components of V.D. have been provided as per approved drawings. Dimensions and galvanizing are OK. Clamp is cleaned and there is no damage to any component including messenger wire.
b) All Nuts & bolts have been properly tightened, to 4 Kg m torque.
c) V.D. Fixed as per approved placement chart.

7. Line Spacer/Spacer Damper/Jumper Spacer:

a) Spacer/Spacer damper fixed as per approved placement chart.

(B) Check for Sag Measurement for Conductor :

1) Sag Board/dynamometer fixed between Loc No- …. & Temperature- ….. ^{o}C
2) Measurement of Sag/Tension.

Item	Phase/ Wire No.	Sag/tension as per chart		Sag/Tension as per actual	
		Initial sagging	Final sagging	Initial sagging	Final sagging
Sag Tension					

3) During paving out/rough sagging, tension in conductor was as per technical specifications (50% of sagging tension).
4) Calibration certification for dynamometer to be checked.
5) Vertical clearance between top conductor and earth wire at minimum clearance point along the span to be indicated ---------

(C) Location wise Dimensional details of the following materials i.e., length and outer diameter before compression, after compression as per drawing and as observed, for steel and aluminum portions may be recorded.

1. Tension clamps for conductor
2. Tension clamps for GSS Earth wire
3. Mid-span joints for conductor
4. Repair Sleeves for conductor
5. Mid-span joints for GSS Earth wire

a) The following may be checked as per approved drawing.
   a) Marking and cutting
   b) Correct sizes of Dies
   c) Centering & fixing of Sleeves
   d) Fixing of all the components i.e., Aluminium end pipes, hole plugs etc.
   e) Compression of sleeves at specified pressure.

b) All the sharp edges have been filled after compression.

c) There is no crack, bend or any damage to joint after compression.

d) Bores in the sleeves are perfectly clean

(D) Drum schedule record covering the following should be maintained:

Name of the line: ……. Name of the Contractor: ……..

Section: From …….. To ……. Sectional length: …..

Sl. No.	Drum No.	Make	Length (metres)	Phase	Paving out between locations	Quantity consumed	Balance Bit length	Bit to be used at	Remarks

1.7 Statutory Inspection:

After completion of the works, final checking of the line shall be done by the contractor to ensure that all the foundation works, tower erection, and stringing have been done strictly according to the specifications and as approved by the purchaser.

a) Wherever required, it should be ensured that revetment is provided.

b) The line insulation is tested by the contractor by providing his own equipment, labour etc. to the satisfaction of the purchaser.

c) The right-of-way all along the route of line is clear of all obstructions and meets requirements of clause 5.3 of IS: 5613 (Part-3, Section-2)-1989.

d) In addition to the tests stipulated in IS: 5613 (Part-3, Section-2)-1989 the tower foundation resistance at the locations decided by the purchaser, shall be measured.

e) Two copies of the profile, route alignment and tower design, structural drawings, bill of material, shop drawings of all towers are to be modified "AS BUILT" and submitted to the purchaser for reference and record.

The SE in charge of construction of the line shall then request the concerned SE (TL&SS)to conduct final inspection of complete line, duly furnishing all records of the line pertaining to design and execution. The SE (O&M) shall arrange for thorough inspection of the line keeping in mind the following main points:

a) Sufficient backfilled earth is lying over each foundation pit and it is adequately compacted.
b) Concreted chimneys and their copings are in good shape.
c) All the tower members are correctly used, strictly according to final approved drawings and are free from any defect or damage whatsoever.
d) All bolts are properly tightened and punched/and half round welded (as specified).
e) The stringing of the conductors and ground wire has been done as per the approved stringing charts and desired clearances are clearly available.
f) All conductor and ground wire accessories are properly installed.
g) All other requirements to complete the work like fixing of danger plates, phase plates, number plate, circuit plates, anti-climbing device, bird guards etc. are properly installed.
h) Ground clearance, mid-span clearances, proper fixing of hardware and insulators shall be checked.

Any defects found as a result of inspection and testing shall be got rectified through the contractor immediately to the satisfaction of the purchaser without any extra charges.

Protection system for the line in the connected substation has to be tested for correct operation with the adopted relay settings communicated by the Power system group. Proper communication between the stations connecting the line and the load dispatch shall be checked and ensured before charging the line.

Necessary charging instructions communicated by Grid operation wing shall be followed and the line shall be idle charged (No load) to check the condition of the line and then the line can be taken into commercial operation. All these operations shall be done with due intimation to the load dispatch centre and under their directions.

Final inspection details for each tower should be furnished by the contractor in the PROFORMA given below.

1.7.1 TRANSMISSION LINES FINAL INSPECTION

LINE NAME:

Inspected by: Structure

Date : Type Ht. Tower Sl. No.

A. CONDUCTOR: Suspension Structures

Type of Hardware Assembly Correct?
Insulators - Clean ? Broken ? Count

	Properly Installed? Yes			No		
	R	Y	B	R	Y	B
Suspension clamp ? …..						
Grading Rings/ Corona Control Rings ? …..						
Armour Rod? …..						
Dampers? …..						
Over Head Groundwire (OHGW) …..						
OHGW Dampers ? …..						

B. CONDUCTOR: Angle Structure

Type of Hardware Assembly Correct?
Insulators - Clean? Broken? Count

		Properly Installed ?					
		Yes			No		
		R	Y	B	R	Y	B
Dead End Bodies ?	…..						
Hardware Components, Cotter Pins	…..						
Dampers ?	…..						
Grading Rings/ Corona Control Rings ?	…..						
Dampers ?	…..						
Groundwire (OHGW)	…..						
Dampers ?	…..						

C. OTHER OBSERVATIONS: Where Applicable

		Properly Installed ?					
		Yes			No		
		R	Y	B	R	Y	B
Span ahead – Correct number of Spacers ?	…..						
Spacers properly installed ?	…..						
Adequate ground clearance obvious ?	…..						
Obvious danger trees ?	…..						
Broken strands or debris on conductor ?	…..						
Span ahead – sag mismatch ?	…..						

D. STRUCTURES: Steel

			Properly Installed ?	
			Yes	No
Towers	: Is there any loose, missing or damaged numbers ?	…..		
	: Are there any missing or loose bolts ?	…..		
Signs	: Number Plate ?	…..		
	: Danger Plate ?	…..		
	: Phase Plate ?	…..		
	: Bird Guards ?	…..		
	: Aerial Warning Required ?	…..		
Backfill	: Is all backfill at proper level	…..		

: Are there rocks in cultivated area ? …..

Counter poise : Required ? …..

: Does route differ from drawing ? …..

: Is site restoration satisfactory ? …..

E. BOLT TORQUE AND COMPRESSION JOINTS (based on site records)

Yes No

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1. Bolts and nuts of suspension clamps, spacers, Dampers, etc., tightened properly ? …..
2. Compression joints made properly ? …..

F. REMARKS: …..

1.8 EHV SUBSTATIONS:

Substations are the points for controlling supply of power on different routes by means of various equipment such as transformers, compensating equipment, circuit breakers, isolators etc. The various circuits are joined together through these components to bus-bar systems at the substations. One of the prime requirements of a good substation layout is that it should be as economical as possible. The layout should ensure desired degree of flexibility, reliability, ease of operation and maintenance and safety of the operation and maintenance personnel. The layouts should not lead to breakdowns due to faults within the substation. While planning the layout and orientation of a substation, adequate provision may be made for installation of towers for the incoming/outgoing lines, in order to avoid right of way problems in future. Also provision may be made accordingly in the construction of emanating transmission lines.

Steps in construction of EHV Substation (132kV and above voltages) are

1) Acquiring suitable land
2) Civil works in switch yard viz. leveling, foundations for equipment, retaining walls, compound wall with security fencing, cable ducts, storm water drains, construction of roads and culverts,
3) Construction of control room,
4) Erection of all electrical equipment including power transformers,
5) Auxiliary works such as Battery and battery charger installation and commissioning and DC distribution, Earthing, switch yard lighting, arrangements for water supply, Fire protection system, Diesel generator set for standby supply etc. and testing and commissioning of the substation.

1.8.1 Land:

Substation layout is influenced to a greater extent by the dimensions of various equipment and their accessories and on the type of Bus-bar arrangement. Suitable land to the extent required for the voltage class of the substation shall be identified taking into consideration, features such as no. of feeders, no. of transformers, type of bus-bar system proposed and future extensions required if any.

Pre requisites of land for substation: Close proximity to loads, proper approach to the site, free from habitations in the surroundings, easy take off arrangements for lines present and future.

Suitable Govt. land with fairly a level surface with a normal soil shall be identified for alienation to APTRANSCO with the help of Revenue Authorities. Govt. of A.P. vide G.O.No 342 dt.20-4-10 issued an order that all the District Collectors / Quasi Government Bodies / Local Government bodies etc., under their control in the State shall take necessary action for giving advance possession of the vacant Government lands for construction of Sub-stations by APTRASCO / DISCOMs pending finalization of alienation and procedural formalities in order to expedite the construction work, and that the APTRANSCO / DISCOMs will follow all the necessary procedural formalities subsequently and payment of land cost will be made as determined by Government.

In case of non availability of suitable govt. land, efforts to procure private land at reasonable value shall be made. The land shall be free from litigations in addition to meeting the requirements as indicated in the pre-requisites.

1.8.2 Land acquisition procedure for Private lands through Revenue Authorities:

i. In case of non-availability of suitable Government lands in the area, to get the confirmation of the same from the concerned Mandal Revenue Officer (Tahasildar) for confirming the non-availability of Government Land in and around the village where the new Sub-Station is proposed to be constructed.

ii. After receipt of confirmation from MRO suitable private lands in the same area has to be identified by APTRANSCO duly conducting joint inspection with revenue authorities.

iii. After identification of private land, concerned RDO shall be requested through a letter for giving proceedings on acquisition of the above said land.

iv. In response to the APTRANSCO's (EE/TLC) request, Concerned RDO will request APTRANSCO to submit the L.P. Schedules in Form I as per LA Manual and also combined sketch in quadruplicate. The APTRANSCO officials (EE/TLC) with the help of revenue authorities have to prepare the L.P. Schedule in prescribed proforma along with field sketch and submit to concerned Dist Collector, who will forward the same to concerned RDO with instructions to collect the approximate land cost from APTRANSCO. Simultaneously, RDO will instruct the concerned Tahsildar to inspect the alignment on ground and submit Draft Notification (D.N.) and Draft Declaration (D.D.) proposals immediately.

v. The DN, DD proposals will be prepared by the Tahasildar and sent to District Collector through RDO for approval.

vi. The Dist Collector will approve the Draft notification and 5-A after enquiry and also send for publication in official Gazette to be printed locally.

vii. Upon receipt of the intimation from RDO / Dist Collector, EE/TLC will prepare the estimate for payment of the land cost and submit the proposals to Head Quarter through SE/TLC.

viii. Upon receipt of the above proposals the construction wing at HQ will circulate a file to the Board through estate officer for approval of Board for authorizing SE/TLC for arranging the payment.

ix. After receipt of authorization, the SE/TLC will arrange the payment of proposed land cost to RDO

x. After getting preliminary valuation proposal from Tahsildar and after payment of estimated land value by APTRANSCO, award enquiry will be conducted by the concerned RDO and the enquiry report submitted to District Collector.

xi. The District level Negotiation Committee consisting of the Dist Collector along with RDO, Tahsildar, and Executive Engineer/TLC then conduct negotiations with the concerned land owners. After consideration of all the relevant factors, the negotiation committee will decide and approve the Market value of the land inclusive of statutory benefits under Sec 11(2) of the L.A. Act.

xii. Based on the minutes of the negotiation committee meeting, the RDO will prepare the Draft award and submit to District collector for approval.

xiii. After draft award approval, notice will be given to land owners by Tahasildar to collect cheques issued by RDO. After issue of cheques to the land owners the site will be taken over by revenue Authorities and issued to APTRANSCO

A substation requires land for switch yard, control and administrative building, stores, security barrack, colony etc. Keeping provision for future expansion and considering increasing cost of land approximate size of land required for different substations are as follows.

132 /33 kV SS -- 5 - 8 acres
220 /132 kV SS -- 8 - 15 acres
400 /220 kV SS -- 45 - 60 acres

The size of the control room building depends on the number of rooms and equipments in the room. A typical control room building of a 400kV substation having one and half breaker bus scheme with 8 nos. diameters, and a 220kV system with double main and transfer bus for 12 nos. breakers on an average requires about 1000sq. metres which includes control room, relay and PLCC room, MCC room, Battery room, office room, conference room, maintenance room, record room, Test laboratory, etc.

In an automated station, relays and communication equipment may be accommodated in an outdoor bay controller unit located in the switch yard. Only computer peripherals and communication equipment need to be accommodated in the control room. The size of the control room gets substantially reduced.

1.9 Important Technical Specifications for Substation Works:

a) **Switchyard Civil works:** include the following

- Foundations for switchyard gantry structures, equipment supporting structures & their control cubicles, bus post insulator, bay marshalling kiosks and lightning mast etc.
- Foundations for power transformers(No. and capacity to be specified) including soak pit underneath transformers & their cooling banks, R.C.C central oil collecting pit and oil & rain / emulsifier, drainage arrangement from transformer soak pits to central oil collecting pit and oil water separator including laying of all necessary R.C.C pipes of class NP-2 and construction of manholes, providing submersible type sump pumps with auto start arrangements for pumping out discharge from central oil collecting pit to oil-water separator etc. as required & approved by the purchaser. This specification normally applies to 400kV class transformers. The specification may be suitably modified for 220kV and below class transformers as required. It is desirable that this specification is adopted for transformers of capacity100MVA and above in 220kV class. The scope shall also include the construction of R.C.C baffle/fire protection walls between transformers as per statutory requirements. (Whether erection of transformer is included or excluded from the scope of the contract shall be specified)
- Pile foundations where required.
- R.C.C cable trenches of various sizes with removable type of R.C.C pre-cast covers including edge protection angles in cable trenches, inserts for cable tray supports etc. The scope shall also include designing and providing suitable arrangements for cable trenches at the crossing of roads, road-cum-rail track etc. using NP-2 class R.C.C pipes or G.I conduits embedded in R.C.C for bearing safely the loads likely to be imposed on them as per applicable I.S/I.R.C codes.
- Suitable water drainage arrangement from cable trenches shall be provided by providing slope along the length of cable trenches and by providing sumps of suitable capacities at required locations for collecting water from cable trenches and disposing of water so collected into nearest storm water drains by providing submersible type sump pumps with auto start and with all necessary electrical/mechanical arrangements as per specification and as required and approved by the purchaser.
- Construction of all CC roads within the switchyard area, R.C.C road-cum-rail track, jacking platforms at the crossings of railway tracks, anchor blocks for facilitating the pulling of the transformers during erection/maintenance etc.
- The final grading & metal spreading of the switchyard including anti-weed treatment. This work shall be carried out after all foundations and underground works like cable trenches, drains etc. have been completed. The final grading shall include spreading of metal layer after giving anti-weed treatment to the soil underneath these layers.

- The complete storm water drainage for the switchyard including all siphons, R.C.C pipe culverts, R.C.C box culverts etc. required for drainage at cable/pipe trench crossings, road/rail track crossings etc. The scope shall also include the connection of the switchyard drainage with the natural drainage.

b) **Substation Construction Works:**

- Soil investigation.
- Leveling of the site.
- Anti weed treatment and anti Termite treatment
- Construction of Security Fencing in the switch yard
- Construction of Service Roads and Drainage System.
- Construction of Control House (single/double storeyed) including supply of doors and windows
- Construction of Fire fighting cum DG set building.
- Stores cum Office building.
- Construction of Platforms
- Construction of 33kV Substation(for auxiliary supply in case of a 400kV substation and 220kV switching stations)
- Water Supply and Sanitary System
- Any other Auxiliary buildings and works as required.

c) **Erection Works:**

- Erection of main and auxiliary structures including supply of raw steel, fabrication and galvanization of structures.

- Erection of all substation/bay equipment including Panels, Power Transformers, Battery and Charger etc.

- Stringing of bus bars, ground wire, jumpering, connections between equipment, buses, etc. including supply of hardware fittings and clamps and connectors.

- Earthing system including laying of C.I.pipes and B.H. coke for earth pits / alternate method of earthing.

- Cable laying and terminations including erection of marshalling kiosk/boxes.

- Yard illumination, fire fighting etc.

Type of Construction: The sub-station structures shall be lattice type galvanized structures. The foundations of main structures are stub type and other structures are foundation bolt type. The 220KV and 132 kV buses are normally strung with single/ double MOOSE ACSR conductor and 400kV buses are strung with double/quadruple MOOSE ACSR conductor depending on the maximum power flow along the bus. Control&Relay panels, LT AC panels, battery, battery charger and D.C distribution board are to be erected in Control house.

In an Automated station control&relay panels and communication equipment form part of bay controller units to be mounted in the outdoor switch yard near the bays.

Drawings: The following drawings shall be provided along with the specification to give an idea about the work involved

- Control house plan, foundation details, Reinforcement details of columns, beams, roof etc., electrification of control house, cable duct in control house.
- Compound wall, Retaining wall
- Cable duct in switchyard, cable duct at road crossing points.
- Earth mat details
- Main gate and wicket gate
- Foundation and structural drawings

1.9.1 CODES AND STANDARDS: All equipment materials fabrication galvanizing and tests shall conform to the latest applicable standards, codes etc. mentioned here in or to equivalent applicable international standards

Sl. No.	STANDARD	TITLE
	IS 8112/1989	43 grade ordinary Portland cement
	IS 1786/1985	High strength deformed steel bars and wires for concrete reinforcement
	IS 456/2000	Code of practice for plain and reinforced concrete
	IS: 1199/1959	Methods of sampling and analysis of concrete.
	IS: 1838	Preformed fillers for expansion joints in concrete non-extruding and resilient type(Bitumen impregnated filler
	IS: 2386 Part III:	Specific gravity, density, voids, absorption and buckling.
	IS: 2505/1980	General requirements for concrete vibrators, immersion type.
	IS: 2506/1985	Screed board concrete vibrators:

IS: 2514/1963	Concrete vibrating tables.
IS: 3025	Methods of sampling and test (physical and chemical) for water used in industry
IS: 3370	Code of practice for concrete structure for the storage of liquids
IS: 3350	Methods of tests for routine control for water used in industry.
IS: 4656	Form vibrators for concrete.
IS: 516/1959	Methods of test for strength of concrete.
IS 383/1970	Course and fine aggregates from natural sources for concrete
IS 2062/1992	Steel for general structural purposes
IS 432(Part-1& /	Mild steel and medium tensile steel bars and hard drawn
Part-2)/1982	Steel wire for concrete reinforcement.
IS 12427/1988	Transmission Tower Bolts
IS 1367 (part II)	Technical supply conditions for threaded steel fasteners - Product grade and tolerances
IS 1363 (partIII)	Hexagon Nuts (size range M5 to M64)
IS3063/1994	Fasteners - single coil rectangular section spring washers
IS2629/1985	Recommended practice for hot dip galvanizing on Iron & Steel
IS4759/1984	Hot dip Zinc coatings on structural steel and allied products
IS7181/1986	Horizontally C.I double flanged pipes for water, gas and sewage valve fittings for compressed gas
IS3224/1979	Cylinders excluding liquefied petroleum gas cylinders
IS2026	Station Transformer
IS5039/1983	Distribution pillars for voltages not exceeding 1000 volts
IS4072/1975	Steel for spring washers
IS1573/1986	Electroplated Coatings of Zinc on Iron & Steel
IS 2202(Part-I)/1991	Wooden flush door shutters
IS4351/1976	Specification for steel Door frames
IS513/1994	Cold rolled low carbon steel sheets and strips

IS617/1975	Aluminum and aluminum alloy ingots and castings for general engineering purposes
IS5561/1970	Electric power connectors
IS 486(Part-I)/ 1993	Metal fittings of Insulators for overhead power lines with normal voltage greater than 1000 V – general requirements&tests
IS 2486	Insulator fittings for overhead power lines with a nominal voltage
(part-2)/1989	greater than 1000V-Dimensional requirements
IS2108/1977	Blackheart malleable iron castings.
IS2486/	Hardware fittings, clamps and connectors
IS4984	P.V.C. Pipes
APSS	Andhra Pradesh Standard Specification.

Climatic & Isoceraunic Conditions: Please refer general terms and conditions for material specifications (Vol-1 Chapter 2.9.1)

1.9.2 Compliance with Regulations: Unless otherwise specified, works shall be carried out in accordance with the Indian Electricity Act. 1910, Indian Electricity Rules 1956 , Electricity Act2003 or any other revisions thereof which may be issued during the currency of the contract and the requirements of any other regulations and Acts in India to which the utility may be subjected to.

1.9.3 The following general terms form part of the specification:

a) APTRANSCO shall provide approved Site-cum-Electrical layouts, Control House drawings, Structural & foundation drawings, Bill of materials, other civil & electrical drawings and list of manufacturers/ suppliers for procurement of equipment & materials.

b) The contractor shall execute the works as per the approved drawings mentioned above and shall procure equipment & materials as per specification from approved list of manufacturers.

c) Contractor shall complete the works in full shape and handover in fully operational condition within time specified in the Contract.

1.10 Construction of Substations:

Leveling: Substation switch yard should be leveled as directed, with the surplus earth left over after back filling structure foundations. If surplus earth is not adequate for leveling, the leveling should be done by excavating earth in any portion of substation site and filling should be done with such earth for leveling switchyard. If this is not sufficient, the switchyard is to be leveled by gravel from the approved borrowed areas. Clearing of the entire site by removing bushes, hedges, unwanted plant growth and other things shall form part of leveling work. The work shall be carried out as per APDSS 301,302 and 138.

While fixing levels for the control room, switch yard and internal roads, factors like flooding of the substation from the adjoining areas, approach roads and canals around the land during rainy season, shall be borne in mind. The levels shall be so fixed that quantity of cutting and filling of earth and filling with borrowed earth is kept at minimum. If need be, the switch yard levels can be fixed in two or three steps without affecting statutory ground clearances prescribed for various voltages.

After award of work, site cum electrical layout drawing with levels fixed shall be issued to the contractor. Contractor shall arrange for leveling the land as per the levels fixed by the department, by cutting and filling the earth to the extent required and filling by borrowed earth wherever required. The soil shall be consolidated after leveling by compacting layers not exceeding 150mm.thickness.

1.10.1 Information to be furnished after award: The following information and data including samples where necessary shall be submitted by the Contractor progressively during the execution of the contract.

- Programme of Execution: As per the time schedule of contract, the Contractor has to submit a Master Programme for completion of the work. This Master Programme may have to be reviewed and updated by the Contractor, quarterly or at more frequent intervals as may be directed by the Engineer depending on the exigencies of the work. Detailed day-to-day programme of every month is submitted by the contractor before the end of the preceding month.
- Samples: Samples of the following materials and any other materials proposed to be used shall be submitted, in sufficient quantities free of cost, for approval. Approved samples will be preserved by the Engineer for future reference. The approval of the Engineer shall not, in any way, relieve the contractor of his responsibility of supplying materials of specified qualities:
    1. Coarse and fine aggregates, Bricks, Road metal. Admixtures.
    2. Plywood for formwork.
    3. Embedded and anchorage materials as requested by the Engineer.
    4. Joint sealing strips and other waterproofing materials, Joint filling compounds.
- Design Mix: Design mix as specified giving proportions of the ingredients, sources of aggregates and cement, along with accompanying test results of trial mixes as per relevant I.S., is to be submitted to the Engineer for his approval before it can be used on the works.
- Detailed working drawings and Bar Bending Schedules in accordance with the specification.
- Detailed Drawings and Designs of Formworks to be used
- Detailed Drawings for Templates & Temporary Supports for Embedment
- Mill Test Reports for Reinforcing Steel to be supplied by the Contractor.

- Inspection Reports in respect of formwork and reinforcement and any other item of work as may be desired by the Engineer.
- Test Reports of various materials and concrete as required under the clause “sampling&testing” of the specification.

Compaction: Compaction shall be achieved by the use of smooth wheeled rollers, pneumatic type rollers, sheep’s foot rollers; vibrating plates, frog rammers; power rammers and such other equipment as shall be specified. Compaction shall be carried out on each layer of thickness not more than 150mm thickness. Density tests shall be made on each compacted layer and the density attained shall not be less than 98% of maximum dry density (standard proctor for the type of material used). A record of the density tests conducted on each layer shall be recorded in a register maintained by field staff.

Anti weed treatment and anti termite treatment for excavated site shall be done

3.10.2 EXCAVATION & FOUNDATIONS FOR STRUCTURES:

a) **Excavation:** Specification shall cover excavation for structures, building, foundations, trenches, drain channels, and underground facilities and retaining walls as shown in the approved drawings and as specified. Earth excavation has to be done in all types of soils which can be excavated with pick axe & crow bars in all conditions such as dry, wet, slushy etc., and in hard rock requiring blasting including shoring, shuttering and dewatering wherever necessary covering initial lead and one extra lift. Detailed procedure is already covered under transmission lines.

b) Backfill: For details refer back filling under construction of transmission lines.

c) Foundation Concrete:

General Requirements: All materials, tests, mixing, placing, formwork, reinforcing and workmanship shall conform to IS: 456-2000 “Code of practice for Plain and Reinforced Concrete for general building construction” and other relevant Indian Standard codes.

<u>Nominal Mix and Design mix</u>: 1:2.5:5, 1:3:6 and 1:4:8 shall be of Nominal Mix. M20 and above shall be of Design Mix. The mix proportions for all grades of concrete shall be designed to obtain strengths for respective grades of concrete.

Preliminary tests as specified in the IS: 456 and required by the purchaser, shall be carried out sufficiently ahead of the actual commencement of the work with different grades of concrete made from representative samples of aggregates and cement expected to be used on the job to ascertain the ratios by weight of cement to total quantities of fine and coarse aggregate and the water cement ratio required to produce a concrete of specified strength and desired workability.

Concrete shall be either ordinary or controlled and in grades designated M-10, M-15, and M-20 as specified in IS: 456 (latest edition). In addition, nominal mixes of 1:3:6 and 1:4:8 of nominal size aggregate of 20 mm maximum or as indicated in drawings, by volume or any other mix as per requirement shall be used where specified.

Ordinary Concrete: Ordinary concrete is recommended only when accurate control is impracticable and not necessary. However, ordinary concrete shall be used only in the lean concrete wherever allowed.

If ordinary concrete made in accordance with the proportions given in IS: 456 for a particular grade does not yield the specified strength and fails to satisfy the requirements of 'Acceptance Criteria' as specified in IS: 456, the cement content shall be increased as directed by the purchaser to obtain a specified strength at no extra cost. This shall not however be classified as a higher grade on the ground that the test strengths were found higher than the minimum specified.

Controlled Concrete: Controlled concrete shall be used on all concrete works, except where specified otherwise. Controlled concrete for use in plain and reinforced concrete structures shall be in grade M-20.

Mixes Design Criteria: Concrete mixes will be designed keeping the following considerations in view.

- Consistent with the various other requirements of the mix, the quantity of water should be kept at the lowest possible level.
- The nominal maximum size of coarse aggregate shall be as large as possible within the limits specified.
- The various fractions of coarse and fine aggregates should be mixed in such a proportion as to produce the best possible combined internal grading giving the densest and most workable mix.
- The finished concrete should have adequate durability in all condition, to withstand satisfactorily the weather and other destruction agencies that it is expected to be subjected to in actual service.
- Concrete shall be thoroughly mixed to a uniform consistency in the mixing machines of approved types. Mixing shall continue until the cement is thoroughly distributed throughout the mass, and shall last at least two minutes or for 80 turns of the mixer after the whole of the water has been added. Any concrete showing signs of initial setting before being deposited shall not be used in the works and shall be removed from the site.
- The concrete shall be discharged from the mixer on to a level watertight platform or floor or into a water tight receptacle. Normally hand mixing of concrete will not be allowed but where the total quantity of concrete is considerably small, the mixing may be done by hand subject to the approval and entirely at the discretion and satisfaction of the Engineer.

Minimum cement content and maximum water-cement ratio for concrete exposed to sulphate attack and for concrete to ensure durability under different condition of exposure, strength requirement for different grades of concrete, proportion for nominal mix concrete, are given in the following tables. For identical condition, if values given in the tables shown below are different from those mentioned in IS: 456, the values as indicated in the table shown herein below shall prevail.

TABLE - I

Grade of concrete	Specific Characteristic Compressive Grade of concrete strength of 15 cm Cubes at 28 days conducted in accordance with IS: 516 (All values in N/Sq.mm)
M - 15	15
M - 20	20
M - 25	25

TABLE – II

Mix proportions (by weight) expected to give different degree of workability with different values of water cement ratio Cement/ Total aggregate ratios.

Workability	Water Cement ratio	Ratio by weight of cement to gravel aggregate		Ratio by weight of cement to crushed stone aggregate	
		20mm Size	40mm size	20mm size	40mm size
1	2	3	4	5	6
Very low	0.4	1:4.8	1:5.3	1:4.5	1:5.4
Slump	0.5	1:7.2	1:7.7	1:6.6	1:7.4
0-25mm	0.6	1:9.4	1:10.0	1:7.8	1:9.6
	0.7	1:10.0	1:12.0	1:8.7	1:10.0

Low	0.4	1:3.9	1:4.5	1:3.5	1:4.0
Slump	0.5	1:5.5	1:6.7	1:5.0	1:5.5
25-60 mm	0.6	1:6.8	1:7.4	1:6.3	1:7.0
	0.7	1:6.0	1:8.5	1:7.4	1:8.0
Medium	0.4	1:3.5	1:3.8	1:3.1	1:3.6
Slump	0.5	1:4.8	1:5.7	1:4.2	1:5.0
50-100 mm	0.6	1:6.0	1:7.3	1:5.2	1:6.2
High	0.4	1:3.2	1:3.5	1:2.9	1:3.3
Slump	0.5	1:4.4	1:5.2	1:3.9	1:4.6
100 -	0.6	1:5.4	1:6.4	1:4.7	1:5.7
175 mm	0.7	1:6.2	1:7.4	1:5.5	1:6.5

Note: The above figures are for guidance only. The actual cement aggregate ratios are to be worked out from the specific gravities of Coarse Aggregates and sand being used and from trial mixes.

Reinforcement: Mild steel round bars, cold twisted and deformed bars as medium tensile or high yield strength steel confirming to IS:432 and IS:1786-1985, plain hard drawn steel wire fabric etc will be used as reinforcement. Detailed procedure and precautions already covered under transmission lines construction.

Form work: For details see form work under transmission lines.

Conveyance of Concrete: The concrete shall be conveyed from the mixer to its place in the works as rapidly as possible and in such a manner that there shall be no separation or loss of the ingredients. In no circumstances shall more than half an hour lapse between the time when water is added to the mix and the time when the concrete is finally consolidated in position. Concrete distributing chutes shall not have inclination of more than 45degrees from the horizontal. In no case shall concrete be dropped from barrows or otherwise from a height of more than one and half meters.

Depositing Concrete: Before any concrete is put in, any filling of pockets or trimming the sides where found necessary to suit the level and line of the concrete to be laid shall be carried out. Unless otherwise approved, concrete shall be placed in one operation to the full thickness of members.

Consolidating Concrete: After concrete has been placed, it shall be spread, if necessary and thoroughly compacted by approved mechanical vibration to maximum subsidence without segregation and thoroughly worked around shape. To secure maximum density and eliminate formation of air pockets, the concrete shall be thoroughly vibrated and worked around all reinforcement, embedded facilities and into corners or forms during and immediately after placing. Mechanical vibrators conforming to IS: 2505, IS: 2506, IS: 2514 and IS: 4656 (all latest edition) shall be used for this purpose. The extent of vibration shall be through the entire depth and width of each new layer. Duration of vibration shall be sufficient to accomplish thorough compaction and complete embedment of reinforcement. Excess cement paste thus formed at the top of each layer shall be removed before the succeeding layer is deposited. Vibrators shall not be used for pushing concrete into adjoining areas. In thin members with heavy congestion of reinforcement or other embedment, where effective use of internal vibrator is, doubtful, in addition to immersion vibrators, form vibrators conforming to IS: 4656 may be used. For slabs and other similar structures, screed vibrator as per IS: 2506 shall be used. Hand tamping may be allowed in rare cases, subject to the approval of the Engineer. Care must be taken to ensure that the inserts, fixtures, reinforcement and formwork are not displaced or distorted during placing and consolidation of concrete.

Immersion type vibration shall be provided at the rate of at least one 65 mm unit per cu.m. per hour together with at least one stand by vibrator of the appropriate size. Vibrators shall be inserted in the concrete at a sufficient number of places so that their fields of influence overlap and shall not be used to work the concrete along with forms or screeds. Where electrically operated vibrators are used, diesel or petrol driven stand by vibrators shall be available for carrying on uninterrupted vibration in case of a power failure.

Concrete to be vibrated shall be placed in level layers of suitable thickness not greater than the effective length of the vibrator needle. The internal vibrator shall not be used to spread the concrete for filling. It is advisable to deposit concrete well in advance of the point of vibration. When the concrete is being continuously deposited to a uniform depth along a member, vibrator shall not be operated too near to the free end of the advancing concrete, usually not within 1.20 meters of it. Every effort shall be made to keep the surface of the previously placed layer of concrete alive so that the succeeding layer can be amalgamated with it by vibration process. Following points shall be kept in mind while vibrating concrete.

- The concrete shall be placed in shallow layers consistent with the method being used to place and vibrate the concrete. Usually concrete shall be placed in thickness not more than 300 mm and on initial placing in thickness not more than 150 mm.
- The vibrator head shall be dipped through filling which is to be consolidated to further depth of 10 to 20 mm in the lowest layer which has already been consolidated.
- Vibration shall be carefully controlled, the internal vibrator being systematically inserted at points minimum 450 mm and maintained in position for a fixed time. Immersion for periods of 5 to 15 seconds should normally be sufficient. The limit of action is judged by surface appearance. The surface shall neither be honey combed nor shall it contain excess mortar.
- The vibrator shall be inserted vertically. With inclined or haphazard insertion it will be impossible to regulate the degree of compaction in all portions of the concrete. Care shall be

taken to prevent contact of immersion vibrators with form work, reinforcement steel and finished surfaces. Immersion vibrators shall not come in contact with reinforcement steel if initial set of concrete around it has started.

- The vibrator shall be allowed to penetrate on its own accord and should be withdrawn quite slowly, at the rate of about 75 mm per second, whilst still running, so as to allow the redistribution of the concrete in its wake.

The rate of placement of concrete shall be such that no cold joint is formed and fresh concrete is placed always against green concrete that is still plastic and workable. Sufficient tarpaulins or other similar protective arrangement for completely covering the still green concrete from rain may be kept at the site of placement. If there has been any sign of washing of cement and sand, the entire affected concrete shall be removed immediately. Suitable precautions shall be taken in advance to guard against rains before leaving the fresh concrete unattended. No accumulation of water shall be permitted on or around freshly laid concrete.

Slabs, beams and similar members shall be poured in one operation. In special circumstances with the approval of the Engineer-in charge, these can be poured in horizontal layers not exceeding fifty (50) cm. in depth. When poured in layers, it must be ensured that the under layer, is not already hardened. Bleeding of under layer if any, shall be effectively removed. Moulding, throating, drip course, etc. shall be poured as shown on the drawings or as directed by the Engineer. Holes shall be provided, and bolts, sleeves, anchors, fastenings or other fixtures shall be embedded in concrete as shown on the drawings or as directed by the Engineer.

In case the forms or supports get displaced during or immediately after the placement and bring the concrete surface out of alignment beyond tolerance limits, the Engineer may direct to remove the portion and reconstruct or repair the same at the Contractor's expense.

The Engineer shall decide upon the time interval between two placements of concrete of different ages coming in contact with each other, taking in consideration the degree of maturity of the older concrete, shrinkage, heat dissipation and the ability of the older concrete to withstand the load imposed upon it by the fresh placement.

Concrete shall not ordinarily be placed under water. In unavoidable cases, such concreting shall be done only with the specific approval of procedure and application by the Engineer-in-charge. The concrete shall contain at least 10 percent more cement than that required for the same mix placed in the dry, the quality of extra cement varying with condition of placing. The relevant clauses of IS: 456 (latest edition) should be adhered to 11.12(D) (w). Retamping of concrete or mortar which has partially hardened shall not be permitted.

All excavations prepared for concrete construction shall be maintained free of water until such concrete work is completed. Water used for flushing concrete placing equipment shall be discharged clear of the concrete and forms.

Contractor shall keep an accurate record of the date on which the concrete is cast for each part of work and date on which the forms are removed.

Finish of Concrete Surfaces: Floor surfaces shall be worked to a smooth even finish to correct levels of falls as indicated in the drawings or as directed.

Curing: Curing shall be as per IS: 456. Unless otherwise specified all concrete shall be moist cured by keeping all exposed surfaces, edges and corners continuously moist for at least twenty one days after being placed, by spraying, ponding or covering with waterproof paper or moisture retaining fabric.

Newly placed concrete shall be protected by approved means from rain, sun and wind. Concrete placed below the ground level shall be protected against contamination from falling earth during and after placing. Concrete placed in ground containing deleterious substances, shall be protected from contact with such ground, or with water draining from such ground, during placing of concrete and for a period of at least three days. The ground water around newly poured concrete shall be kept to an approved level by pumping out or other adequate means of drainage to prevent floatation or flooding.

As soon as the concrete has hardened sufficiently, it shall be covered either with sand, Hessian, canvas burlap or similar materials which will hold moisture for long period and prevent loss of moisture from concrete and kept continuously wet for at least 18 (eighteen) days after final setting. Curing by continuous sprinkling of water will be allowed if the Engineer is satisfied with the adequacy of the arrangements made by the Contractor.

Curing of concrete shall start after 8 hours of placement and in hot weather within 4 hours of placement of exposed faces. During the first 24 hours, the concrete shall be cured by use of wet burlap or such other means to cover the concrete surfaces. In very hot weather, precaution shall be taken to see that the temperature of wet concrete does not exceed 38 deg. C while placing.

Concrete slabs and floors shall be cured by flooding with water of minimum 25 mm depth for the period mentioned above. Approved curing compounds may be used in lieu of moist curing with the permission of the Engineer-in-charge. Such compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set.

Wash water: Wash water shall be removed in a manner to prevent running down and staining of concrete surfaces which will be exposed at the completion of the work. Should unsightly wash water streak develop on the exposed surfaces, they shall be removed and water has to be lead to a suitable place as directed by Engineer- in charge.

Grouting: The blockouts and bolt holes which have to be grouted shall be cleaned thoroughly by use of compressed air immediately before taking up the grouting operations. Cement sand mix in 1:1 proportion and aluminum powder or anti-shrinkage admixture of approved quality shall be first blended thoroughly in the required proportion as per manufacturer's specification. Grout shall then be prepared by mixing this admixture with water in the proportion of 2 parts by weight of cement to one part by weight of water. The quantity of aluminum powder shall usually be of the order of 0.005% by weight of cement. Any grout which has been mixed for a period longer than half an hour shall not be used on the work.

Concrete surfaces receiving the grout shall be properly roughened removing laitance and exposing good concrete. The steel surfaces coming in contact with the grout should be cleaned of rust, mill scales, paints, oil or grease and be wet before setting into place for grouting.

Immediately after preparation, the grout shall be poured into the block outs, pockets and bolts holes either from the sides or through the holes provided for this purpose in the base plate by using special equipment for pressure grouting. It shall be ensured by poking with rod and by tapping of bolts, that the block out is completely filled without leaving any voids. The pouring shall stop as soon as each hole is filled and any excess grout found on the surface on the concrete foundation shall be completely removed and the surface dried.

Under-Pinning/Grouting: It shall be resorted to for filling the space between the underside of base plate and the top of foundation concrete. After grouting has been completed, space between the top surface of the foundation concrete and the underside of the base plate shall be filled with mortar or concrete depending upon thickness to be filled as follows:-

Less than 40 mm	Dry packed mortar
Over 40 mm	Dry packed fine concrete

Use of dry pack concrete: The widely used method of obtaining satisfactory grout is based on principle of using lowest water cement ratio reducing the shrinkage to a minimum. Pozzolana cement having less shrinkage than ordinary Portland cement is preferred for this grouting. Only enough water shall be added to produce a grout. The proper amount of mixing water and proper consistency are those which will produce a grout which is at the point of becoming rubbery when the material is solidly packed. Any mortar which has been mixed for a period longer than an hour shall not be used.

Use of special admixtures: To reduce the shrinkage, anti-shrinkage materials as specified earlier to be added.

Plastering: Plastering foundation plinths 12mm thick in 1:3 cement mortar and white washing (two coats) with janatacem cement paint. All projections of plinths and masonry above ground level shall also be provided with janatacem cement paint.

1.10.3 CABLE DUCT:

Cable & Pipe Trenches (400kV SS Switch yard):

- Cable and pipe trenches shall be of reinforced concrete type with removable type reinforcement cement concrete covers. These trenches shall not be used as storm water drains. The bed of the cable/pipe trenches along their length shall be provided a slope of 1:750 to 1:1000 to drain any rain/seepage water that may enter them. The overall depth of various type of cable/pipe trenches shall be so decided as to take care of above provision of longitudinal slope along their length without compromising the clearance required between bottom most tray of cable trench and bed of the cable trench.

- Suitable expansion joints shall be provided in cable/pipe trenches as per IS specification with PVC water stoppers, bitumen impregnated filler boards, bitumen sealing compound as per specifications or as directed by the purchaser. The water proofing cement additive shall be used for the construction of cable trenches to ensure water tight construction.

- The water from cable trenches shall be collected in suitably located sumps from where this water shall be disposed off by pumping into nearest storm water drains. The sump pits shall be of R.C.C construction covered at top with provision of manhole, rungs and installing 2 Nos. of 100% capacity submersible type sump pumps for pumping out the water from the sump pit with auto start and auto shutdown depending upon the level of water in the sump pit. All accessories like suction and discharge pipes for transferring water from sump pits to nearest storm water drains shall be provided. The grade of concrete for the construction of sump pits is M-20 conforming to IS: 456-2000.

- All cable trenches shall be provided with edge protection angles of size not less than 45x45x5 mm and suitable length as decided at the time of engineering. Suitable lugs of reinforcement steel (10 mm dia minimum) shall be welded to edge protection angles for ensuring their rigidity in the concrete. The weight of a single pre-cast R.C.C cover shall not be more than 75 Kg. Suitable lifting hooks of size 10mm MS rod minimum shall be provided for easy handling of these covers.

- The covers of cable trenches shall be of such designs that do not allow any rainwater to enter into them. Necessary embedded steel plates shall be provided for supporting the cable trays.

- The top of cable trenches shall be kept 150 mm above finished ground level. The backfilling shall be with excavated soils.

- In cable/pipe trenches, construction joints shall be provided between the base slab and sidewall with PVC water stoppers.

1.10.3.1 Cable Trench in 220&132kV Substations:

Switch yard: The cable duct in the switchyard shall be constructed as per drawing. It shall comprise of 230mm thick brick work in cement mortar 1:6 on either sides. The depth and width of the duct shall be 500mm and 960mm respectively. Cables are to be buried in sand in this duct over 1:4:8 CC with 40mm HBG metal bed of 100mm thick. The cable duct shall be covered with a RCC slab of 50mm thick of proportion 1:2:4 with 10 to 12mm HBG metal with 8mm tor steel placed at 150mm in either direction. The cable duct covering slab shall be in flush with the top of the brick work.

Road Crossing: Construction of cable duct in the switch yard for Road Crossing by providing 2 rows of 300mm dia RCC Hume pipe (plain ended pipe)& collars required confirming to BIS 458/1988 NP2 class duly embedded in cement concrete 1:3:6 with 50% 40mm & 50% 20 mm HBG metal as per drawing including cost & conveyance of all materials, labour charges, leads, lifts and curing etc, complete as per the directions of the Engineer in charge for the finished item of work.

Control Room: In the control room cable duct is to be constructed as per the approved drawing at lintel levels as per instructions of Engineer-in-charge at site. G.I. Weld mesh cable trays of 300mm width and 3 meters long with 25 x 25 x 4 mm angle frames to be placed in the duct. These cable trays are to be supported on Galvanized M.S.Angles of 45 x 45 x 5mm, and fixed in the cable duct as per the drawing. Cable duct will be covered with 7 mm Galvanized chequered plate. The main cable trenches entering at control room should be sealed to avoid entry of any creatures.

1.10.4 TRANSFORMER FOUNDATIONS: It shall consist of a R.C.C. soak pit having pedestal for supporting the transformer/reactor and its cooling bank etc. The size of the soak pit shall be 1.0 M bigger all round than the plan size of transformer. The depth of soak pit shall be adequate to accommodate the full quantity of oil contained in the transformer plus 50% of emulsifier water in voids of metal filling inside the soak pit.

The metal size to be filled in the soak pit shall be of 60 mm to 40 mm nominal size and it shall be ensured that 40% of voids are available in the metal filling after its packing in soak pit. The top of the metal filling inside the soak pit shall be 200 mm below the top of the rail.

Central Oil collecting Pit: A common R.C.C central oil-collecting pit shall be provided for all the transformers. This pit shall be closed type and waterproof construction with necessary manholes and rungs etc. for maintenance purposes. The soak pits of transformers shall be connected to this central oil-collecting pit through underground R.C.C pipes and manholes. The size of the oil collecting pit shall be adequate to accommodate the full quantity of oil contained in the largest transformer including rain water and emulsifier water required for the biggest transformer and to ensure that no oil/emulsifier water remains in the transformer soak pit/drain pipes and the level of soak pit shall be accordingly decided. The size of R.C.C pipes to be used for connecting the soak pit of the transformers to the central oil collecting pit shall not be less than 300 mm diameter and shall be of class NP4 conforming to IS: 458(latest) as per recommendations of tariff Advisory Committee. The central oil collecting pit shall have provision for installing 2 Nos. of 100% capacity sump pumps with all accessories like suction and discharge pipes for transferring discharge to oil-water separator such that each pump can pump oil/rain water/emulsifier discharge of auto-transformer of biggest transformer in the switchyard. The suitable size oil-water separator shall be designed and provided by the contractor in a manner that oil would be separated from water and same shall be retained in oil water separator while water shall be disposed off to the nearest storm water drain. The oil water separator shall also be of R.C.C construction. Design of transformer foundations shall be carried out based on the relevant drawings, loading data etc. to be furnished by the purchaser.

1.10.5 Drainage of Switchyard Area: Suitable drainage arrangement shall be designed and provided by to drain off the rainwater quickly and efficiently from switchyard area. For this purpose, the yard shall be sloped away from control building and also from cable trenches, so as to prevent ingress of rainwater into them. The arrangements of drainage provided shall be connected at suitable points to drainage system for rest of the switchyard (or the water shall be drained off to suitable outlet as approved by the purchaser).

All surface drains shall be constructed with brick masonry in cement-sand mortar 1:5 (1 cement: 5 Coarse sand) and these shall be plastered inside with cement-sand mortar 1:5 (1 cement: 5 fine sand). The thickness of plaster shall be not less than 20 mm. The bricks to be used for the construction of drains shall be of 2nd class conforming to relevant IS code. The longitudinal slope of drains shall be so decided that there is no accumulation of silt in the drains and rain water is disposed off as quickly as possible without causing any flooding in the switchyard area. However, the slope of drains shall not be lesser than 1:1000.

The minimum width of any drain shall not be less than 400 mm and depth of drain shall not be less than 300 mm.

1.10.6 EARTHING SYSTEM: Details

	Item	**Size**	**Material**
i)	Main Earthing Conductor	40 mm dia rod	Mild Steel
ii)	Conductor above ground level and earthing leads for equipment structures, columns and other auxiliary structures buildings.	75x12 mm flat	Galvanized Steel
iii)	Earthing leads for cable trenches.	50 x 8mm	G. S Flat
iv)	Rod Electrode	40 mm dia	MildSteel3000mm long rod
v)	Riser below ground connecting Earth Mat to above ground level Earthing GS flat	40mm dia	M.S.Rod
vi)	Earthing of Indoor LT panels and outdoor Marshalling boxes, MOM Boxes, Junction Boxes & Lighting Panels, cable trays & cables.	50 x 8 mm	G.S.Flat
vii)	CI pipe electrode Pipe back filled treated with BH coke mixed with salt (in treated earth pit)	2.75 mtrs. 125 mm dia.	CI pipe electrode

viii) Earthing for Motors	25 x 3 mm flat	Galvanized Steel

Connections from mat to the switchyard and transformer yard equipment; framework and other earthing points shall be made.

1.10.6.1 DESIGN CONSIDERATION: The design of the earthing mat shall be based on the following:

Average soil resistivity: (Ohm-metre)	As per soil test results to be determined prior to preparation of designs
Magnitude of design fault current:	
Duration of fault (Second):	40KA/ One (1)
Duration of shock (Second):	Half (0.5)
Material of earthing mat:	Mild Steel conductor
Type of joints	
a) Permanent:	Welded
b) Suitable for testing operations:	Bolted
Values of maximum allowable Temperature in	
a) Welded joints (deg.C) :	620
b) Bolted joints (deg.C) :	310
Value of design ambient temperature:	As per project site data
Type of surface layer:	Crushed rock of size 15-20 mm
Average resistivity of surface layer (Ohm-meter):	3000
Thickness of surface layer:	150 mm
Minimum size and type of earthing mat conductor	MS Rod 40mm dia
Allowance for corrosiveness:	To be considered in design according to type of soil

The design of the earthing mat shall be such that the safe values of touch, step and transfer potential are not exceeded under any condition. The combined resistance of earth grid including rods in the station shall not exceed 1.0 Ω (maximum). Earth electrodes shall be provided as required and connected to earth mat to achieve the desired value.

All conductors buried in earth and concrete shall be mild steel. All conductors above

ground level and earthing leads shall be galvanized steel.

After completion of earth mat, the earth resistivity may be measured. In case the earth resistance is more than one ohm, earth mat may be extended /extra electrodes installed or other appropriate steps taken so that the earth resistance is less than one ohm.

1.10.6.2 EARTH MAT: M.S.Flat of sizes 100x16mm and 50x8mm confirming to IS 2062 shall be used for earthing. The earth mat shall be as per the drawing and extend over the entire switchyard. The earth mat shall be formed with the steel flats buried in the ground at a depth of 600 mm on edge. Wherever necessary, these shall have to be buried at larger depths to restrict potentials within permissible values. G.I. wire shall be used to connect the overhead ground wires to the ground mat, along the structures at all the locations.

All the junctions of the steel flats while forming the earth mat and taking risers from the earth mat for giving earth connections to equipment, steel structures, conduits cable sheaths shall be properly welded. All joints shall be provided with suitable angle pieces for proper contact between two flats.

The earth mat shall be formed by welding 50 x 8 mm steel flat to the 100 x 16 mm peripheral earth conductor. The grounding grid shall be spaced about 5 meters, in longitude and about 5 meters in the transverse directions. After completion of earth mat, the earth resistivity may be measured. In case the earth resistance is more than one ohm, earth mat may be extended / extra electrodes installed so that the earth resistance is brought below one ohm.

Wherever earthing conductors cross cable trenches, underground service ducts, pipes, tunnels, railway tracks etc., it shall be laid minimum 300 mm below them and shall be re-routed in case it fouls with equipment/structure foundations.
Earthing conductors along their run in cable trench, cable ladders, walls, etc. shall be supported by suitable welding/cleating at intervals of 750 mm. Earthing conductors along cable trenches shall be on the wall nearer to the equipment. Wherever it passes through walls, floors, etc., galvanized iron sleeves shall be provided for the passage of the conductor. Both ends of sleeve shall be sealed to prevent the passage of water through the sleeves.

Earthing conductor around the building in addition to earthmat below the building shall be buried in earth at a minimum distance of 1500 mm from the outer boundary of the building. In case high temperature is encountered at some location, the earthing conductor shall be laid minimum 1500 mm away from such location. Reinforcement provided in the building shall also be connected to earthmat. The area of reinforcements shall not be considered contributing to the earthmat design requirement.

In outdoor areas, tap connections shall be brought 450 mm above ground level for making connections in future, if equipment is not available at the time of installations.

Earthing conductors embedded in the concrete shall have approximately 50 mm concrete cover.

If the earthing mat extends right up to fencing and the design calculations reveal that the values of touch potentials both from within and outside the fenced-in area are within safe limits, fencing shall be connected with the earthing mat at frequent intervals. If the earthing mat extends right up to the fencing, but the calculations reveal that touch potential at the fence is beyond tolerable limits, the earthing mat shall be terminated about 1.5 meter within the boundary line of the fence and the fence shall be electrically isolated and independently earthed by running earthing conductor underneath the fence and bounded with the fence at frequent intervals or by means of adequate number of earthing electrodes.

1.10.6.3 Installation: Back-fill material to be placed over buried earth conductor shall be free from stones and other harmful mixtures. Back-fill material shall be placed in layers of 150 mm, uniformly spread along the ditch, and tempered. Planks or other protections shall be placed over conductors in hazardous areas after layer of earth has been placed over the conductor, but before placement of balance of back fill. If the excavated soil is found unsuitable for back filling, suitable soil brought from outside shall be used.

Earthing wires shall be installed before the commencement of concrete work.

1.10.6.4 Equipment & Structural Earthing:

Earthing pads/terminals shall be provided by the Supplier of the apparatus/equipment at accessible position. The connection between earthing pads and the earthing grid shall be made by short and direct earthing leads free from kinks and splices. Neutral connection shall never be used for the equipment earthing.

Steel/RCC columns, metallic stairs etc. shall be connected to the nearby earthing grid conductor by two earthing leads. Electrical continuity shall be ensured by bonding different sections of hand-rails and metallic stairs.

Metallic pipes; conduits and cable tray sections for cable installation shall be bonded to ensure electrical continuity and connected to earthing conductors at regular interval. Apart from intermediate connections, beginning and end points shall also be connected to earthing system. Metallic conduits shall not be used as earth continuity conductor.

A separate earthing conductor shall be provided for earthing lighting fixtures, receptacles, switches, junction boxes, lighting conduits etc.

Wherever earthing conductor crosses or runs along metallic structures such as gas, water, steam conduits, etc. and steel reinforcement in concrete it shall be bonded to the same.

Light poles, junction boxes on the poles, cable and cable boxes/glands, lockout switches etc. shall be connected to the earthing conductor running along with the supply cable which in turn shall be connected to earthing grid conductor at a minimum two points whether specifically shown or not.

Railway tracks within switchyard area shall be bonded across fishplates and connected to earthing grid at several locations. At the point where track leaves the plant substation area, the rail section shall be provided with insulated joint at both ends.

Every alternate post of the fence and gates shall be connected to earthing loop by one lead.

Flexible earthing connectors shall be provided where flexible conduits are connected to rigid conduits to ensure continuity.

Metallic frames of all electrical equipments shall be earthed by two separate and distinct connections with earthing system. Shield wire in substations shall be connected to the earthing grid at every alternate switchyard gantry tower

A separate earth electrode (rod of 3.0m) shall be provided adjacent to structures supporting lightning arrester and coupling capacitors. Earth connections shall be as short and as straight as practicable. Lightning arresters and lighting down conductors and CVT are connected to main mat at least at two points at a depth of 600mm below ground. The risers taken along the main switchyard structures and equipment structures (up to their top) shall be clamped to the structures at an interval of not more than one meter.

1.10.6.5 Jointing:

Earthing connections with equipment earthing pads and at treated / untreated pits shall be bolted type. Contact surfaces shall be free from scale, paint, enamel, grease, rust or dirt. <u>Two bolts shall be provided for making each connection</u>. Equipment bolted connection, after being checked and tested, shall be painted with <u>anti corrosive paint/compound</u>.

The design of earthing mat shall provide for welded joints between the earthing mat conductors, except where the mat may have to be isolated from equipment, cable sheath, test pits, etc. for testing. The joints intended to be isolated for testing shall be bolted. Connection between equipment earthing lead and main earthing conductors and between main earthing conductors shall be welded/brazed type.

<u>The welds shall be treated with Barium Chromate to protect them from rusting. The exposed steel conductors/risers shall be protected with bituminous paint. The Barium Chromate treated surfaces shall thereafter be painted with red lead and aluminum paint and coated with bituminous paint</u>.

Steel to copper connections shall be brazed type and shall be treated to prevent moisture ingression.

Resistance of the joint shall not be more than the resistance of the equivalent length of the conductor.

1.10.6.6 Power Cable Earthing:

Metallic sheaths and armor of all multi core power cables shall be earthed at both equipment and switchgear ends as per IS: 1255. Sheath and armor of single core power cables shall be earthed at switchgear end only.

1.10.6.7 Specific Requirement for Earthing Systems:

Each earthing lead from the neutral of the power transformer shall be directly connected to pipe electrodes of treated earth pits which, in turn, shall be connected to station earthing grid. All pipe electrodes shall have cement concrete pit with a Cast Iron cover hinged to a cast iron frame to have an access to the joints.

Auxiliary earth mat of size 900 x 900 mm comprising of closely spaced (300x300mm) conductors shall be provided at 300 mm below ground under the operating handles of the isolators further, and connected to the main mat at least at two points. Operating handle of isolator shall be bonded together by a flexible connection. MOM boxes both for main and earth switch shall be directly connected to the earthing mat.

Galvanized Steel: Steel conductors above ground level shall be galvanized according to IS: 2629. The minimum weight of the zinc coating shall be 650 gm/sq.m.

Each transformer shall be provided with 3 nos treated earth pits near to them for earthing (as per the standard practice). Cast iron pipes 125 mm in dia and 2.75 meters long and 12.7 mm/ 9.5mm thick shall be buried vertically to a depth of 2.75 metres in the pits. Finely broken coke and salt shall be filled at least 150 mm around the pipe for the entire depth. These earth pits in turn shall be connected to the earth mat. Circular R.C.C. Collar with diameter of 1 meter/0.75metres and height of 65cm, 50mm thickness shall also be provided for each treated pit. Where it is not possible to go to a depth of 2.75 metres, 1.3M x1.3M MS plate of 25mm thickness shall be buried vertically in a pit of 2metres depth, surrounded by finely broken coke or Bentonite powder. Earth pit with MS plate shall be located at least 2 metres away from any building or structural foundation. Plates shall be at least 15 metres apart.

All fence corner posts and gate posts shall be connected to the ground by providing 32 mm dia M.S. rods of 3 meter length near the posts and connected to the main grounding mat.

All paint, enamel and scale shall be removed from surface of contact in metal surface before making ground connection.

50 x 8 mm (flat) ground conductor shall be run in cable routes and shall be connected to the ground mat at an interval of 10 metres.

Earth pits shall be provided near the Lightning arrestors pits for earthing (as per the standard practice).

1.10.7 CABLES:

LT Power Cable: XLPE insulated 1100 V grade power cables shall be FR LS type of category C1 conforming to IS: 7098 Part-I (as amended up to date). The conductor shall be stranded aluminum, circular/shaped and compacted. In multi-core cables, the core shall be identified by red, yellow, blue and black colored strips or coloring of insulation. For multi-core cables the inner sheath and outer sheath shall be of extruded PVC of Type ST-2 of IS: 5831. The outer sheath shall have FRLS properties. Armoring for single core cables shall be aluminum strips/wires and for multi-core cables galvanized steel strips/ wires.

PVC insulated 1100V grade power cables shall be FR type of category C1 conforming to IS: 1554 (Part-I) (as amended up to date) and shall be suitable for a steady conductor temperature of 70 deg. C. The conductor shall be stranded aluminum. The insulation shall be extruded PVC of Type-A of IS: 5831. The inner and outer sheath shall be of extruded PVC of Type ST-1 of IS: 5831. The outer sheath shall have FRLS properties. The armor shall be galvanized steel wire or strip for multi-core cables and aluminum wire or strip for single core cables conforming to IS: 3975.

Control Cables: The 1100V grade control cables shall be FR type category C1 conforming to IS: 1554(Part-I) (as amended up to date). The conductor shall be stranded copper. The insulation shall be extruded PVC of Type-A of IS: 5831. The inner and outer sheath shall be extruded PVC of type ST-1 of IS: 5831, and shall be gray in color except where specifically advised by the Purchaser to be black. The armor shall be of galvanized steel wire / strip for control cables. The outer sheath shall have FRLS properties.

Cores shall be identified as per IS: 1554 (Part-I) for cables up to five (5) cores. For cables with more than five (5) cores, the identification shall be done by printing legible alphabets on all cores. The alphabets shall be white, and shall be printed at about 100 mm interval all along the cable length.

CABLING: Cabling shall be on cable racks, in built up trenches, vertical channels, excavated trenches for direct burial, pulled through pipes, and conduits laid in concrete ducts, run clamped on wall/ceiling/steel structures etc.

Cables in outdoor switchyard shall be laid on angles embedded in trenches, excavated trenches for direct burial, and pulled through pipes and conduits. In cable vault below control room building / bay kiosk, cables shall be laid on ladder type cable trays clamped on wall / ceiling / steel structures etc. as approved.

Cables inside the Switchyard shall be laid on angle supports at 600 mm spacing with separate tiers for control and power cables.

Cables shall be generally located adjoining the electrical equipment through the pipe insert embedded in the floor. In the case of equipments located away from cable trench either pipe inserts shall be embedded in the floor connecting the cable trench and the equipment or in case the distance is small, notch/opening on the floor shall be provided. In all these cases necessary bending radii as recommended by the cable supplier shall be maintained.

Cable supporting angles shall be welded to the continuous vertical supporting structure embedded in the wall to the suitable anchor inserts welded to the reinforcement of the wall (wherever applicable).

All metal parts inside the trench shall be bonded to earthing systems.

All steel structures/plates would be painted with non-corrosive paint and earthing conductor in cable trench shall be painted red.

Trench wall shall be clear of the equipment by minimum 100 mm.

Necessary opening and G.I. pipes shall be provided for taking out cables for lighting fixtures.

Necessary HDPE pipes shall be supplied and provided to run optical fibre wire wherever required.

Cables entering the control room from outdoor areas shall be sealed. Spare glands shall be sealed for control panels and marshalling boxes .Cables shall cross control room basement wall in 4" R.C.C. Hume Pipe embedded in cement concrete in basement wall.

In each cable run some extra length shall be kept at a suitable point to enable one or two straight through joints to be made, should the cable develop fault at a later date.

Metal sheath and armor of the cable shall be bound to the earthing system of the station by a steel strip wire. Bending the metal sheaths of single core cables in close **trefoil_**formation shall be as stipulated in the relevant codes of practices.

1.10.8 LIGHTNING PROTECTION SYSTEM: Direct Stroke Lightning Protection system covers lightning masts and overhead shield wires wherever necessary to protect the entire 400/220 KV switchyard including bus-bars, equipment buildings transformer yards, feeder yards, auxiliaries etc. from the direct stroke of lightning.

The following Indian Standards can be followed to the extent these are relevant:

- Protection of buildings and allied structures against lightning.	IS: 2309:196
- Code of Practice for Earthing.	IS: 3043-19, Indian Electricity Rules with latest amendments
- National Electricity Safety Code	IEEE-80.

3.10.8.1 DESIGN REQUIREMENTS: The direct stroke lightning protection system shall be based on adequate number of lightning masts of appropriate height installed in the switchyard in such a manner that they provide adequate shielding cover to all the 400/220 KV bus-bars, their connections to the bay equipment and other equipment from direct lightning strokes.

The lightning masts shall consist of latticed steel structures on the top of which pipes of adequate dimensions and height shall be rigidly fixed suitably.

Conductors of the lightning protection system shall not be connected with the conductors of the safety earthing system above ground level.

Down conductors shall be cleated on the structures at 750 mm interval.

A 40 mm dia, 3000 mm long MS Earth Electrode shall be provided with lightning masts. Connection between each down conductor and rod electrodes shall be made via test joint located approximately 1500 mm above ground level.

Lightning conductors shall not pass through or run inside G.I. conduits.

All metallic structures within a vicinity of 2000 mm in air and 5000 mm below ground shall be bounded to the conductors of lightning protection system.

Lightning protection system installation shall be in strict accordance with the latest editions of Indian Electricity Rules, Indian Standards and Codes of Practice and Regulations existing in the locality where the system is installed.

Ground down leads shall be used to connect lightning receiver pipe on the lightning mast to the grounding mat.

Lightning protection system down conductors shall not be connected to other conductors above ground level. Also no intermediate earthing connection shall be made to lightning arrester, transformer and voltage transformer earthing leads, which shall be directly connected to rod electrode.

The lightning protection system shall not be in direct contact with underground metallic service ducts and cables.

1.10.9 Lighting System: The equipment such as distribution boards, lighting panels for normal and emergency lighting, lighting fixtures, luminaries, lamps, wiring accessories, junction boxes conduits, conduit accessories, fittings etc. and materials as would be found necessary for illuminating the switchyard with S.V lamps, rechargeable fitting shall be provided by the contractor as per the specification here under.

The high pressure sodium vapor lamps with fittings conforming to relevant IS where applicable with latest revisions of M/s.Crompton Greaves make of Model SSS 251H 250 Watts capacity or equivalent of Phillips or GEC or Bajaj make for yard lighting of EHT sub stations. The luminary shall have deep drawn anodized single piece aluminum body with circular/oval lamp compartment with suitable control gear consisting of low loss heavy duty electronic ballast like OPAL make, power factor improved capacitor, external electronic igniter and also provided with detachable parabolic reflectors. These fittings shall be provided for A.C lighting as per lighting arrangement specified in the drawing. The locations of the light fittings in the switchyard will be indicated by the Engineer. The twin tube rechargeable emergency light fittings shall be portable and of approved quality.

Alternately energy efficient lamps such as CFLs / LEDs with wattage sufficient to provide adequate illumination in the switch yard may be considered.

The lighting system shall consist of normal AC lighting from 3 phase 415 volts supply.

YARD LIGHTING PILLAR BOX: Whether proof out-door type, 'Yard lighting Pillar Box for AC lighting having the following specifications for EHT sub-stations is to be provided.
The box should be made of 2 mm thick Galvanized M.S.Sheet of size 700 x 500 x 150mm (as per drawing). The box should have hinged type door vermin proof, weather proof. Rubber beading has to be provided around the door. Door of the box should be provided with panel type lock. The top portion of the box shall be slanting, so that the rain water will fall away easily.

The box should be provided with 1 No. 60 Amps 3-Pole MCBs, 6 Nos. 20 Amps and 6 Nos. 10 Amps, Single pole MCBs and required copper Bus bars (20 mm x 5 mm) duly mounted Insulators fixed to Fibre glass sheet (neatly fixed in the box) with sufficient access for giving the cable connections. 20 Nos. cable glands should be supplied and the required holes are to be provided in the box duly half punched for taking cables into the box as per convenience. One hole should be of 35 mm dia for three phase cable and rest of 16 mm dia for lighting cables.

4 Nos. Galvanized M.S.Flats 50 x 6 mm should be welded to the box with one No. hole suitable for 5/8" dia bolts to facilitate easy mounting.

SUPPORTS FOR FIXTURES:

i) The lights shall be mounted on structures with necessary cantilever arrangement

ii) The steel mounting arrangements shall be as per the drawing and same shall be galvanized. The mounting arrangement shall be earthed at two locations with 8 SWG GI Wire.

iii) All lighting fixtures shall be mounted in accordance with the standard installation practice. Splices in lighting circuits shall be avoided. Required size of fuses shall be provided for each light junction box.

1.10.10 Marshalling Boxes for C.Ts, P.Ts, and C.V.Ts.

The box should be made of 2 mm thick Galvanized M.S.Sheet of size 750x400x150 mm with hinged type door, vermin proof and weather proof. Rubber beading has to be provided around the door. Necessary brackets on the back side of the box should be provided for mounting on the structures. Doors of the box should be provided with panel type look. The roof portion of the box shall be slanting so that rain water will not stagnate. Two rows having 20 Nos. terminals in one and 14 Nos. in other should be provided in the box. The terminals should be of disconnecting and testing type (Type CDTTS). Three Nos. holes (Half punched) suitable for 6x2.5 sq.mm copper cable and 3 Nos. holes (half punched) suitable for 4x2.5 Sq.mm copper cable should be provided at the bottom to take the cables into the box. Suitable cable glands should be provided. Terminals in the Marshalling box should have facility for easy earthing, shorting, isolating and testing. 2 Sets of Earthing stud of 1/2" dia with suitable nuts, flat and spring washers are to be provided.

For Marshalling boxes for PTs: Ten Nos. (10 Nos.) HRC fuses of 2 amps rating of reputed make, with neutral link (with Bolts and Nuts) and one No. 3 pole MCB (10 amps) shall be provided.

For Marshalling boxes for CVTs: 6 Nos. HRC Fuses of 2 Amps rating of reputed make, with neutral link with bolts and nuts shall be provided.

MARSHALLING KIOSKS: The marshalling kiosk shall be of out door type suitable for operation in humid, dusty and tropical atmosphere with seasonal wet, dry and dusty condition as per clause-6.1 of I.S 5039/1969.The kiosk should be made of 3mm Galvanized M.S Sheet of size 1200x800x450mm.Each kiosk shall consist of

a) Detachable blank gland plate at the bottom

b) 200 Nos Heavy duty terminals stud type (5mm Sq) of rating 15 Amps to take 2.5 Sq mm copper / 4 Sq.mm Aluminum conductors.

c) 2 Amps HRC fuses (Reputed make)

d) Provision for three Numbers test terminal blocks.

e) Local illumination lamps - 2 Nos.

f) 2 /3- Pin 5/15 Amps. Multi point Plug with Switch - 3 Nos.

g) The terminal blocks shall be provided in vertical formation. They shall be fully enclosed with removable covers made of barrier moulded integrally. Such block shall have washer and binding screw for external connection and white marking strip for ex-circuit identification and moulded plastic cover. All terminals shall be clearly marked with identification markers.

h) Arrangement of terminals shall be as to safely connect or disconnect terminals on live circuits and replace the fuse links.

i) Adequate space heaters shall be provided in the Marshalling kiosk as required.

j) The box shall be provided with self supporting Galvanized M.S.Channel 100x50mm.,welded to the bottom side of the Box and 4 Nos. holes are to be provided (suitable for 3/4" dia bolts) for fixing to the plinth with galvanized bolts.

k) The Kiosk shall be provided with a set of double hinged doors at the front and back. The doors shall be provided with 2Nos panel locks and 1No.pad lock. It shall have a door switch operated AC illuminating lamps which gets switched on when door is opened and gets switched off when closed. Two No. studs shall be provided on the body for giving earth connection to Marshalling Boxes.

1.10.11 Erection of Structures:

The Structures shall be erected by piece-meal method on the foundations, after allowing the required curing time for the foundations. The members shall not be strained or bent during the course of erection. Care shall be taken to see that the jointing surfaces are clean and free from dirt or grit and fit properly. The structures shall be erected strictly in accordance with the approved drawings. After erection of structures the bolts shall be checked to ascertain that all nuts are fully tight. The structures must be truly vertical after erection and no straining shall be permitted to bring them to vertical position. The tolerance allowed for verticality is 1 in 360 structure height.

1.10.12 Stringing of Busbar & Ground Wire:

The bus will be formed with single/Twin/ Quadruple Moose/ ACSR conductor and shall be strung to required tension as per switchyard layout drawing. The stringing of bus conductors covers installation of tension insulator strings, suspension insulator strings, post type insulator stacks and other accessories along with tensioning of conductor and clamps. The jumpering to various equipment and the ground wire stringing shall also be done. The G.I. Ground wire shall be strung as detailed in the layout drawing.

The sag of bus conductor shall not be more than 1%. Damaged conductors shall not be used. No joints are to be made. The conductor surface shall be clean and smooth without any projections, sharp points, cuts or abrasions, etc., and the conductor shall be continuous in span.

1.10.13 Erection of Equipment:

Erection of equipment shall be in accordance with the manufacturer's installation drawings / instructions and recommendations

For erection of control , relay and LTAC panels and DC distribution Board in control room MS channels are required to be embedded in floor and grouting of foundations bolts in these channels is also to be done by the contractor. Control and Relay panels, AC and DC distribution boards, Battery and charger, communication equipment (PLCC panels/ OLTE, exchanges, battery and charger etc.) are to be erected as per the layout.

Rubber mat of approved quantity is to be provided in the control room in front of the panels of 137 cm width and 15 mm thickness throughout the panel length.

Power transformers, Circuit breakers, Instrument transformers (CTs,CVTs,IVTs), LAs, Isolators with/without earth switch, wave traps and Bus bars shall be erected in the switch yard as shown in the substation layout. Marshalling boxes are to be mounted underneath the instrument transformers on their support structures.

Marshalling kiosks are to be erected on the foundations laid at different locations as shown in the drawing for interconnection between equipment groups as per the drawing.

1.10.14 Supply of CO2 Fire Extinguishers :

Carbon-di-oxide (CO2) gas filled cylinders fitted with appropriate valves conforming to IS 3224 are to be provided in the substation. The test certificates issued by the Chief Controller of Explosives Department and cylinder manufacturer's certificates for the supplies already made should be made available.

The following codes and standards shall be applicable for conducting test unless otherwise modified or supplemented by the enclosed procedure and mutually agreed to between the Purchaser and the contractor.

1.	NFPA – 13	:	Standard for the installation of sprinkler system
2.	NFPA – 15	:	Standard for water spray fixed system for the fire protection
3.	NFPA – 12A	:	Standard for Halon 1301 Fire Extinguishing System
4.	NFPA – 72E	:	Standard on Automatic Fire Detectors.
5.	Fire Protection Manual by		TAC (Latest Edition).
6.	NFPA – 12	:	Standard on Carbon dioxide extinguisher systems.
7.	IS: 3034	:	Fire safety of industrial building: Electrical generating and distributing stations code of practice

1.10.15 Construction of Fire Protection Wall:

Fire protection walls are to be constructed as per the approved drawing between the Power Transformers (Normally provided for power transformers of 220kV class and above and for 132kV 50 MVA capacity and above).

1.10.16 Spreading of HBG Metal:
20 mm HBG metal of 100 mm thickness shall be spread in switch yard. Kerb stones of size 200 x200 mm shall be provided in the switchyard to retain the metal all along the periphery of the metal spreading where ever it is required. The Kerb stones shall be buried in the ground up to 100mm deep. The joints between the Kerb stones shall be done in CM (1:6) and plastering the Kerb stones shall be done in CM (1:2).

Before spreading the HBG metal care shall be taken to remove all the vegetation and roots of the plant. The trimming of the earth surface for perfect level ground should be carried out and the surface should be watered and rammed for consolidation with suitable means and the earth surface should be given chemical treatment for anti-vegetation growth.
The crushed metal dust or quarry dust should not be used. The HBG metal shall be brought from the approved Quarry as directed by engineer

1.10.17 Construction of Control House (Single storeyed)

FOUNDATION EXCAVATION: This work shall be done as per drawing for control
House and as per the technical specification. In case hard rock is met with, anchor rods shall be provided with 1000mm length of 16mm dia tor after drilling 20mm dia hole for a depth of 500mm inside hard rock and 500mm above hard rock for fixing in position with foundation mat. The anchor rod shall be fixed in the hole with C.M. (1:2) as directed by the Engineer.

FOUNDATION CONCRETE: Cement concrete 1:4:8 with 40 mm well graded hard broken metal for foundations 100mm thick including cost and conveyance of all materials, all leads and lifts and curing etc. complete for finished item of work as base concrete for the walls and columns of the structures.

FOUNDATION BASEMENT:

MASONRY:
Random rubble or uncoarsed rubble masonry with hard stone in cement mortar 1:6 for foundations up to ground level including cost and conveyance of all materials all leads and lifts and curing etc., complete for finished work and including cost of cement.

Coarsed rubble stone masonry 2nd sort with hard stone in cement mortar 1:6 for basement and wall above G.L., masonry work above G L including cost and conveyance of all materials ,all leads and lifts and curing etc., complete for finished item of work. The relevant APSS clauses 601,602 &615 are applicable to this work.

Pile foundations for BC soils: This should be done as per the drawing for pile foundation and as per the Technical Specification. The C.R. Masonry shall be executed over grade beam from ground level to finished floor level.

PLINTH BEAM: As specified in drawing for control house, plinth beam is to be provided.

SUPERSTRUCTURE:

Brick work in cement mortar 1:6 for walls in superstructure at ground floor and first floor and parapet with well burnt 2nd class country bricks including scaffolding, cost and conveyance of all materials all leads and lifts and curing etc., complete and including cost of cement. The relevant APSS clauses 501&504 are applicable to this work.

FILLING FOUNDATION AND BASEMENT: Back filling of foundations shall be done with excavated soils including watering and consolidating in 150mm layers for normal soils. Sand cushion for foundations and flooring area including, watering and consolidation shall be provided for BC soils. Anti-termite and Anti-weed treatment for foundations basement and flooring shall be provided. Compaction shall be obtained up to 98% proctor density.

FLOORING:

- Providing of CC (1:4:8), 100mm thick for flooring using 20mm and 40mm HBG Metal (each 50%), all leads and lifts, all labour charges, curing etc., including cost of cement. The work shall be carried out as per APSS clause No.402.

- Providing flooring and dadoing with ceramic tiles of approved quality of size and thickness with suitable colour border over cement mortar bed of CM (1:8) 12 mm thick over CC bed already laid or RCC roof slab, including neat cement slurry of honey like consistency spread @ 3.3.kgs per sqm & jointed neatly with white cement paste to full depth mixed with pigment of matching shade inclusive of cost and conveyance of all materials, all leads and lifts, curing etc., complete for finished item of work for rooms other than battery room & PLCC room. The work shall be carried out complying with APSS clauses 701 & 707.

- Skirting for height of 150mm with ceramic tiles of approved quality of size and thickness with suitable colour shall be laid over a base coat C.M (1:3) 12 mm thick with cement slurry of honey like consistency spread at the rate of 3.30 kgs per sqm and jointed with white cement paste mixed with pigment of matching shade to full depth provided along the periphery. The work shall be carried out complying with APSS clauses 701 & 707.

- Plastering in cement mortar 1:3, 12 mm thick and finishing smooth to the required slope and thread lined for battery room flooring including curing, shall be done. The Battery room flooring, sides, shall be provided with superior quality Acid resistant paint of approved colour two coats, over one coat of primer. The acid resistant painting shall be carried out complying to APSS clauses 1201 & 1214.

- Vinyl flooring with 1.5mm thick shall be provided for PLCC room with adhesive of good quality over CM (1:3) 20 mm thick finished surface. The samples of the materials shall be got approved by the Engineer-in-charge of work before commitment of the work.

FALSE FLOORING: MS Pedestals shall be with 20mm dia stud, top 15 mm machine threaded along with nut and check nut with necessary washers for level adjustment. The stud shall be fixed to 100x100x6 mm MS plate on top and bottom. The top plate will be welded with restraining angle 25x25x3 mm, 38mm long as per drawings, the pedestal shall be placed at all junctions of the panels 600x600mm and at such other locations as specified by the Engineer-in-charges. The pedestal shall be securely fixed to the floor with suitable adhesive.

Cold rolled steel channel stringers shall be of size 40x40x3.15mm placed over top head of pedestals in both directions true to level and alignment.

The floor panels of size 600x600mm, 35mm thick phenol formaldehyde resin bonded three layered teak wood particle board (Nova Teak super or equivalent) with 2mm high pressure decorative laminated, super shade finish of fire resistant quality or equivalent, fixed to the board surface with adhesive of approved quality.

The floor panels shall have holes and openings of size indicated in the drawings and as per directions of the Engineer-in-charge. The edges of panels shall have a hard PVC beading of approved shape and size. The beading shall be flush fitted with suitable size groove cut along the edges of the panels and fixed with adhesive.

All the MS sections shall be galvanized. The floor panels shall be numbered.

SUPPLY AND FIXING OF DOORS AND WINDOWS:

A) Supplying & fixing of Door frame made of roll formed section of 1.25 mm thick CRCA section, size should be 50 x75 mm with 32 mm rebate for doors along with accessories such as M.S. hinges 100mm long etc., as per the technical specification given in Appendix.

B) Supply & fixing 30mm thick solid bond wood block board type with teak veneer on one face and commercial ply on another face for single/double leaf conforming to IS 2202 (part-1) - 1973 suitable for the door frames of size 1.220 m x 2.135 m, 0.915 m x 2.135 m, 0.750 m x 2.135 m.

C) Supply, fabrication and erection of Aluminium anodized sliding windows using Jindal /equivalent Hindalco sections.

i)**Two Track windows**: Using aluminum anodized sections of Series C Jindal sections and outer frame top horizontals & both verticals of 20694 of size 62 x 29.5 mm x 1.30thick and bottom horizontal - two track frame of 20703 of size 62 x 29.5 mm x1.20 mm thick, Shutter frame top, bottom and verticals of 20529 of size 50 mm x 20 mm x 1.50 mm thick and Weather interlocking frame of 20531 of size 50 x 20 x 1.50 mm thick with plain clear float glass 5 mm thick fixed including supply and fixing aluminum handles of 100 mm for each shutter, nylon rollers assembly and all labour charges for fixing the fixtures with required no.of screws, bolts and nuts and including labour charges for fixing the frame in position, fixing shutter to frame etc. completed for finished item of work .

D) **Double Leaf Door (partly glazed & partly panelled):** using Jindal / eqvivalent Hindalco sections of size 101.60mmx44.75mmx2.40mm @ 1.834 Kg/m (Jindal Sec 14021) for frame and 47.62mmx44.45mmx2.02mm @ 1.052 Kg/m (Jindal Sec 19569) for shutter verticals, 47.62mmx44.45mmx1.95mm @ 0.974 Kg/m (Jindal Sec 19571) for shutter top, 114.30mmx44.45mmx2.15mm @ 1.824 Kg/m (Jindal Sec 19574) for shutter bottom, 83.50mmx44.45mmx2.40 mm @ 1.679 Kg/m (Jindal Sec 19525) for shutter middle and fitted with 5mm thick plain glass on upper half and 12mm thick both sides prelaminated cement particle board for lower half of the shutters including cost & conveyance of all materials, 1st quality double action floor springs (for inner & outer rotation), central pivots, rubber beading, heavy duty Mortice lock 6/7 levers with PC/CP handles, labour charges & other incidental charges complete as per the drawing and as per the directions of Engineer in-charge for finished item of work.

E) **Single Leaf Door (partly glazed & partly panelled):** Using Jindal / equivalent Hindalco sections and outer frame top horizontals & both verticals of 14021 of size 101.6 x 44.75 x 2.40 mm, Shutter frame top of size 44.45 mm x 47.62 mm x 1.95 section 19571 , bottom of size 44.45 mm x 114.30 mm x 2.15 section 19574 and verticals of 19569 of size 44.45 mm x 47.62 mm x 2.02 and Middle lock rail of 19525 of size 83.50 x 44.45 x 2.40 mm and fitted with 12mm thick both sides prelaminated cement particle board for shutter including supply and fixing aluminium handles of 100 mm for each shutter, floor springs/ hydraulic door closure assembly and all labour charges for fixing the fixtures with required no.of screws, bolts and nuts and including labour charges for fixing the frame in position, fixing shutter to frame etc. completed for finished item of work.

F) **Single Leaf Door (panelled):** Using sections of size 63.50mmx38.10mmx2.00mm @ 1.054 Kg/m (Jindal Sec 14013) for frame and 47.62mmx44.45mmx1.90mm @ 0.911 Kg/m (Jindal Sec 19570) for shutter verticals, 47.62mmx44.45mmx1.95mm @ 0.974 Kg/m (Jindal Sec 19571) for shutter top, 114.30mmx44.45mmx2.15mm @ 1.824 Kg/m (Jindal Sec 19574) for shutter bottom, 83.50mmx44.45mmx1.70mm @ 1.243 Kg/m (Jindal Sec 19535) for shutter middle and fitted with 12mm thick prelaminated cement particle board truly exterior grade both sides laminated (Bison Lam or equivalent) for shutter including cost & conveyance of all materials, glazing clips, rubber beading, automatic door closer (Hyper brand IS 3564), heavy duty Mortice lock 6/7 levers with PC/CP handles, labour charges & other incidental charges etc., complete as per the drawing and as per the directions of Engineer-in-charge for finished item of work.

G) **Safety Grills**: Using 7.50mm thick Aluminium grill (as approved by the department) @ 3.58 Kg/Sqm and 'U' section of Jindal / Equivalent Hindalco size12.50mmx12.50mmx1.00mm @ 0.133 Kg/m (Jindal sec 17533) for frame including cost & conveyance of all materials, labour charges and other incidental charges etc., complete as per the drawing and as per the directions of Engineer-in-charge for finished item of work.

H) **Ventilator:** Using section of Jindal / Equivalent Hindalco section of size 81.25mmx38.10mmx1.75mm @ 1.093 Kg/m (Jindal Sec 14071) for frame and 'U' section of size 12.50mmx12.50mmx1.00mm @ 0.133 Kg/m (Jindal Sec 17533) for louvers and inserting 5mm thick plain glass panes including cost & conveyance of all materials, labour charges and other incidental charges complete as per the drawing and as per the directions of Engineer-in-charge for finished item of work.

BED BLOCKS UNDER LINTELS:

Bed blocks in CC 1:3:6 proportion using 20mm size HBG metal under lintels with necessary form work shall be provided.

LINTELS:

RCC (1:2:4) nominal mix (conforming to I.S: 456) for lintels using 12 mm to 20 mm size HBG metal conforming to IS:383, including scaffolding, centering, machine mixing, vibrating curing, finishing, cost and conveyance of all materials, all leads and lifts in all position of the building at all heights, including cost of cement and steel for finished item of work.

COLUMNS & BEAMS:

RCC(1:2:4) nominal mix (conforming to I.S: 456) for footings, plinth beams, columns and beams with 12 mm to 20 mm size hard broken Granite metal conforming to IS:383, including cost of cement , steel centering, scaffolding, shuttering , machine mixing, Vibrating, curing and finishing to the required tolerances. The work shall be carried out complying with APSS clauses 313,402 & 403.

SUN SHADES:

RCC (1:2:4) nominal mix (conforming to I.S: 456) for sunshade of 75mm average thick, using 12mm to 20 mm size hard broken Granite metal conforming to IS:383, including scaffolding, centering, machine mixing, vibrating, curing and finishing to the required slopes and providing lip at the bottom ends including cement plastering 12mm thick with CM 1:5 proportion dubara sponge finish to the exposed faces of sun shades, including the cost and conveyance of all materials

RCC ROOF SLAB:

RCC (1:2:4) nominal mix (conforming to I.S: 456) using 12mm to 20 mm size hard broken Granite metal conforming to IS:383, for required thickness including cost of cement, centering charges, machine mixing, laying, vibrating, curing etc. PVC rain water pipes of 110 mm dia (4Kg/cm2) shall be provided from roof level to ground level. Opening shall be left over for providing 110 dia PVC Pipes while casting the slab.

SAMPLING AND STRENGTH TEST OF CONCRETE MIX: Samples from each fresh concrete shall be taken as per ISI1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516. In order to get a relatively quicker idea of the quality of concrete, optional tests at 7 days may be carried out. The sampling should be spread over the entire period of concreting and cover all mixing units.

Frequency:

Quantity of concrete in work cum.	Number of samples
1 to 5 cum	1
6 to 15 cum	2
16 to 30 cum	3
31 to 50 cum	4
51 and above	4 + one additional sample for each additional 50 cum or part there of.

Three test specimens shall be made for each sample for testing at 28 days. Additional samples may be required for various purposes such as to determine strength of concrete at 7 days etc.

PLASTERING ITEMS:

Plastering to walls in superstructure with cement mortar (1:5) proportion 12mm thick on even surface side and 20 mm thick on uneven surface side with 16mm thick in CM(1:6) for Ist coat & 4mm thick in CM(1:4) for second coat including scaffolding, cost and conveyance of all materials, all leads and lifts and curing etc., complete. Plastering to the roof slab with cement mortar (1:3) 20mm thick and with Acco proof cement compound of 1 Kg per bag of cement including cost of cement, duly making necessary slopes to drain the rain water. Plastering to roof ceiling with C.M. (1:3) 12mm thick.

Pointing to RR/CRS masonry in basement in cement mortar with CM (1:5) including cost and conveyance of all materials, all leads and lifts and curing etc., complete for finished item of work

PAINTING ITEMS:

Cost of tools and plant, paint, Brushes etc., required for the work shall be borne by contractor. The work shall be carried out complying with APSS clauses 908, 911, 1201,1212,1214,1216 & 1221.

i. Painting to wood work 2 coats with synthetic enamel paint first grade of approved make and colour over a primary coat (total 3 coats including cost of paints and primer etc.)

ii. Painting 2 coats to the steel work (Grills) with synthetic enamel paint first grade of approved make and colour over a primary coat (total 3 coats including the cost of the paint and primer.)

iii. Painting 2 coats with rubber based acid resisting enamel paint of approved quality and make over one coat of primer to the walls, flooring and ceiling of the battery room including the cost of the paint.

iv. Painting the outside of the walls with two coats of water proof, cement paint of approved Colour and make(Snowcem ,Berger or J&N paint) over a primary coat (total 3 coats) in all heights including cost and conveyance of all materials, all leads and lifts, scaffolding and curing etc., complete.

v. Painting the internal walls with 2 coats of Ready mixed plastic emulsion paint of approved quality and make (Asian ,Berger , ICI , Nerolac , Dulux , Jonson&Nicholson make) over one coat of cement primer paint (total 3 coats). The rate quoted shall include scaffolding, cost and conveyance of all materials, all leads and lifts complete.

vi. Painting and writing names for identification of rooms in Control room/ House with superior quality synthetic enamel paint 2 coats neatly, including cost of paint, brushes, labour charges etc in complete shape as directed by the engineer- in- charge.

1.10.17.1 AIR CONDITIONING SYSTEM:

Air conditioning units for control room and bay kiosks shall be set to maintain the following inside conditions.

DBT 24.4°C±2°C

Air conditioning requirement in Control room building and bay kiosks shall be met using split AC units. Design (heat load) calculation has to be made to estimate the required no. of split AC units for erection in control room. The AC units of high wall type split AC units of 2TR capacity each complete with air cooled outdoor condensing unit having hermetically sealed compressor and high wall type indoor evaporator unit with cordless remote controller shall be provided.

2Nos. AC units of 2 TR capacity shall be installed in each bay kiosk (1 working + 1 stand by). In case of failure of one unit the other unit shall come into service to restore normalcy. Provision shall be made to monitor/control all the AC units through Sub-Station automation system (SAS)

The split AC units will be complete with indoor evaporator unit, outdoor condensing units and cordless remote control units.

Outdoor unit shall comprise of hermetically sealed reciprocating/ rotary compressors mounted on vibration isolators, propeller type axial flow fans and copper tube aluminum finned coils all assembled in a sheet metal casing. The casing and the total unit shall be properly treated and shall be weatherproof type. They shall be compact in size and shall have horizontal discharge of air.

The indoor units shall be high wall type. The indoor unit shall be compact and shall have elegant appearance. They shall have low noise centrifugal blowers driven by special motors and copper tube aluminum finned cooling coils. Removable and washable polypropylene filters shall be provided. They shall be complete with multi function cordless remote control unit with special features like programmable timer, sleep mode and soft dry mode etc.

Ventilation System:
Exhaust fans of propeller type/axial type shall be provided for the rooms which are not air conditioned, complete with suitable drive motors, DOL starters, rain protection cowl with screen, grouting bolts etc. These shall be fed from a local distribution board. The schedule of wall mounted ventilation/exhaust fans are as mentioned below.

Sl. No	Location	Capacity (each)	Static Pr. (mm Hg)
1.	Cable vault	3000	15
2.	MCC room	2000	10
3.	Office room, Aux buildings	1500	5
4.	Store room	1500	5
5.	Toilets	1000	5
6.	Pantry / guest house	500	5

ENVIRONMENT ASPECTS FOR SUBSTATION:

Ground cleaning operations during starting of the construction of substation shall be carried out by manual or mechanical methods only. No chemical method shall be used that may lead to chemical contamination of the site.

CONSTRUCTION OF SEPTIC TANK:

Septic tank of size 2 x 0.9 x 2.3 meters (Inner dimension) is to be constructed with RR walls 450mm wide on all four sides in CM (1:6), CC(1:3:6) with 20 mm HBG metal 230 mm thick at the bottom, providing 75mm thick baffle in RCC 1:2:4 wall as required from the inlet pipe level towards floor of the septic tank and roof slab of 100mm thick in RCC(1:2:4) with 12 to 20 mm HBG metal with an opening of 0.6 x 0.6 meters for manhole. The septic tank is to be provided with 4.5meters long 110 mm dia PVC ventilating pipe with cowl. The outlet from the septic tank should be standard 'T' fitting of glazed earthen wear pipe. The center of the outlet pipe should be about 150mm below the center of the inlet. The floor and sides of the septic tank should be plastered in cement mortar (1:3) 20 mm thick. The thickness of the wall should be 450 mm. The floor of the tank should slope at 1 in 30 towards one end to facilitate cleaning of deposits and the manhole should be above this. The reinforcement for the roof slab and baffle wall should be with 12 mm and 6 mm dia M.S rounds at 150mm C/C. The tank should be provided with 0.6 x 0.6 meters size C.I. frame and cover for manhole. The inlet and outlet pipes shall be S.W.G. 101.6mm dia. S.W.G. pipe of 101.6mm dia shall be laid from water closets, wash basin, bath, and urinal to septic tank inclusive of all specials and accessories.

CONSTRUCTION OF MANHOLES:

Manhole of 457.2mmx 457.2mm size up to 914.4mm depth, to be constructed over bed concrete of 1:4:8 with 40 mm HBG metal 100 mm thick, with230 mm thick brick masonry in CM(1:6), and plastered inside with CM (1:3) 12 mm thick. The channels in the manhole should be semicircular in the bottom half and of diameter equal to seven. Above the horizontal diameter, the sides should be extended vertically to the same level as the crown of the outgoing pipes and the top edge suitably rounded off. The manhole is to be provided with 0.45 x 0.45 meter C.I. frame and cover.

1.10.18 Formation of Roads:

WBM ROAD: Providing, laying, spreading and compacting stone aggregates of 63 mm nominal single size to 150 mm compact thickness (in two layers) water bound macadam specification including spreading in uniform thickness, hand packing, rolling with three wheel 80-100 kN static roller/ Vibratory Roller 80-100 kN in stages to proper grade and camber, applying and brooming, crushable screening to fill-up the interstices of coarse aggregate, watering and compacting to the required density Grading 2 as per Technical Specification **Clause 405 MORD**.

Over the 63 mm nominal single size metal surface providing, laying, spreading and compacting stone aggregates of 40 mm Single nominal size to 75mm thick compacted water bound macadam specification including spreading in uniform thickness, hand packing, rolling with three wheel 80-100 kN static roller/ Vibratory Roller 80-100 kN in stages to proper grade and camber, applying and brooming, crushable screening to fill-up the interstices of coarse aggregate, watering and compacting to the required density Grading 3 as per Technical Specification **Clause 405 MORD** including cost and conveyance of all materials to the site and stacking all the materials for pre measurements and excavations and embankment for road width for road formation, labour charges for all operational and incidental items and hire charges for the power roller etc complete.

CC ROAD:

Preparation of Surface: The WBM surface over which CC road is to be laid shall be thoroughly cleaned with brushes and brooms etc. as directed. The base for laying of concrete road shall be free of soft spots and shall be properly drained. The prepared base shall conform to the lines, grades and cross sections as directed. 150 mm thick cement concrete (1:3:6) using 50% of 40 mm HBG metal & 50% of 20 mm HBG metal shall be laid for forming road.

Laying: The use of forms, locations of joints, concrete mixing, transporting placing compaction, curing etc shall be as per clause 1515 of APSS. The joints shall be placed in with ½" thick Mastic pads at the intervals as per the directions of the Engineers- in- charge.

1.10.19 Erection of Gates: Main gates shall be supported on RCC pillars. These shall include necessary anchors, rollers, guides etc. in complete shape. Main gate pillars shall be constructed as per the approved drawing. No. Wicket gate shall be grouted into pillars constructed in brick masonry. After erection of gates they shall be painted with two coats of superior quality enamel paint over a coat of primer

1.10.20 Construction of Compound Wall:

The compound wall shall be constructed as per the approved drawing No. SE/TSS 1/99. All the material including cement, reinforcement steel and barbed wire shall be procured by the contractor. 10 rows of barbed wire 150 mm apart over the compound wall as indicated in the drawing is to be strung. The M.S. Angles to be grouted in compound wall are to be supplied by the contractor himself and fixed at 4.5 meters intervals. Compound wall shall be painting with two coats white washing with Janata cem on plastered surface. During construction of compound wall due to different levels obtained along the boundary, the contractor may have to raise the basement portion of wall as directed by the Engineer-in-charge. The G.I. barbed wire using IOA 12 Gauge shall confirm to IS: 278 -1978 latest of Glidden type (type-B) with line wire and point wire of 2.5 mm dia.

1.10.21 Electrification of Control House:

i) Electrification of the Control House is to be done with flexible copper unsheathed PVC cable with No. 14 SWG GI wire for earth continuity in surface PVC box type casing run over the walls of the Control House. The various sizes of copper wire to be used for wiring is as follows.

   (a) Wiring with 2 of 22/0.30 (1.5 sq.mm) copper wire is to be used for light, bell, fan and exhaust fan.

   (b) Wiring with 2 of 56/0.30(4 sq.mm) flexible copper unsheathed PVC cable shall also be used for mains from distribution Board to Lighting points.

(c) Wiring with 4 of 84/0.3(6.0 sq.mm) flexible copper PVC cable in PVC box type casing with No. 8 SWG G.I wire for earth continuity for run of mains from AC panel to 32 Amps ICTP Main switch.

(d) Wiring with 2 of 56/0.3(4.0 sq.mm) flexible copper PVC cable in PVC Box type casing with earthing clips from Main switch to Distribution Board.

(e) Wiring with 2 of 36/0.3(2.5 sq.mm) flexible copper PVC cable in PVC Box type casing with earthing clips from Distribution Board to 15 Amps 3 pin Power plug.

ii) The work should be carried out in conformity with code of practice for Electrical wiring and fittings in Government Buildings and Indian Standard Specifications. Samples of fittings, switches and all other materials including wire should be got approved by Engineer in charge before use. Holes made in the Walls for fixtures and other switch Boards etc., should be properly filled with cement mortar and patch work should be painted neatly.

1.10.22 COMMON BUILDING MATERIALS Requirements:

The aggregates such as sand, metal shall be obtained from the source as indicated in lead statements. The aggregates both fine and coarse shall comply with the requirements of I.S.456 for concrete and I.S.383 for sand for use in rendering, plastering and mortar except as hereinafter stated and shall be clean, washed and free from dirt. Samples shall be submitted to the Engineer and all aggregates used in the work shall be atleast equal to the approved samples.

FINE AGGREGATE: The fine aggregate for concrete, shall consist of naturally occurring and graded in accordance with the requirements of IS.383 for grading Zone-2 or grading Zone-3 except that no particle shall exceed 3/16 inch. It shall be free from excessive sharpness. Fine aggregate cement mortar and lime mortar and rendering plastering shall comply with IS 383.

COARSE AGGREGATE: Coarse aggregate shall be graded to produce sound concrete and for reinforced concrete shall be such that at least 5% by weight will pass a mesh of a size 1/4 per inch less than the minimum lateral distance between the reinforcing bars or 1/4 inch less than the minimum cover, whichever is smaller.

WATER FOR CONCRETE:

Clean fresh water shall be used for mixing concrete grout and mortar and curing. The water used for mixing and curing shall be free from deleterious matter and acids and alkaline substances in a solution or suspension. Potable water shall generally be used for mixing and curing concrete.

In respect of drinking water, filtration and chlorination by approved means shall be installed as necessary to obtain the required standard. Storage and distribution of potable water shall be such as to prevent contamination.

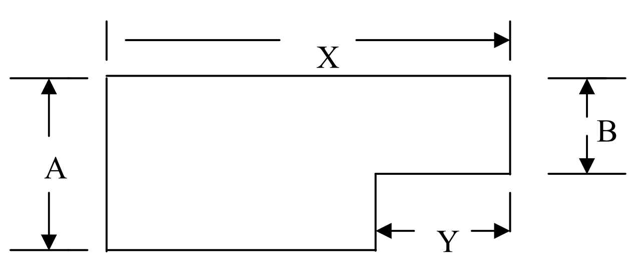
PROCUREMENT OF STEEL, FABRICATION & GALVANISATION:

Steel such as MS angles, plates, Channels and M.S Rounds required for fabrication of structures shall be procured by the contractor. The structures shall be fabricated as per the structural drawings and galvanized. Proto type structure shall be fabricated and shop drawings for all the structures, stub setting templates etc. shall be furnished. Mass fabrication of the structures shall be done after their approval.

DOORS AND WINDOWS

Cold formed M.S. Hollow Door Frames: The Cold formed pressed steel frames shall be manufactured from cold rolled sheet metal of 1.25 mm thickness and of size 105 x 60 mm. The frames shall be thoroughly cleaned. Free of rust, mill scale, dirt, oil etc., by mechanical and chemical means before giving an anticorrosive red oxide primer. The selection of raw material and construction of frame shall be as per the recommendations of Indian Specification I.S.513-1963 and I.S. 4351-1976.The door frame shall be provided with 100mm M.S hinges and along with accessories

- **Material Finish**: The door and frames shall be supplied in red oxide primer painted finish.
- **Tolerances:** Tolerances on thickness and other dimensions of the materials shall be as per I.S. 513 and I.S.4351 latest issued.
- **Packing**: Door frames shall be packed in knockdown conditions ready to be erected at site. Each frame shall be packed separately along with corresponding accessories in a gunny wrapping.
- Section dimensions of the M.S cold formed Hollow door frames X=105mm, Y=30mm, A=60mm, B=45mm Thickness of MS steel used shall be 1.25 mm as per I.S.4351-1976.



ACCESSORIES:

The following accessories shall be supplied along with each door frame.

i) Built in (welded) hinges of 100 mm size--3Nos. for single shutter door and 6 Nos. for double shutter door.
ii) Hold fasts -- 6 (six) Nos.
iii) Bottom tie of 10 mm square rod -- 1 (one) No.
iv) Fastening bolts and nuts -- 8(eight) Nos.
v) Stiffeners -- 4 Nos on either side and 3 Nos on top at suitable intervals.

Shutters: Shutter shall be of block board solid core flush type commercial make conforming to I.S. 2202(part - 1) 1973 Thickness shall be 30 mm. Acceptance tests will be done on the doors as per above ISS.

Sizes of Shutters for Doors: The over all sizes for doors shall be mentioned in the schedule. The actual sizes of doors shutters shall be manufactured duly deducting 2 x 75 mm width wise and 1 x 75 mm length wise towards provision of MS door frames (No MS frame for the bottom threshold)

Accessories: The following accessories shall be supplied along with each Door.

i)	Tower Bolt	:	3 Nos. for double as per the note.
ii)	Tower bolts	:	2 Nos. for single leaf in specification.
iii)	Al drops	:	1 No.
iv)	Stopper	:	2 Nos. for double leaf.
v)	Stopper	:	1 No. for single
vi)	Handle	:	1 No.

Aluminum Windows, Ventilators and Fittings:

The aluminum windows, ventilators shall conform to relevant IS specifications. All windows, ventilators, louvers etc., shall be of sizes as specified and conform to the description in the respective item of work. All fixtures and fittings necessary for the satisfactory operation of the windows and ventilators shall be provided. The windows and ventilators shall be obtained from an approved manufacturer fabricated at site or specific approval of such purchase and fabrication shall be obtained beforehand. Sample shall also be totally approved before further manufacture starts, unless this is waived in writing by the engineer. The contractor shall obtain windows with friction hinges in place of windows with pigsties if so directed by the engineer. For centre hung and top hinge ventilators suitable spring catch/pulley and chord arrangement shall be provided for facility of opening. Whenever fly mesh over windows has been called for, they shall be fixed on the window and suitable lever type or roto type arrangement shall be provided for opening or closing of the glazed panels from inside. Prior approval of the engineer shall be taken before order is placed with manufacturer. Aluminum safety grills shall be provided as directed by Engineer-in-charge.

Where aluminum windows are specified to be air tight, necessary padding material such as rubber, felt or any other approved material should be provided.

Glazed windows, louvers and ventilators shall be provided with either clear or pin headed glass 5 mm thick (as may be directed during execution), which shall be free from all blemishes and shall conform to IS: 1761.

Aluminum Doors: The door shall be built from anodized aluminum sections. The finished work shall be plumb, in line and free from corrugation, depression of wavy appearance. Field connections of all works may be made with concealed screws or approved type of fasteners or may be welded as approved by the engineer. All glazing shall be of high approved quality.

Partitions: The partition shall be hollow aluminium section of 63x38 mm.16 gauge (with in filled timber of silver oak) frame work, fully glazed or as per drawing Glazing shall be fixed to the frame work with anodized aluminium sections and performed rubber beading all around.

SANITARY FITTINGS:

Sanitary fittings shall be of porcelain type in the toilets of the control room and ceramic tiles flooring in toilets.

Sanitary fittings to be provided are of standard make conforming to ISI specification and of approved colour. Following is the list of fittings to be provided in the toilets.

1.	Water closet with flushing tank	}	
2.	Wash Hand Basin	}	as per schedule
3.	Flat back urinal	}	

All the above fittings are properly fixed in the flooring and walls with suitable means and neatly finished. Plumbing work for water line for toilets and bath rooms and wash hand basin shall be done with 15mm dia. G.I.Pipe. Main line from Syntex tank shall be with 20mm dia. G.I.Pipe line. W.C. line shall be laid with C.I. waste pipe line and connected to the main line in the man holes.

Bath room water and waste water from wash hand basin are taken separately and connected into a man hole located out side and later on connected to the pipe line to the septic tank. All the pipe joints are neatly finished with cement paste and buried in the flooring, with necessary accessories like '0'traps, gully traps and necessary CI/SWG bends. Care shall be taken to see that joints before covering with earth / concrete are tested for leakage and rectification carried out, if any and closed.

The ceramic tiles of approved colour and make should be neatly fixed in toilets up to 5feet level on the walls and also on flooring over a bed cement paste on the concrete. Care shall be taken while laying the ceramic tiles on flooring that proper slopes are maintained to avoid stagnation of water. The adequate down ward slope shall be maintained while laying flooring tiles to drain out water to the gully traps. It is desirable to lay flooring tiles with mat finish k type to avoid slippery surface.

Anti-weed Treatment:

For safeguarding the switch yard against the growth of weeds, weedicides (such as Biodex-C, Grammaxene, Fernoxene or equivalent products) should be mixed with water in accordance with the manufacturer's instruction (3 liters of weedicide mixed with 200 liters of water is a standard practice) and this solution should be spread over the earth with a chemical spraying pump on the ground.

The anti weed treatment should be given only after moisture content of the soil is brought below 29%. After completion of spraying of the anti-weed chemicals and before taking up the next activity, a period of 24 hours should be allowed for penetration of the chemical in to the soil.

Anti-Termite treatment: Required to set up a chemical barrier against attack by subterranean termites in the areas like cable trenches etc. This work shall in general, be executed as specified in IS: 6313 part -II and as per approved specification of the agency having special know-how for the job. All necessary work to ensure uniform distribution and proper penetration of treating solution shall be done. Soil treatment shall not be done when it is raining or when the soil is wet with rain or sub soil water. Once formed, the treated soil barrier shall not be distributed.

Chemicals and rate of application: Any of the following chemicals (conforming to relevant Indian standards) in water emulsion shall be applied by pressure pumps uniformly over the area treated.

Chemicals	Concentration / weight percent
Dieldrin (IS: 1052-1962)	0.5
Aldrin (IS: 1306-1958)	0.5
Chlordane (IS: 2863-1964)	1.0
Heptachlor	0.5

Treatment of Cable Trenches: Cable trenches may be fully enveloped by the chemical barrier by treating with chemicals at the rate of 15 liters /sqm. on vertical surfaces of excavated trench walls and bottom surfaces at the rate of 5 liters /sqm. Chemical treatment shall be done in stages following the compaction of earth in layers. The treatment shall be carried out after the ramming operation is done by padding the earth at 150mm.Centres close to the wall surface and spraying the chemicals in the specified dose.

Permanent Storm Water Drainage System: Rain water PVC pipes shall be adequately provided to drain out the rain water without over flow. Minimum 110mm dia pipe, 4kg/sq.cm. pressure shall be provided to drain out 40 sqm of roof surface area. All vertical down spout pipes and pipe fittings shall run inside the walls .All vertical down spout pipes shall be connected to water proof roofing by means of lead funnels, protected at the out side by a cover net of brass wire or by 90 deg. Bends (elbow).

<u>PVC Pipes:</u> PVC Pipes where called for shall be either unplasticised PVC pipes or high density polyethylene pipes supplied with appropriate fittings.

<u>Pipes and Fittings</u>: The pipes and fittings shall be of 10 kgs per Sq.m. pressure class. The plastic pipes are to be handled with care and stored in a place protected from sun. Plastic pipes and fittings shall confirm to ISI: 4984.

1.11 PILE FOUNDATIONS

Bored Piles: RCC cast in SITU:

Installation depth shall be related to the ‘top of rock. Identification of the top of rock shall be on the basis of visual assessment of the pile spoil and on boring conditions. The horizon depth shall be confirmed, when encountered, by visual examination of a standard penetration test sample in accordance with IS-2131, 198, taken from each pile bore.

The piles shall be socketted into hard rock strata up to a depth of 1000 mm. The length of socketting shall be adjusted after test pile is cast and tested and /or pile spoil.

Setting out: Setting out shall be carried out from the main grid lines of the proposed structures. Immediately before installation of the pile, the pile position shall be marked with suitable identification of pins or markers.

Position: For a pile head cut off, at or above ground level, the maximum permitted deviation of the pile head cut off center from the center point, shown on the setting out drawing, shall be 50 mm in any direction. For a pile head cut off below ground level an additional tolerance will be permitted on the assumption that the pile head has been within tolerance, if the cut off had been at ground level.

Verticality: The maximum permitted deviation of the finished pile from the vertical shall be 1 in 100.

FORCIBLE CORRECTIONS: Forcible corrections to concrete piles shall not be permitted.

PILING PROGRAMME: The contractor shall inform the Engineer each day of the programme of piling for the following day and shall give adequate notice of his intention to work outside normal hours and/or at week ends.

DAMAGE TO PILES:

The contractor shall ensure that damage does not occur to completed piles.

RECORDS:

The following records concerning pile foundations shall be prepared and made available.

a) Contract reference, pile location type and reference

b) Specified cut off level, Ground level at commencement of pile installation/Working level (if difference from ground level)

c) Diameter of pile. Date and time of boring, Date and time of concreting

d) Levels at which seepages encountered

e) Bottom level and diameter of temporary casing

f) Level of top of rock together with details of sampling (level, length, type, description)

g) Pile toe level, Top of finished concrete level

h) Level of water or drilling fluid at commencement of placing concrete

i) Details of drilling fluid including specific gravity measurement as directed

j) Details of pile base cleaning operations

k) Full details of permanent casing, Length and details of reinforcement placed

l) Volume of concrete installed in pile; Method of placing concrete; Concrete mix and control test results

<u>Construction of Piles</u>: Sequence shall be selected to avoid piles being bored close to other recently constructed piles.
Drilling fluid (Bentonite) shall be in accordance with clause A 3.1 of IS 2911 Part-I, Section-II. The equipment and accessories required for construction of bored piles shall be of a standard type.

Boring: While boring in cohesion less deposits below the water table, care shall be taken to avoid the inflow of water and soil into the bore hole by adding water and maintaining a level potentially above the standing water level. If the hole is unstable during boring either temporary casing or substitution of drilling fluid for the water shall be used to ensure stability. In cohesive soils, water shall not be added for boring purposes.

Temporary casing shall be advanced with the boring tools, and excavation shall not be carried out below the toe of the casing.

Temporary casings shall be free from significant distortion. They shall be of uniform cross section throughout each continuous length. They shall be free from internal projections and encrusted concrete which might prevent the formation of piles.

Stability of Pile excavation using Bentonite Slurry or equivalent: The level of the fluid in the excavation shall be maintained so that the fluid pressure always exceeds the pressures exerted by the soils and external ground water, and an adequate temporary casing shall be used in conjunction with the method to ensure stability of the strata near ground level in the base and shall be maintained at a level not less than 1 mtr. above the equilibrium level of the ground water. During boring the consistency of the drilling fluid shall be controlled in accordance with IS-2911 part-I, section-II.

Spillage and disposal of Drilling Fluid: All reasonable steps shall be taken to prevent the spillage of bentonite suspension on the site in areas outside the immediate vicinity of boring. Discarded bentonite shall be removed from the site immediately. Any disposal of bentonite shall comply with the regulation of the local controlling authority.

Pumping from Bore holes: Pumping from bore hole shall not generally be done. However small quantities of accumulated water may be pumped from dry bore for cleaning out purposes prior to concreting.

Continuity of Construction: Boring of any pile once commenced shall be completed and concreted on the same working day.

Cleanliness of Base Piles: On completion of boring, loose, disturbed or remoulded soil and rock shall be removed from the base of the pile.

Reinforcement of Pile: The main longitudinal reinforcing bars in piles shall be in one continuous length unless otherwise approved. In long piles, joints will be permitted in main longitudinal bars but these shall be kept to a minimum. Joints in adjacent bars shall be staggered at least 1m apart along the length of the pile. Lapped joints shall be staggered by at least 1.3 times the lap length. Joints in reinforcement shall be such that the full strength of the bar is effective across the joint and the reinforcement cage is of sound construction for installation in the pile bore.

Longitudinal reinforcement shall be provided for the full length of the pile and shall extend above pile cut-off level as shown in drawings. Longitudinal reinforcement shall be formed into a rigid cage to resist deformation during handling and installation if necessary by the use of additional reinforcement subject to the approval of the Engineer.

Lap or splice joints shall be provided with sufficient link bars to resist eccentric forces. Minimum cover to main reinforcement in the pile shaft shall be 75 mm and should be subject to approval of Engineer.

General Concreting: The method of placing and the workability of the concrete shall be such that a continuous monolithic concrete shaft of the full cross section is formed. Mechanical vibrators shall not be used to compact concrete.

Concrete Mix Parameters: Concrete in piles shall be of grade M15 except that its consistency shall be compatible with the particular method of pile installation proposed. The slump of the concrete shall range between 100 and 180 mm depending on the manner of concreting in accordance with clause 6.34 of IS 2911 Part I

The concrete shall be placed in such a manner that segregation does not occur. Concrete to be placed below water or drilling fluid shall be placed by tremie or other approved method and shall not be discharged freely into water for drilling mud. Where tremie placing is to be used it shall be in accordance with clause 7.5 of IS 2911 Part I. Section 2. Where concrete is placed through drilling mud, the specific gravity of the mud at the bottom of the boring shall not exceed 1.2 immediate prior to placing concrete. The amount of mud to be sampled should be adequate to suit the test apparatus (generally ½ to 1 litre is adequate.)

Concrete shall be cast to a minimum of 500 mm above the cut off level or local ground water level whichever is the higher.

Extraction of Casing: The method of extracting the temporary casing shall be such that the concrete in the casing does not lift and maintains its workability so that it flows freely against the pile bore. Utmost care shall be exercised in maintaining an adequate head of concrete above the bottom of the casing until concreting is completed so as to prevent the inflow of soil and/or water into the bore.

Temporary Backfilling: Sections of empty hole remaining above the head of the pile shall be temporarily backfilled with sand of a distinctive colour prior to excavation for pile cap construction.

Load Tests on Pile: The load tests shall be carried out on the pile after 28 days after the installation of the pile in position. The load tests shall be carried out on single pile.

Method of testing: The test shall be conducted as per ISS 2911 (Part I – Para D4 Cyclic – loading tests) except as described herein.

The test load to be applied on the loading platform supported on pile shall be twice the proposed safe designed load of the pile. The test load shall be applied in 7 increments equal to ¼, ½, ¾ 1, 1 ¼ , 1 ¾, and 2 times the proposed working load. Readings of the settlement and rebounds shall be reckoned against a constant elevation bench mark and shall be recorded to 1/30th of a cm. for each increment or decrement of load. After the proposed work load has been applied and for each increment thereafter the test load shall remain in place until there is no settlement in a two hour period. The final test load shall remain in place until the settlement does not exceed 1/30th of a cm. in 48 hours. The final test loading shall be removed in decrements not exceeding 1/4th of the total test load with intervals of not less than 1 hour rebound shall be recorded after each decrement is removed and the final rebound shall be recorded 24 hours after the entire test load has been removed.

Number of Tests: Not less than 2 (two) piles should be subjected to load tests for 100 Nos. of piles installed. The piles to be tested shall be selected from separate groups or as indicated by the Engineer. Further tests, if necessary shall be made on the basis of the results of load tests. The test piles shall be used for foundation of the structure. Net settlement of the top of pile after the conduct of cyclic tests with the maximum load of twice the design load shall not be greater than 12 mm

Pull out Test: A trial pile shall be installed in such a location as directed by the Engineer, where it does not interfere with working piles. The specification and details of the trial pile shall be same as for working pile. An outer casing shall be provided such that the trial pile has a clearance of at least 20mm alround. The object of the test is to determine the strength of socketting provided for in the drawing and adjustments, if any required. The test shall be carried out to failure point.

Method of Measurement: Forming pile shaft shall be measured in running metres from the approved toe level to cut-off level for each diameter of pile.

Empty boring shall be measured in running metres from working ground level to cut-off level for each diameter of pile.

Concrete pile shaft shall be measured in running metres from the approved toe level to cut-off level for each diameter of pile.

Reinforcement including projection above cut-off level is measured by weight in tonnes. The weight shall be arrived at my multiplying the length, shown on the drawings or otherwise directed by the Engineer – in charge by the sectional weights.

Trial piles, reactions piles, rock chiseling if any shall be measured and 'clubbed together' with works piles, although tests are enumerated separately.

IS CODES (LATEST EDITIONS): Important relevant IS in this section.

IS 2911 – Part I Section	:	Concrete piles section bored cast in situ piles.
IS 2911 – Part IV	:	Load test on piles.
IS 2131	:	Method for standard penetration test for soils

UNDER REAMED PILES.

The execution of under reamed pile foundation shall conform to IS code 2911 (Part III) 1978 and specification given in building Digest No. 56 of Central Building Research Institute Roorkee.

The depths of piles are tentatively assessed with double bulb. The depths are likely to be increased or decreased based on site conditions.

1.12 Field Quality Plan:

1.12.1 Civil works: In respect of foundations, foundation materials, earth work, roads etc, field quality plan for transmission lines explained earlier, may be referred.

Field quality plan for structures, electrical equipment and other related materials& works in the substations is given here under.

Contractor and Transco's project supervisor should ensure that all materials received at site are inspected and cleared by the purchase unit.

On receipt of the materials at site, packing cases of all the materials should be checked for any damages, by the contractor. Quantity of materials received as per the approved drawings to be checked and shortages if any to be reported. After opening the package, check for internal damages, cracks, deformations/ deep scratches etc. to the materials, damage to any porcelain parts, cementing, sealing gaskets, terminal blocks, space heaters etc, should be done. All oil filled equipment should be checked for oil leakages. Ensure proper handling and storage of the packages as per the directions given on the package or as given in the drawings/bill of materials/packing list.

All the checks are to be made by the contractor and random check done by AE/AEE/EE

Storage of materials: Check that all assemblies/components are properly packed in their original or similar packing with suitable clamps, brace and polythene covers as required. All the packages are stored in a ventilated and covered storage. All small fragile items are stored in proper containers at safe locations to avoid any damage. These shall be stored as per the directions given in the Instruction Manual. Necessary identification marks or tags should be kept intact for easy identification. Items shall be stored in an orderly manner to facilitate easy removal from storage site as and when required without causing any damage. Heavy packages shall not be stacked one above the other. There should not be any sudden jerks or impact on the packages while handling .Packages should not be dropped on the ground.

Following specific checks on the materials noted against each, in addition to the general checks mentioned above shall be carried out.

1.12.2 Main and Auxiliary Structure:

Receipt of required quantity of hardware (bolts&nuts, washers, foundation bolts) and their dimensions and suitability as per drawings.

Structures are clean, free from sharp kinks, bends etc. galvanizing of steel structures and any kind of defects on galvanized surfaces.

Necessary identification marks on each of the structure members for matching as per the approved drawings.

Structures are stacked to avoid direct contact with soil or water and to avoid white rust cover.

To be stored section wise, size wise for identification and easy removal.

Check for centre to centre distance of foundation bolts, finished ground level setting, grouting works.

Check for proper lifting arrangement, verticality, leveling and alignment, tightness of bolts and structure earthing.

1.12.3 Current and Voltage Transformers:

Name plate for required rating and design as per the approved drawings.

Marking of proper terminals, identification marks for primary and secondary terminals, neutral terminal in case of CVT.

Nitrogen and oil leakage.

To be stored in a place protected from dirt, dust, ingress of moisture and stored vertically as per the manufacturer’s instructions.

Ensure lifting of CT/VT using lifting lugs only. Check for orientation of incoming and outgoing.

Erection as per instruction Manual. Check for tightening of all bolts& nuts, and level with respect to Aluminum tube.

Check earthing terminal for connection to earth at correct location. In case of CVT ensure earthing of HF connection if it is not utilized.

Check for oil levels up to the mark.

1.12.4 Isolators:

Any damage to galvanized parts and galvanization defects.

All current carrying parts, insulators and operating mechanism are to be stored to protect from dirt and moisture as per manufacturer's instructions.

Structures are erected as per approved drawing. Foundation bolts are tightened properly.

Base shall be installed over the two structure columns.

Installation of rotary assembly on the base.

Support insulators shall be installed properly.

Lever plates to be installed as per manufacturer's instruction Manual.

Cross tandem pipes are coupled correctly.

Operating mechanism should be correctly assembled and erected at required height and fixed at correct location as shown in the drawing.

Adequate tightening of nuts with torque wrench, to be ensured.

Check connections to the isolator.

1.12.5 Lightning Arrester:

Ensure ratings as per the order.

Surge counters, corona rings and supports are stored indoors in a safe manner.

Arrester should be erected by/handled with chain pulley and Nylon rope round the porcelain .

For arresters provided with insulating base, the base must be bolted to the structure.

Surge monitor should be mounted as per drawing at a convenient height and should be connected in parallel to the insulating base.

Care shall be taken to avoid corona rings striking the porcelain.

1.12.6 Bay Marshalling Box:

Terminal blocks/terminals are not damaged

Necessary cable glands have been received/fitted as per the approved drawings and the box is vermin proof.

Doors are operating and are properly lockable and keys are available.

Any glass (fragile) items are broken/missing. Relays, instruments, gauges, meters etc. are in their position.

1.12.7.Clamps and connectors: General checks as indicated above.

1.12.8 Insulators&Insulator Hardware including bus Post Type Insulator:

Receipt of necessary items like hardware, corona ring etc. as per the drawing.

Properly repacked to avoid any damage before sending for storage.

Install the insulator stacks over the columns and secure the bolts properly.

Check for clearances of insulators before and after erection

1.12.9 Earth wire, Conductor and Cables:

Rolling of drums in proper direction as per the mark indicated on the drums at the time of storage or erection.

1.12.10 IPS Aluminum Tubes:

Measure ID&OD of the Aluminum tube to check the thickness as per specification

Properly stacked to avoid direct contact with soil or water (Follow manufacturer's instructions if any).

1.12.11 Circuit Breakers:

All components of CB received as per packing list/bill of materials

Check for any gas leakage/oil leakage/smell.

Shall be stored as per manufacturer's instructions and away from inflammable material.

Control cubicle should be stored duly covering with dry and covered plates.

Ensure completeness of erection of CB as per drawing and Manual in correct phase sequence and location with proper tools.

Check for all wire and bus connection and tightness of bellow connections.

Check for all cable terminations and electrical continuity

After filling with SF6 gas and air at required pressures, check for leakages thoroughly.

Check for connection between individual pole unit and control unit.

1.12.12 Control& Relay Panels and LT Switch gear:

Proper mounting of all required mountings (Ref: approved drawing, specification, bill of materials, packing list)

Proper operation of doors and availability of keys.

All indicating lamps, fuses/MCBs, alarms, terminals including spare terminals, panel wiring as per the approved drawings, bill of materials.

Shall be stored above ground in vertical position under cover shed, protecting from rain, dust and fire.

Ensure foundation/ground is level. Panels should be in one level and line. Should be bolted to the seating channels properly.

Check for the arrangement for cable entry and vermin proof arrangement.

1.12.13 Checks before erection (Pre-erection checks)

Before taking up erection of structures/equipment, all relevant drawings, instruction/erection manuals should be made available at site.

After assembly of sub-components of an equipment ensure that all insulators and conductors are thoroughly cleaned, all terminals are smooth and free from dirt, dents and paints etc.

Ensure that ends of aluminum tubes, earth conductors etc. which are to be welded are properly cleaned and are free from paints.

All welding materials/equipments, electrodes, filler wire, welding machine are made available at site. Electrodes used shall bear ISI mark. All protective and safety measures shall be ensured while welding. (Reference to Specification, approved welding procedure may be made). Qualified welder should be employed for all welding works.

All tools and tackles and instruments required for erection shall be available and in working condition.

1.12.14 Civil works: Reference (Datum) levels and co-ordinates should be checked. Referred centre lines of complete switchyard installation are permanently and clearly marked to the given dimensions.

Check that various openings/pockets, embedments and foundation blocks have been provided at required locations to the given dimensions in the lay out/ foundation drawing.

Check that various foundation bolts that are to be grouted are done so at proper location to the given dimensions as per the drawing and as per the design. Correctness of foundation bolt size and its projection above ground level should be checked. Wherever possible foundation bolts are to be welded to main reinforcement steel. Any deviations noticed in the civil works are to be recorded in writing and reported to competent authority (EE/SE/CE Civil) and remedial measures taken before commencement of erection.

All equipment are placed/erected in position, matching with the dimensions and level given in the lay out.

Check the earthing scheme and ensure that necessary points have been brought to necessary working level from station earth for equipment earthing purpose at required locations.

(Reference to approved switchyard layout drawing, foundation drawing station earthing layout and equipment earthing details may be made).

1.12.15 Checks during erection:

Check that pre-layout survey has been carried out and necessary modification done, to verify and achieve the position of various equipments to the connected levels and position of foundation bolts, pockets and cut-outs.

Check that structures are erected with proper alignment and specified levels are maintained. Structures shall be properly tightened /grouted only after alignment.

Check that associate equipments are placed in their proper position during erection.

Check that clearances between phases, phase to earth are conforming to design/standard values.

Check that CTs are erected strictly as per the layout drawing and in correct order to see that polarity is correct. Secondary of CTs shall remain shorted until they are connected to the instruments/relays. Oil levels shall be checked for level marked in the gauge.

Check that earthing of various equipments, structures etc. are done as per approved earthing drawing.

(Reference to approved layout and foundation drawings, general arrangement drawing, manufacturers' instruction manuals)

1.12.16 Stringing of Main Bus-bars:

Ensure providing correct insulator stinging with hardware mounted.

Check for tension for sag of strung busbar.

Check for torque values while tightening clamps of conductors.

Check for electrical clearances.

1.12.17 Illumination System:

Check the conduit fixing, tightness of bolts, glanding, dressing, electrical wiring continuity, and proper earthing .

Check for correct rating of lamps and sockets and their correct location as per drawing and their proper fixing.

Conduct all operational tests on lighting fixtures with supply voltage and check the correctness and working of the protective devices (fuses, MCBs, no fuse breakers etc).

1.12.18 Earthing System:

Check for the routing, bending of MS/GI earth flats, MS rods, for quality in welding at joints, equipment, Steel structures etc. Check for the tightness of all bolts.

Check the depth of earth pits and dimensions as per drawing. Check for the addition of salt and coke/ bentonite powder or any other chemicals as per specification in case of a treated pit. Check the Masonry work, treatment of welded joints etc.

Check the continuity of earth, between individual equipment earth to main earthing system. Measure earth resistance values of individual electrodes.

1.12.19 Aluminum Tube:

Remove the scratches on the Al.tube by polishing.

Ensure proper alignment of Aluminum tube, and correct length of Al.tube.

Conduct Dye penetration test ,visual MV drop test and radiography tests on welded joints to check the quality.

1.12.20 Cables, Cable support/tray and route:

Check the cable support/tray and route and ensure that no sharp objects are available in the cable route.

Check for bend radius, for cable tags, proper earthing of cable trench/tray.

Make sure that proper gradient is maintained in the cable trench.

Wherever cable trenches are not provided, ensure proper burial of cables in ground, duly providing markers at regular intervals.

All the checks indicated above right from receipt of materials to storage, handling, pre erection and erection stages should be done by the contractor on 100% materials and to be counter checked and reviewed by the officers of APTransco at random.

Damages or shortages are to be rectified/replaced by the contractor as instructed by Transco as per provisions of contract.

After erection, required pre-commissioning tests on various equipment shall be got done by the contractor/manufacturer or by Transco as per the contract provisions. Various pre-commissioning tests to be done are explained in the chapter on Testing& Commissioning of Transmission Projects. A record of test results of all tests together with reference values (factory test results) shall be prepared by the construction unit in charge of the project, which should be reviewed and approved by the Project Manager (EE/SE, construction) before commissioning.

1.13 Quality Control:

Contractor shall establish and maintain quality control for different items of work and materials as may be directed by the Engineer to assure compliance with contract requirements and maintain and submit to the Engineer records of the same. Field Quality Assurance Plan for ensuring the quality at various stages during execution of works shall be prepared and shall be binding on both the contractor and project executing unit.

Copies of records and tests for the items noted in the quality plan, as well as, records of corrective action taken shall be submitted to the Engineer for approval as may be desired.

Field officers in charge of execution of project (both electrical and civil engineers) are responsible for quality control at various stages of project execution, as they oversee the works on a regular basis.

The Quality Control wing at Headquarters under the Joint Managing Director (Vigilance and Security) will conduct quality control checks at random while carrying out inspections of construction of all new EHV substations and lines. Field construction units should prepare in advance, weekly programme for execution of project works in consultation with the contractor and intimate the same to the quality control wing, who in turn would arrange for inspection of various works as directed by JMD (V&S).

Observations of Quality Control wing, made with reference to specifications and Quality Assurance Plan/Field Quality Plan during the inspections will be recorded in the Prescribed Form. This form shall be signed by the field officers, contractor or his representative, and by the Engineer from QC unit and a copy of the same shall be issued to the field Engineer and the contractor at site for taking action on the observations made and to send a report on action taken on the remarks.

The detailed inspection reports of QC wing will be sent to concerned Executive Engineer, Chief Engineer, with copies to JMD (Vigilance & Security) and Technical Directors concerned.

Action taken reports received from the field construction units will be consolidated by QC unit and put up for review by JMD (V&S).

QC remarks and the field reports will also be periodically reviewed by the CMD, JMD (V&S) and the technical Directors once in a quarter.

1.13.1 Penalties to be imposed for deficiencies in quality of works:

During execution of works, if any deficiency in quality of works is found in deviation to the specification / Agreement, penalty shall be levied for different nature of deficiencies as mentioned below under different categories.

Category I: Not using (i) prescribed shoring, shuttering and dewatering equipment, (ii) measurement boxes, (iii) Form boxes for different types of foundations and steel measuring boxes, (iv) not providing adequate number of chairs to the steel reinforcements, (v) not carrying out back filling and compaction of the foundation pits in layers and leveling the tower footings properly, (vi) not ensuring that the excavated earth is dumped at least 2 meters away from the pit etc., and (vii) not providing copings to the tower legs / stubs,(viii) not providing water tanker, Earth rammers/Earth vibrators.

Category II: Use of reinforcement steel without ISI mark, not using vibrators for effective consolidation of the concrete during foundation works, not using proper templates for firmly keeping the stubs in position when templates are supplied by the contractor & improper fixing of stubs, non ensuring of tower verticality, use of rusted stubs and tower parts if supply is by the contractor, non painting of butt joints and rusted stubs with zinc rich paint immediately after erection of the towers & stringing, non fixing of earth flat to the stub, non deployment of technical personnel for supervision of works by the contractor. Also not fixing of vibration dampers firmly, repair sleeves wherever necessary, not properly fixing of arcing horns both tower side and line side and bird guards etc., as per specification.

Category III: Use of improper grade / quality of raw material like H.B.G. metal, water and sand for concreting, using clogged and / or lump / clotted cement for concreting, not ensuring proper curing for foundation concrete, not ensuring that all the members of the tower are placed in position and firmly fixed with bolts and nuts immediately after erection of tower, not ensuring that Half round seam welding of the nuts before stringing of the line.

For the deficiencies in the quality of works noticed by the engineer, penalties should be levied at the rates indicated below for each category and for repetition of deficiency.

Category type	First instance(Rs)	Second instance (Rs)	Third instance (Rs)
Category I	5,000 /-	10,000/-	15,000 /-
Category II	7,500 /-	15,000/-	22,500 /-
Category III	10,000 /-	20,000/-	30,000 /-

Penalty for quality lapses on various aspects, as indicated above, will be levied accordingly as directed by CMD in the review meeting.

Repeated violations of quality will entail in Blacklist/Debar of the default contracting Agency.

It is mandatory to test the construction materials before commencement of work. The QC wing also shall collect samples of construction materials at random for testing the same at Standard Laboratories. If the samples fail to fulfill the test results as per Standards, action shall be taken to make good the loss sustained.

The Quality Assurance Plans (QAP) and Field Quality Plans (FQP) shall be reviewed periodically and updated taking into consideration any amendments/modifications to National and International Standards and Codes and Standard practices in TRANSCO.

1.13.2 Accountability of Field Officers in charge of Works:

Site Order Book shall be maintained at all Work Sites to record the instructions of field officers to the contractors in respect of works. This Book shall be signed by both the Field Officers and the Contractor or his representative in token of acknowledgement for compliance. This shall be reviewed by all Senior Officers visiting the work spots during their inspection.

The material / work shall be in conformity with the specification.

Marking of date of concreting, type of tower, classification of foundation on the stub after completion of foundation casting shall be mandatory.

1.13.3 Statutory Inspection:

After completion of the substation works, the contractor shall carryout final checking of all the works done as per the contract to make sure the works are completed duly maintaining the quality as per the specification. All the required tests on civil and electrical installations in the scope of contractor shall be conducted and test reports furnished to the SE Construction for approval.

The EE, Construction shall get all the equipment tested for proper installation and operation in accordance with the manufacturer’s recommendations.

All the equipment particulars as per the nameplate and the particulars of lines to be energized from the newly constructed substation such as voltage and length of the line, configuration, size and no. of conductors employed, details of equipment connected at the other end of the line etc. shall be furnished to the CE/Power Systems to conduct necessary studies and issue the relay settings including the CT and VT ratios to be adopted. The EE in charge shall arrange to ensure installation of communication facility (PLCC/Optic Fibre etc) through the telecommunication wing before completing the substation works. The relays shall be got tested by MRT wing with the approved settings to ensure proper operation of protection. Services of the manufacturers shall be utilized wherever stipulated in the tenders depending on the need.

The EE/SE Construction shall arrange to furnish the following documents to the SE O&M (TL&SS):

- Structural and layout drawings of the substation
- All drawings and details related to control room, other buildings, fire protection systems, Diesel Generator systems, AC and DC distributions, water supply arrangement etc
- All drawings, details and instruction manuals supplied by the manufacturers for all the equipment installed in the substation
- Details about the earthing provided in the station together with the earthing layout drawings.
- Cable schedules giving full details of the inter connections made between the equipment in the switch yard and the control room
- Approved relay settings communicated by the CE Power systems

The SE (O&M) will arrange for inspection of all the civil works and all electrical and miscellaneous works done by the contractor in line with the specification to ensure no omissions at any stage. Observations made by the SE and the remarks if any communicated shall be complied with by the Construction unit and the contractor before energizing the substation.

The SE (O&M) shall arrange for testing the relays with the approved settings to ensure correct operation and arrange for conducting pre-commissioning tests on all the equipment. Communication facilities available both departmental and P&T shall be checked for normal operation.

After ensuring that every thing has been checked and found correct, the substation shall be idle charged duly informing SE Grid Operation(Load Despatch Centre) and under his directions.

1.14 Safety Requirements in construction of Transmission Lines & Substations

Safety shall form an integral part of work processes to ensure safety for employees including employees of contractors and sub-contractors as well as visitors.

Provisions relating to Transco:- A sound and scientific safety management system should be set up which shall include:

a) Formulation of a written statement of policy in respect of safety and health of employees.

b) Defining and documenting responsibilities for all levels of functionaries to carry out safety related activities including responsibilities of the contractors.

c) Preparing detailed Safety Manual complying with statutory requirements, manufacturers' recommendations, BIS and any other relevant standards and codes.

d) Establishing procedures to identify hazards that could give rise to the potential of injury health impairment or death and measures to control impact of such hazards.

e) Providing adequate human, physical and financial resources to implement the safety management system.

f) Providing safe working environment and evolving framework for occupational safety and health.

g) Providing and maintaining medical facilities.

h) Providing adequate training to all employees to make them aware of safety related issues.

i) Establishing system for accident reporting, analysis, investigation and implementation of recommendations.

j) Establishing system for proper communication, documentation and record management in relation to occupational safety and health.

k) Filing periodic and other returns to the statutory bodies as required under various Acts and Rules within stipulated time.

l) Formulating emergency management plan for quickly and effectively dealing with probable emergencies that may arise on site as well as off-site.

m) Establishing methodology for internal and external audit of safety management system.

n) Establishing system for periodic monitoring and review of safety system by Management.

o) Overseeing the safety performance of the contractors.

Detailed site specific safety manuals should be prepared. However common safety manuals may be prepared for similar installations. Safety Manuals shall be prepared for construction of Transmission Lines and Substations and for Operation& Maintenance of Lines & Substations.

1.14.1 Provisions relating to Contractor:

Transco shall incorporate requisite safety provisions in the contract document which are required to be complied by the contractor's personnel during execution of contract to facilitate safe working during execution of works.

Contractor shall observe safety requirements as laid down in the contract as well as comply with statutory requirements as provided in the existing Acts/Rules. In case of sub-contracts, it shall be the responsibility of main contractor that all safety requirements are followed by the employees/staff of the sub-contractors.

One of the employees of the contractor shall act as safety coordinator, who will liaison with safety officer on matters relating to safety.

Contractor shall be responsible for non-compliance of any of the safety measures, implications, injuries, fatalities and compensation arising out of such situations or incidents.

In case of any accident, contractor shall immediately submit a statement of such accidents to the department and the safety officer concerned for the project showing the details of accident, any injury /casualties, extent of property damage and remedial action taken to prevent recurrence. The contractor shall submit a statement of various accidents to the department at the end of each month within a week.

1.14.2 Reporting of accidents:

i) Notice of any accident, resulting in death of any person or in such bodily injury which is likely to cause death or prevents the injured person from working for a period of 48 hours or more, shall be sent to the statutory authorities within the prescribed time as per the Factories Act and Rules or the Building and other Construction workers (Regulation of Employment and Conditions of Service) Act and Rules as applicable.

ii) Cases of outage of a substation or a transmission line 132kV and above due to any accident related to any equipment (e.g. fire, explosion, emission of hazardous chemicals, collapse of transmission tower, flooding of sub-station area) shall be reported to the Authority within 24 hours, whether or not any death or disablement is caused to any person.

1.14.3 Emergency Management Plan:

i) An on site emergency management plan shall be formulated for a) each substation and b) group of transmission lines for quickly and effectively dealing with probable emergencies like fire, explosion, gas leakages, landslides, floods etc. and reducing response time.

ii) Provisions to be made for the onsite emergency management plans shall conform to the following:

(a) Major fire in cable gallery

(b) Major fire in transformer yard

iii) Onsite emergency management plan shall include the following:-

(a) Name and address of Chief incident controller

(b) Alarm system and method of reporting/declaring emergency

(c) Emergency response procedure including response to Off-site emergency management plan and Crisis& Disaster management plan.

(d) Details of the key personnel of the emergency team and their responsibilities

(e) Addresses and contact numbers of outside organizations (including local administration, police, hospitals, organizations located nearby) involved in assisting during emergency with their role

(f) Risk assessment information giving possible nature of incidents/events giving rise to emergency conditions, risk analysis and impact assessment.

(g) Details about the site:

i) Locations where emergency can arise

ii) Emergency control room/Alternate emergency control room

iii) Demarcation of safe assembly zone relevant to each type emergency condition

(h) Internal and external communication plan during emergency

(i) Details of fire fighting and other facilities and their operating procedures available to deal with emergency conditions

(j) Details of first aid and hospital services available and their adequacy.

(k) Post emergency activities:

(i) Collection of records

(ii) Conducting enquiries and concluding preventive measures

(iii) Making insurance claims

(iv) Preparation of enquiry report and suggestion scheme

(v) Implementation of enquiry report recommendations

(vi) Rehabilitation of affected persons

(vii) To restart the plant

iv) Onsite emergency management plan for the substations and lines should be prepared by the department before commissioning. In case of existing substations and lines the plan may be prepared within 90 days.

However in case of construction of Substations and lines, emergency action plan shall be prepared, before commencement of construction activity, to handle emergencies like fire, explosion, collapse of lifting appliances and transport equipment, collapse of building or structures, gas leakages, landslides, floods etc.

v) Department should ensure that a mock drill of the onsite emergency management plan is conducted at least once every six months.

1.14.4 Medical facilities:

Medical facilities shall be provided to arrange immediate relief to accident victims. A fully equipped first-aid box shall be made available at the plant or at the site. A few persons (say 5) should be trained in first-aid procedures amongst whom at least one shall always be available during the working period. Arrangements for procuring ambulance van for transportation of persons involved in serious accident or sickness to the hospital; shall be made at short notice.

1.14.5 Safety Training and Awareness:

Regular training programmes should be conducted for all employees covering general safety awareness, first-aid, emergency procedures including shock treatment , use of personal protective equipment, safety pre-cautions while handling electro-mechanical equipment, use of different types of fire fighting equipment, response in the event of emergencies including fire, floods, landslides, earthquakes etc., site specific hazards and relevant safety acts, rules and regulations.
Project implementing officer shall ensure that adequate safety training is provided by the contractor to his personnel.

1.14.6 Safety Manual for construction of Substations and lines:

A Safety Manual shall be prepared with the following contents:

Safety policy, Safety organization, Responsibilities of contractor, responsibilities of employees, Reporting of accidents, Enquiry of accident/dangerous occurrence, occupational health and medical facilities, emergency management plan, location of safety equipment and emergency facilities in the substation, safety inspections/audits, Safety training, awareness and promotion, Personal protection equipment, communication facilities, Fire prevention and protection, emergency escape routes.

Tools for working at height: Scaffolds, Ladders, Working platform, Fall arresting equipment, Temporary stairs, Suspended jhoolas, Floor openings.

Safe working environment: Illumination and emergency lighting, Noise pollution, Harmful gases and dust pollution, Thermal radiation, Ventilation, Confined spaces.

Safety in handling oils, Safety in painting works, Safety in transportation, earth moving equipment and other construction equipment/machinery, Safety in use of electricity

Safety in handling electrical equipment such as: Earthing of equipment, working on bus-bars, transformers, circuit breakers, insulators etc, Working on lines during installation of insulators, stringing of conductors, jumpering and fixing of spacers/vibration dampers, EHV/HV static capacitor banks, opening or splicing de-energized conductors or overhead ground wires, storage batteries, testing of MV/HV/EHV equipment, SF6 gas filled equipment.

House keeping, Safety in material handling, safety in use of lifting machines and tackles, Safety while lifting heavy equipment, fencing of rotating machinery, Safety during demolition and excavations, Safety while working in any rainy and foggy environment, safety during blasting, Safety in trenches works, Handling and use of explosives, handling of flammable gases, safety in piling, safety in structural steel works, Safety in concreting work, Safety in welding and cutting operations, Safety in grinding and machining, safety in use of hand tools and power operated tools, Safety in waste disposal, safety in road cutting works, working adjacent to rail tracks& roads .

MANUAL ON TESTING&COMMISSIONING OF EHVSUBSTATIONS AND LINES

2.1 SUBSTATION : TESTING OF EQUIPMENT

2.1.1 POWER TRANSFORMERS

After installation of transformer on the plinth, accessories viz. Radiators, Headers, Bushings, Air Blowers, Oil pumps with connecting pipes, OLTC Drive mechanism and the connecting pipes to diverter switch compartments, Marshalling box, etc. have to be mounted on the transformer as per the manufacturers' drawings.

Oil should be admitted into the transformer from its bottom valve and suction side to be connected to the top valve to evacuate nitrogen/dry air inside the transformer as the oil fills from the bottom. It is preferable to fill the oil received from the works (in barrels) into an oil tanker of sufficient capacity and filter this oil separately. This helps in removing moisture absorbed in the oil during transport and storage. Fairly moisture free filtered oil now can be admitted from the oil tanker to the transformer.

The following check list provides various checks to be conducted for transformer assembly.

1	Availability of erection drawings and literature at site	Yes/No
2	Whether all components available at site in good condition	Yes/No
3	Rinsed all the piping, radiators, conservator etc. with 60kV tested oil and blocked with dummy plates	Yes/No
4	Filtered the oil for 60kV BDV and recorded in the erection register	Yes/No
5	Measured the IR values of HV, MV condenser type bushings(with a 5kV megger) and observed more than 5000 MΩ after removing coverings, wrappers etc and cleaning	Yes/No
6	Washed with hot oil (in case of other bushings of plain porcelain type)	Yes/No
7	Assembled the bushing after fixing corona shield and removing links and bends in pull through leads, on the turret at proper incline	Yes/No
8	Complete assembly of HV, LV, Ter. & Neutral bushings done correctly	Yes/No
9	Completed all piping work, conservator, explosion vent, equalizer pipes etc. as per the drawing and filled with oil , Bucholz relay checked	Yes/No
10	Filled radiator after washing individually and ensuring removal of blanking plates and free movement of butterfly valves both top and bottom	Yes/No
11	Measured IR values with temperature after filling of oil and compared with factory test value and recorded in the register.	Yes/No
12	For drying out of Transformer	
	(a) Applied proper lagging around the transformer. Fire fighting equipment kept at site	Yes/No
	(b) Filter machine cleaned and filled with transformer oil	Yes/No
	(c) Filter connected with outlet into the conservator and inlet from the bottom tank	Yes/No
	(d) Filter heaters switched on and the filter temperature maintained less than 60ºC and filter vacuum maintained at755mm of mercury	Yes/No
	(e) Dehydration process for 7 days maintained oil temperature 60ºC in the transformer (thermometer pockets filled with oil)	Yes/No

13	Filled the radiators with 60kV BDV tested oil. Opened the bottom butterfly valve provided between main tank and radiators after opening top air release valve to communicate with main tank	Yes/No
14	All gases released from different release points in the order of ascending heights	Yes/No
15	HV, LV, Tertiary Neutral earthing provided. Body earthing at two sides, earthing of DM and FCC provided	Yes/No
16	Petroleum jelly applied in clamps and connectors in the transformer bushing studs and checked the tightness	Yes/No
17	Blue silica gel crystals of 2.5 to 4mm size filled in the breather. Breather filled with oil after removing bottom cup, transit protection cover, cork packing etc.	Yes/No
18	Removed blanking plates on explosion vent pipe and fixed diaphragm	Yes/No
19	In case of transformers provided with thermo-siphon filter and air-cell (pronol bag) breathing arrangement checked up as per manufacturers recommendations	Yes/No
20	All air release points and other points thoroughly checked to ensure that there is no oil leakage	Yes/No
21	Connecting test taps of all 132,220,400kV condenser bushings	Yes/no
22	Oil level in main& OLTC conservators upto the mark	Yes/No
23	Filling of oil in oil packets of OTI & WTI	Yes/No
24	Welding of wheel stoppers to the rails	Yes/No

2.1.1.1 Testing of Transformer

After installation and assembly at site, the following pre-commissioning tests on transformer should be conducted. These are basically low voltage tests.

- Ratio
- Polarity and vector group
- Measurement of Magnetizing current and No Load losses (3-phase 415V to be supplied on low voltage side of the transformer)
- Measurement of Short circuit current, Load losses and Impedance [at all taps] (3-phase 415volts supply to be given on the high voltage side and the other side shorted)
- Magnetic Balance Test
- Measurement of winding resistance at all taps
- Insulation Resistance and polarization index

2.1.1.2 Testing of Auxiliary Protective devices

Checking of operation of alarms and trips of following auxiliary relays

i) High temperature settings for oil and winding temperatures
ii) Bucholz relay and OLTC oil surge relay

iii) Pressure relief device
iv) MOG of conservator

Checking for running /stopping of cooler fans and/or oil circulating pumps in groups at the set temperarures/pressures. Conduct all checks and tests on turret mounted CTs as indicated under CTs

2.1.1.3 OLTC

- Checking for manual and electrical operation (both local & remote and lower & raise) of On Load Tap Changer and for continuity between the operations
- Check for operation of limit switches at the extreme tap positions and mechanical interlock between manual and electrical operation
- Check for Master/Follower and out of step relay operation of transformers if parallel operation is intended

2.1.1.4 Tests for reference (Signature): The following tests should be done before commissioning and the results compared with the factory test results. These results should be kept as reference values for comparison with the future test results of these tests while conducting, as a part of O&M later.

- Measurement of Capacitance and tanδ of windings, Condenser Bushings
- Dissolved Gas analysis
- Furan Analysis (to measure degree of polymerization)
- Frequency Response Analysis
- Recovery Voltage Measurement
- Oil sample test for Dielectric strength, acidity, specific resistance, moisture content and tanδ

2.1.1.5 Tests on main protective relays:

The following protective relays connected to the transformer HV/IV/Tertiary sides shall be tested for proper operation duly adopting the settings communicated by the Power systems

- Over current / Earth fault relays (directional/non-directional)
- Operation of the instantaneous elements for the set current value
- Differential relays with bias and restraint features including through current stability
- Restricted Earth fault relays
- Local Breaker Backup (LBB) relays
- Over flux relay
- Under and Over voltage relays

Testing procedures for the above protective relays are described under the topic “Testing of Relays”.

2.1.2 CIRCUIT BREAKERS

Physical checks for any damages to components of the circuit breaker should be made. Tightness of connections at all jumpers, flanges, joints in pipes, valves etc. should be checked. Check for oil/ gas/ air leakages at concerned valves/pipes and all oil seals, gaskets should be made. Checking and tightening of all foundation bolts should be done.

The following pre-commissioning tests/checks shall be conducted.

- Measurement of Insulation Resistance – Phase to earth, Between phases, across contacts with breaker open
- Measurement of Capacitance and tanδ of Voltage Grading capacitors. The grading capacitors are oil filled paper capacitor type
- Purity and Dew point measurement of SF6 gas at rated pressure of the breaker and at atmospheric pressure
- In ABCBs Dew point of air to be measured. Air serves as insulation as well as arc quenching medium
- Measurement of CB close, open, close-open, timings with CB Operation analyzer
- Measurement of Dynamic contact Resistance and contact travel
- Operation of Pole Discrepancy relay: To measure the difference in closing and opening times of different poles of CB where the poles are individually operated (220kV and above). Simultaneous closing of all the three poles in case of a three pole/ gang operated breaker (132kV and below)
- Check for proper working of carrier inter trip and auto-reclose features (for feeder breakers)
- Check for capacitor tripping device where provided
- Measurement of resistance and current drawn by close coil and trip coils I&II
- Checking of interconnecting cables to bay marshalling box
- Checking of operating mechanism
- Checking of operation counter and all mechanical indications
- Checking of all Non-return valves/ Safety valves
- Checking of local/remote breaker operations

Check for correct operation of following operational lockouts at set pressures

- SF6 gas pressure- alarm and lockout at different set pressures
- Pneumatic operating system – Automatic start/stop of air compressor at set pressures
- CB closing lockout
- CB operational lockout
- CB auto-reclose lockout

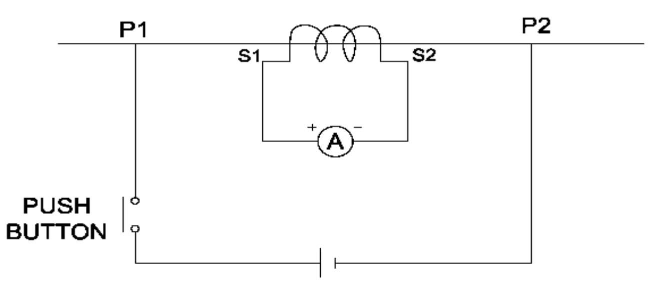
2.1.3 CURRENT TRANSFORMERS

Physical observation of the CTs for proper installation with respect to the drawings and SS layout should be made. Tightness of bolts of support structures to the foundation and CT base mounting to the support structure shall be ensured. Oil leakages in case of oil filled CTs and SF6 gas leakages/rated pressure of gas in case of SF6 gas filled CTs to be observed. Bellows provided for taking care of oil expansion shall be checked for proper functioning.

The following checks and electrical tests shall be conducted.

- Checking of tightness of all electrical connections including connections made in the marshalling box.
- Checking for tightness of CT secondary terminals and checking healthiness of secondary terminal bushings.
- Checking for short circuiting the secondary terminals of such CT secondary windings which are not required. Shorting should be done at secondary terminals in the CT secondary terminal box.
- Checking for earthing of common point of three phases of each secondary winding at one point only, preferably at the marshalling box.
- Measurement of IR values including Di-electric absorption ratio and Polarization index of primary to body and primary to secondary with a 5 kV megger
- Measurement of IR values between secondary winding of each core to body and between different secondary windings of the CT with a 0.5 kV megger
- Measurement of capacitance and tan∂ of the CT.
- Measurement of secondary winding resistance of each secondary winding
- Testing for Magnetization characteristics (knee point voltage) of CT cores.
- Ratio test for approved CT ratios in all the cores including complete wiring in the secondary side (up to the C&R panels) to ensure correct ratio and continuity of the wiring.
- Check for polarity of CTs, to ensure correct directional sensitivity of metering and protection system.

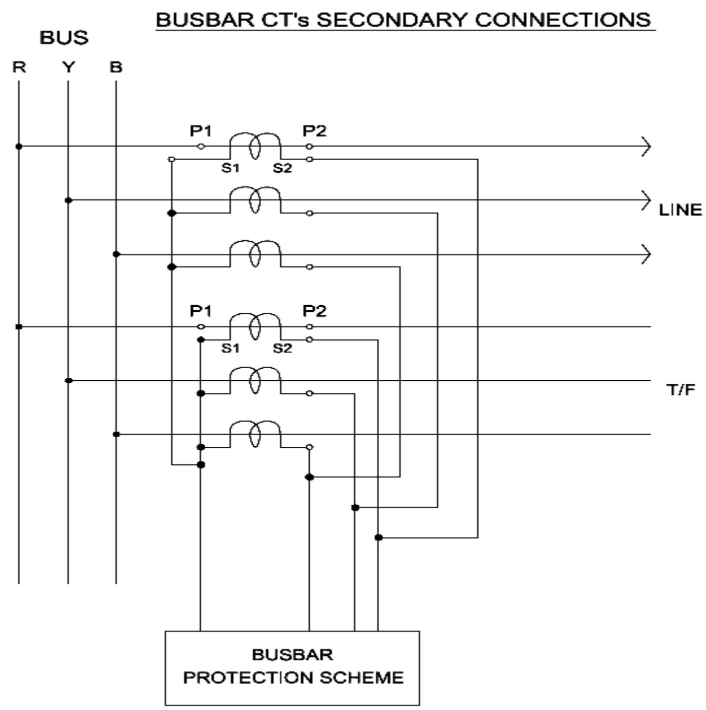
Each CT should be individually tested to verify the polarity markings on primary and secondary windings. Test circuit is given below.

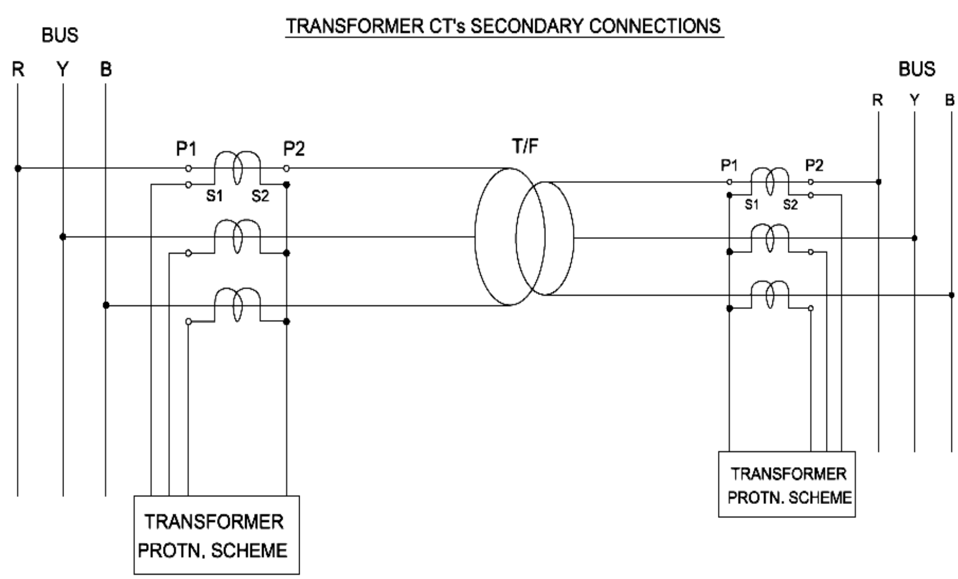


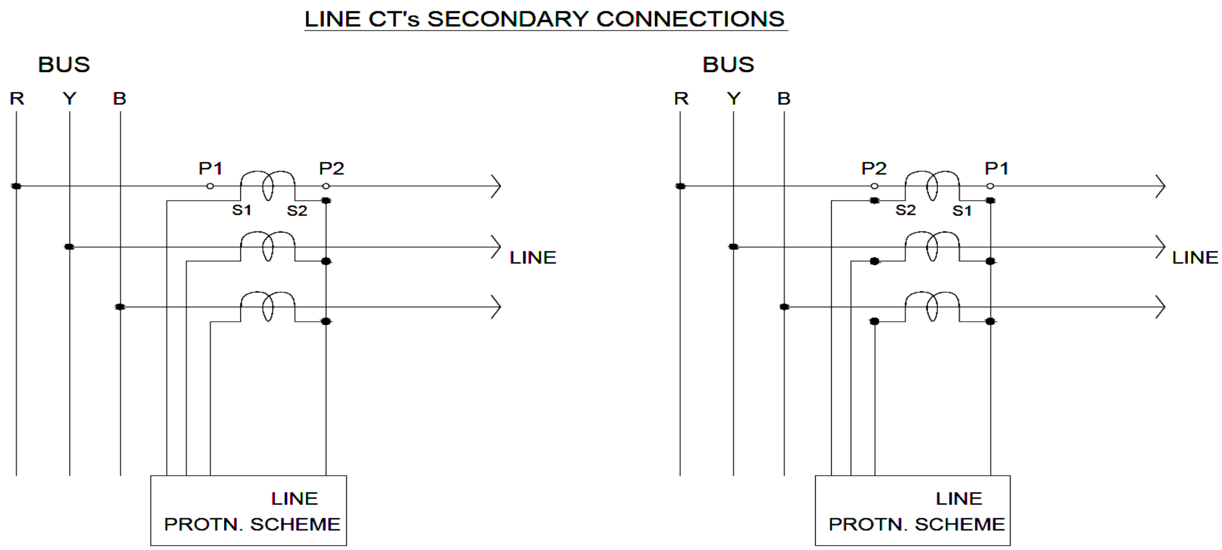
CT Polarity test

Ammeter “A” is a robust moving coil permanent magnet center zero type instrument. Primary winding is given DC supply momentarily from a low voltage battery through a push button. When push button is pressed with the above markings on CT and ammeter, the ammeter should give a +ve flick, indicating correct polarity. Multi meters and Digital ammeters can also be used.

CT secondary connections to transformers, bus bars, and feeders:







Where CT secondary connections are to be made in star, the star point should be made as follows.

Irrespective of the polarity on the primary side, star point on secondary side shall be on line side for feeders and on the equipment side for the bus bars, and transformers as shown in the figures in the previous page.

Eg. In case of a feeder protection, if P1 is towards the bus, then S2s' are to be shorted and if P2 is towards bus then S1s' are to be shorted.

2.1.4 VOLTAGE TRANSFORMERS (CVTs / IVTs)

Visual observation for any cracks/breakages should be made. Mounting of capacitor stacks, electro magnetic units, and terminal box shall be checked for correctness as per the drawing. Tightness of foundation bolts connecting the support structures to the foundation and the bolts connecting base of the VTs/CVTs to the supporting structures should be ensured. The following checks shall be made.

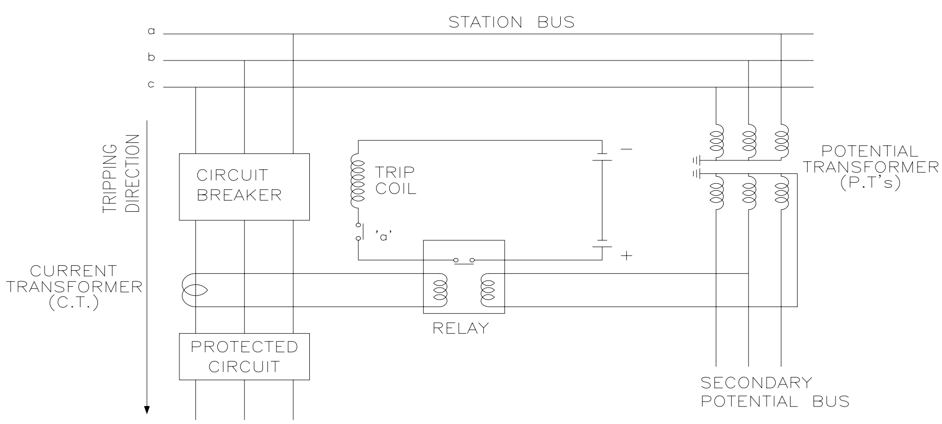
- Check for tightness of all electrical connections on primary and secondary sides of CVTS/VTs including connections in the marshalling box.
- Check for oil leakages and oil level
- Ratio test –voltage in all the secondary windings should be measured
- Insulation resistance of primary to body and primary to secondary windings to be measured by a 5 kV megger
- Insulation resistance of secondary to body and between secondary windings to be measure by a0.5 kV megger
- Measurement of capacitance and tan ∂ of CVTs
- Checking of HF point in case of CVTs. Caution given on the name plate by the manufacturer should be followed
- Check for adopting the approved ratios and connections for different secondary windings

2.1.5 PROTECTIVE RELAYS

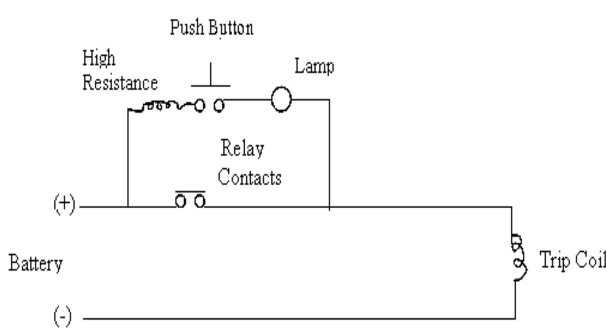
Function of Protective Relaying

It is to cause a prompt removal from service of any element of a power system when it suffers a short circuit or when it starts to operate in any abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system. The relaying equipment is aided in this task by circuit breakers that are capable of disconnecting the faulty element when they are called upon to do by the relaying equipment.

The basic connections of a protective relay and healthy trip circuit are indicated below.



BASIC CONNECTIONS OF A PROTECTIVE RELAY



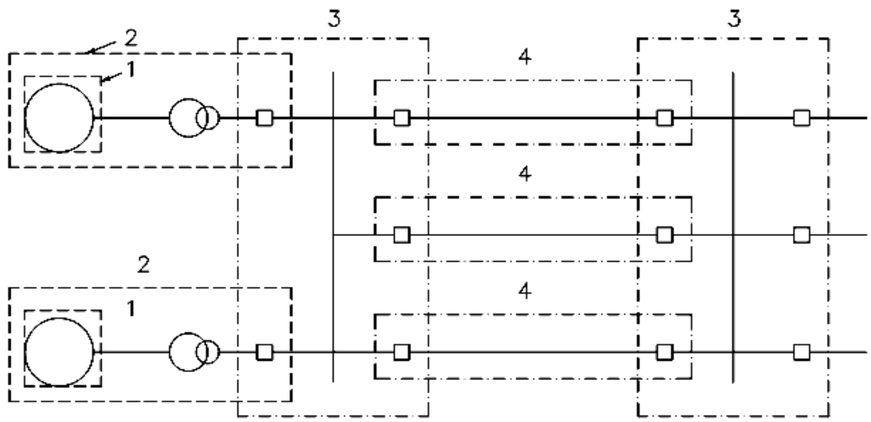
2.1.5.1 Functional requirement of relay:

i) **Reliability**: The most important requisite of protective relay is reliability since they supervise the circuit for a long time before a fault occurs; if a fault then occurs, the relays must respond instantly and correctly.

ii) **Selectivity**: The relay must be able to discriminate (select) between those conditions for which prompt operation is required and those for which no operation, or time delayed operation is required.

iii) **Sensitivity**: The relaying equipment must be sufficiently sensitive so that it operates reliably when required under the actual conditions that produces least operating tendency.

iv) **Speed:** The relay must operate at the required speed. It should neither be too slow which may result in damage to the equipment nor should it be too fast which may result in undesired operation.



1. GENERATOR PROTECTIVE ZONE
2. GENERATOR TRANSFPRMER UNIT PROTACTIVE ZONE
3. BUSBAR PROTECTIVE ZONE
4. TRANSMISSION LINE PROTECTIVE ZONE

PROTECTIVE ZONES

2.1.5.2 Norms of Protection being followed in APTRANSCO

Lines

Sl.No.	Voltage	Protection Scheme
1.	400 KV Line	Main-I: Non switched or Numerical Distance Scheme Main-II: Non switched or Numerical Distance Scheme
2.	220 KV Line	Main-I: Non switched distance scheme (Fed from Bus PTs) Main-II: Non switched distance scheme (Fed from line CVTs) With a changeover facility from bus PT to line CVT and vice-versa.
3.	132 KV lines	Main Protection: Switched or numerical distance scheme (fed from bus From Bus PT) Back up Protection: 3 Nos. directional IDMT O/L Relays and 1 No. directional IDMT E/L relay.
4.	33 KV lines	Non-directional IDMT 3 OIL and 1 E/L relays.
5.	11 KV lines	Non-directional IDMT 2 OIL and 1 E/L relays.

Note: 33kV and 11kV lines are provided with instantaneous elements

Bus bars: All 220 KV and 400kV bus bars will have busbar protection scheme with main and check zone

Breaker failure protection: The LBB protection scheme will be provided for all 220KV and 400kV stations (along with busbar protection scheme)

Transformers:

Voltage ratio & capacity	HV Side	LV Side	Common relays
l. 132/33or1lKV above 8 MV A and below 31.5 MV A	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Buchholz, OL TC Buchholz, OT, WT
ii. 132/33 or 11KV, 31.5 MVA & above	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Over flux, Buchholz, OL TC PRV,OT, WT
Iii. 220/33 or 11KV, 3l.5MVA& 50MVA 220/132KV, 100 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 dir. relay	Differential, Over flux, Buchholz, OL TC PRV,OT, WT
iv. 400/220KV 3l5MVA	3 directional O/L relays (with dir.highset) + 1 directional E/L relays. Restricted E/F relay + 3 Directional OIL relays for action	3 directional O/L relays (with dir.highset)+ 1 directional E/L relay. Restricted E/F relay	Differential, Over flux, Buchholz, OL TC PRV, OT, WT and overload (alarm) relay

2.1.5.3 DEVICE NUMBERS AND THEIR UNIVERSAL NOMENCLATURE

2	Time delay relay
3	Interlocking relay
21	Distance relay
25	Check synchronizing relay
27	Under voltage relay
30	Annunciator relay
32	Directional power (Reverse power) relay
37	Low forward power relay
40	Field failure (loss of excitation) relay
46	Negative phase sequence relay
49	Machine or Transformer Thermal relay

50	Instantaneous Over current relay
51	A.C IDMT over current relay
52	Circuit breaker
52a	Circuit breaker Auxiliary switch “Normally open” (‘a’ contact)
52b	Circuit breaker Auxiliary switch “Normally closed” (‘b’ contact)
55	Power Factor relay
56	Field Application relay
59	Over voltage relay
60	Voltage or current balance relay
64	Earth fault relay
67	Directional relay
68	Locking relay
74	Alarm relay
76	D.C Over current relay
78	Phase angle measuring or out of step relay
79	AC Auto reclose relay
81	Frequency relay
81U	Under frequency relay
81O	Over frequency relay
83	Automatic selective control or transfer relay
[illegible]	[illegible]
86	Tripping Relay
87	Differential relay
87G	Generator differential relay
87GT	Overall differential relay
87U	UAT differential relay
87NT	Restricted earth fault relay
95	Trip circuit supervision relay
99	Over flux relay
186A	Auto reclose lockout relay
186B	Auto reclose lockout relay

2.1.5.4 Data to be furnished to Power Systems Unit for computing Relay Settings:

(a) Power Transformers:

Voltage ratio, No. of windings, Rated capacity, Short circuit withstand capacity, % Impedance, Tapping range, Method of neutral grounding

Current transformer on HV and IV/LV sides: No. of cores, Ratios of each core and its accuracy class, Rated burden in VA, Short circuit withstand capacity, Knee point voltage of protection class cores

Bus PT on HV and IV/LV sides: Ratio, No. of windings and their accuracy class, Capacitors and intermediate transformer details and compensating reactor details in case of CVTs.
Circuit breakers on HV and IV/LV sides: Rated current, breaking capacity and peak making capacity, Breaker open and close timings, Individual pole operated/ gang operated, pole discrepancy features

Control &Relay Panels: Make and type of relays

(b) Capacitors:

Rated Voltage, Current, KVAR rating and capacitance of individual capacitor, Total No. of capacitors and no. of parallel / series groups per phase, Single or double star formation, Inrush current capability,

Series reactor: Rating, inductance, rated current, inrush withstand current
Current transformers: No. of cores, ratio of each core and accuracy class, Rated burden in VA, Short circuit withstand capacity

Neutral Displacement protection: Method of neutral unbalance protection i.e. by Neutral CT or by RVT, ratios/ voltage ratings

Circuit breaker: rated current, breaking capacity and peak making capacity, breaker open and close timings

Control & Relay Panels: Make and types of relays provided, particulars of automatic power-factor correction relays provided and switching steps/ sequence, if any

(c) Transmission Lines:

Line length in Km, Size of conductor and no. of sub conductors per phase, configuration of the line, No. of locations

Current Transformers: No. of cores, Ratio of each core and accuracy class, rated burden in VA, short circuit withstand capability, Knee point voltage of protection class cores

Voltage Transformers (Both line CVT and Bus VT): Ratio, No. of windings and their accuracy class, Capacitors and intermediate transformer details and compensating reactor details in case of CVTs.
Circuit breakers: Rated current, breaking capacity and peak making capacity, Breaker open and close timings, Individual pole operated/ gang operated, pole discrepancy features
Control & Relay Panels: Make and Type of Relays

After receipt of the information as mentioned above; in respect of new substation/ line, new bay in a substation, new line, or augmentation, Power system wing works out the type of protection and the relay settings to be adopted for various relays duly taking into consideration impedance to the source and fault (both remote and dead faults), fault levels at the buses of the substations under consideration, maximum continuous operating voltages and currents etc.

Approved settings for various relays installed in the substation as communicated by Power system unit should be adopted .Testing of relays shall be done adopting the approved settings.

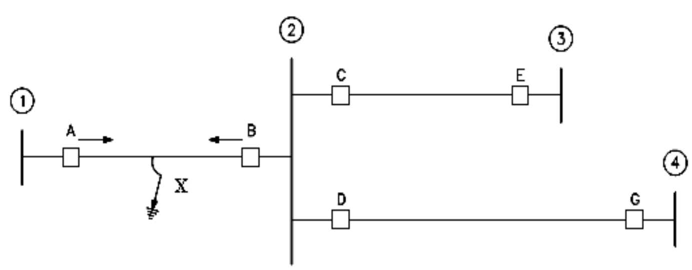
2.1.5.4 TRANSMISSION LINE PROTECTION

Distance Relays Principles

Introduction: In a Power Transmission system, it is impossible to co-ordinate over current or directional over current relays to provide protection for the transmission lines, since for a given fault location, the current seen by the relay varies over a wide range depending upon the system operating conditions.

Impedance relays offer protection of transmission lines connected in a network. Though "Unit" protection is ideal for feeders, it is found that "Unit" protection for feeders is not economical when long lines are involved. A Non-Unit form of protection like distance relay, offers considerable economic and technical advantage. They are comparatively simple to apply, operate with extremely high speed, and both primary and backup protection features are inherent in them. Moreover, they can be easily modified to work as unit schemes by coordinating them with power line carrier facilities and are suitable for high speed reclosing. The impedance relay is made to respond to the impedance between the relay location and the fault point. The impedance is proportional to the distance to the fault, (hence the name 'distance relay') and is therefore independent of the fault current levels.

Ex: Consider the following system to be a section of a larger system:



For the fault at X, the relays at A & B will operate in the forward direction (i.e. for currents flowing from the bus onto the line)

A distance relay compares the currents and voltages at the relaying point with current providing the operating torque and the voltage provides the restraining torque. In other words an impedance relay is a voltage restrained overcurrent relay.

The equation at the balance point in a simple impedance relay is $K_1V^2 = K_2I^2$ or $V/I = K_3$ where K_1, K_2 and K_3 are constants. In other words, the relay is on the verge of operation at a constant value of V/I ratio, which may be expressed as an impedance.

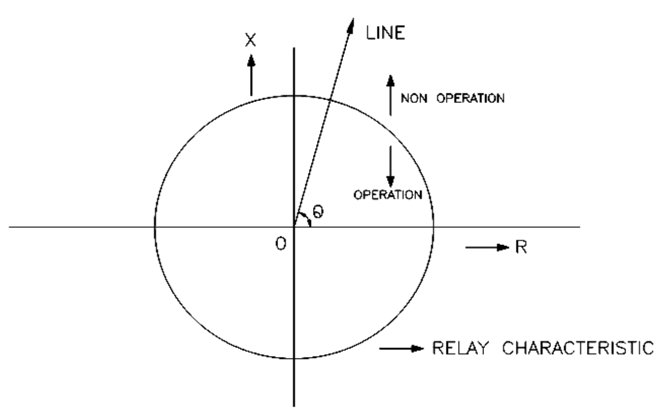
For a fault at the far end of the line, the local voltage is the IZ drop in the line and therefore the voltage to current ratio for such a fault will be 'Z', where Z is the impedance of the line. For a fault internal to the protected section, V/I < Z and for a fault beyond the protection section, V/I is > Z. The V/I ratio at the relay can be termed as the "impedance" seen by the relay. The relay will operate if the impedance seen by the relay is less than 'Z'. Since the impedance seen is directly proportional to the length of the line between the relay and the fault, it is also a measure of distance to the fault from the relay and hence such relays which compare the voltage and currents are called "distance relays".

Since the operating characteristics of the relay depend upon the ratio of voltage and current and the phase angle between them, their characteristics can be best represented on an R-X diagram where both V/I ratio and the phase angle can be plotted in terms of an impedance R+jX. Further, the power system impedance like fault impedance, power swings, loads etc. can also be plotted on the same R-X diagram. Therefore response of a particular relay during power swing, faults and other system disturbances can easily be assessed.

Types of Distance Relays:

(1) Impedance relay
(2) Reactance relay
(3) Mho relay
(4) Modified Impedance relay

Impedance relay: Characteristics of an impedance relay on R-X diagram is shown in fig

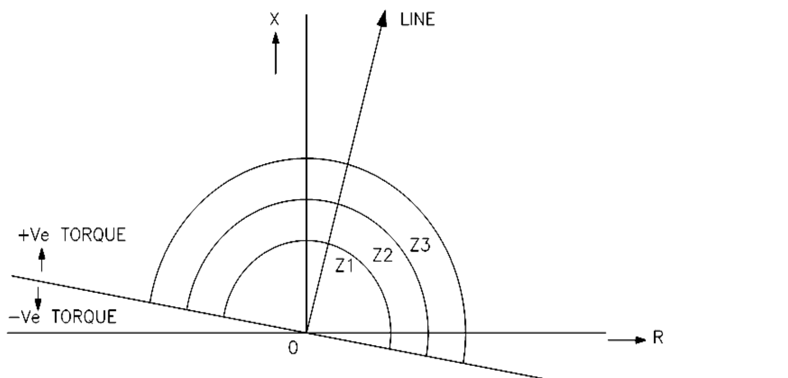


IMPEDANCE RELAY

The numerical value of the ratio of V to I is shown as the length of the radius vector, such as Z and the phase angle between V and I determines the position of the vector, as shown.

Operation of the impedance relay is practically independent of the phase angle between V and I. The operating characteristic is a circle with its center at the origin, and hence the relay is non-directional.

Characteristic of a directional impedance relay in the complex R-X phase is shown below

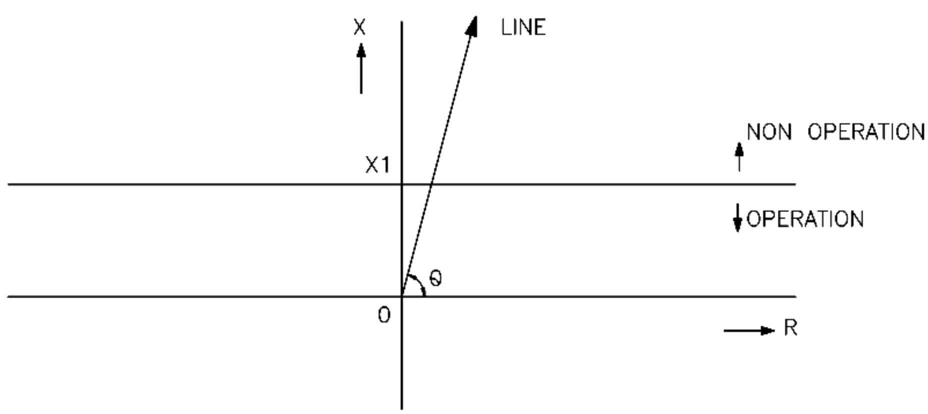


DIRECTIONAL IMPEDANCE RELAY

Along the line impedance locus line, the positive sequence impedance of the protected line as seen by the relay between its location and different points along the protected line can be plotted. The directional unit of the relay causes separation of the regions of the relay characteristic shown in the figure by a line drawn perpendicular to the line impedance locus. The net result is that tripping will occur only for points that are both within the circles and above the directional unit characteristic.

Reactance type Distance Relay

Reactance relay measures V/I Sin Ø (i.e. Z sin Ø). Whenever the reactance measured by the relay is less than the set value, the relay operates. The operating characteristic on R-X diagram is indicated below:



REACTANCE RELAY

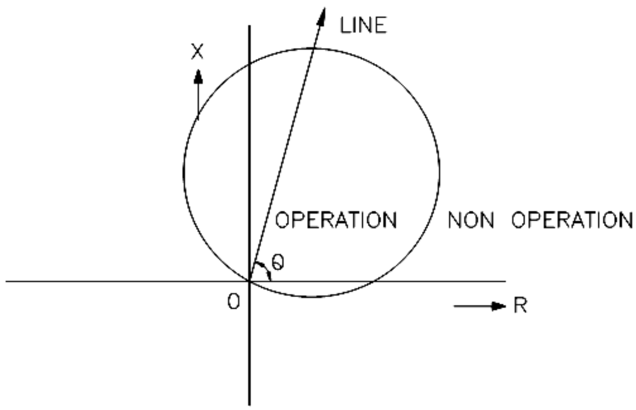
The resistance component of impedance has no effect on the operation of reactance relay. The relay responds solely to reactance component of impedance. This relay is inherently non-directional. The relay is most suitable to detect earth faults where the effect of arc resistance may render other types of relays to detect faults with difficulty.

Mho relay:

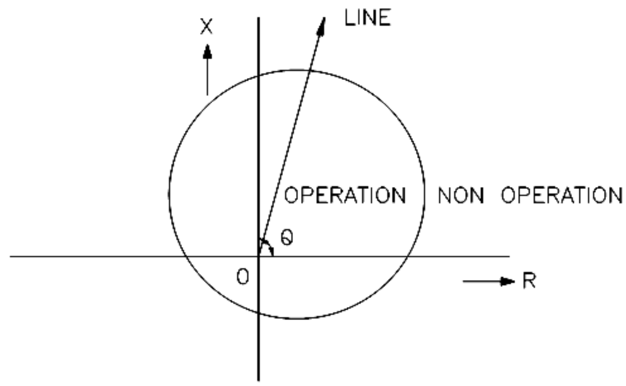
This is a directional impedance relay, also known as admittance relay. Its characteristic on R-X diagram is a circle whose circumference passes through the origin as illustrated in Figure below showing that the relay is inherently directional and it only operates for faults in the forward direction.

Modified impedance relay:

Also known as offset Mho relay whose characteristic encloses the origin on R-X diagram as indicated in the figure below



MHO RELAY



OFFSET MHO RELAY

This offset mho relay has three main applications: -

i) Busbar zone backup
ii) Carrier starting unit in distance/carrier blocking schemes.
iii) Power Swing blocking.

Other Operating characteristics

During the days of electromagnetic relays, the characteristics involving straight lines and / or circles on R-X diagram were only possible. With the advent of static relays, microprocessor based relays and presently of numerical relays, desired / required operating characteristic is possible giving wider choice for selection of relays.

DISTANCE RELAYS APPLICATION

Relay Setting

Since the distance relays are fed from the secondaries of line CTs and bus PTs/line CVTs, the line parameters are to be converted into secondary values to set the relay as per requirements.

$$\mathbf{Z_{secy} = Z_{pri}/Impedance\ ratio}$$

(where Impedance ratio = P.T.Ratio/C.T.Ratio)

It is to be noted that C.T Ratios (and P.T Ratios) and relay settings are inter-related. Hence any change in C.T .ratio has to be effected along with revision of relay settings only.

For the lines, the impedance in Ohms per KM is approximately as under:

KV	**Z1 (=Z2)**	**Line Angle**
132 KV	0.4	60 to 70 Deg
220 KV	0.4	70 to 80 Deg
400 KV	0.3	80 to 85 Deg

A distance relay is either of 3 zones or 4 zones to provide protection.

To ensure proper coordination between distance relays in power system, it is customary to choose relay ohmic setting as follows: -

Sino.	**Zones**	**Reactance**	**Time**
1.	Zone-1	80% of ZL	Instantaneous o intentional time delay)
2.	Zone-2	100% of ZL + 40-50% of ZSL	0.3 to 0.4 seconds
3.	Zone-3	100% of ZL + 120% of ZSL	0.6 to 0.8 seconds
4.	Zone-4	100% of ZL + 120% of ZLL	0.9 to 1.5 seconds

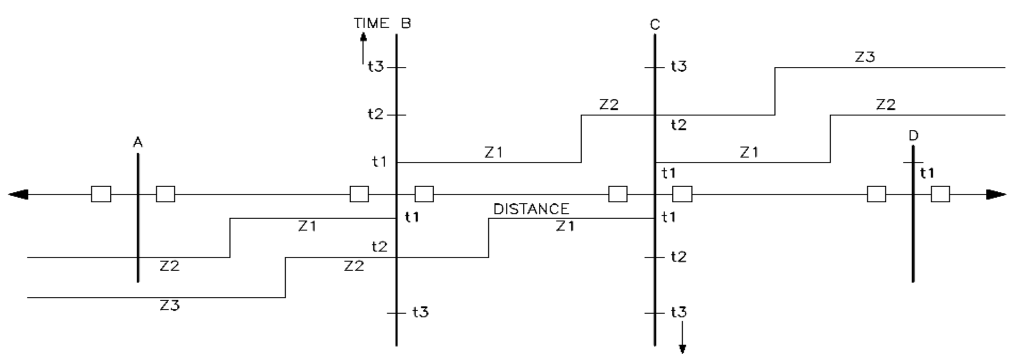
Where ZL = Positive sequence impedance of line to be protected.
ZSL = Positive sequence impedance of adjacent shortest line.
ZLL = Positive sequence impedance of adjacent longest line.

Note:

i) Where a three zone relay only is available, the zone 3 will be set to cover the adjacent longest line

ii) The zonal timings will be carefully selected to properly grade with the relays on adjoining sections.

Typical 3 zone time distance characteristic of distance relay is shown in sketch below:



THREE ZONE TIME–DISTANCE CHARACTERISTICS

The zone-1 reach is limited to 80% of ZL to provide a reasonable margin against a possible overreach due to errors in CTs, PTs, relay measurement, line parameters, etc.
The zone-2 reach is set to cover up to 40-50% of adjoining line so that this will definitely cover the balance 20% of main line (after zone-1 reach) and provides backup to adjoining line relay. Zone-2 setting shall be not less than 120% of ZL in order to ensure definite coverage of 100% of main line.
The zone-3 & zone-4 reaches will be suitably set to provide backup for relays on adjacent lines with proper time gradation.

Distance Scheme consists of the following major components

- i) **Starters.**
- ii) **Measuring units.**
- iii) **Timers**
- iv) **Auxiliary relays**

i) Starters:
The starting relay (or starter) initiates the distance scheme in the event of a fault within the required reach (more than zone-3).

Other functions of the starter are:

a) Starting of timer relays for second and third zones.
b) Switching of the respective faulty phase currents and voltage to the measuring unit in a switched scheme.

The starters are generally of Mho or impedance type.

With Mho type starters: Measuring units for phase and earth faults can be either directional or non-directional as Mho starters are inherently directional
With impedance type starters: Measuring units have to be directional as impedance starters are non-directional.
The under impedance in conjunction with the directional relay also can be used as starter which will then function similar to the Mho starter.

ii) Measuring units: They are generally of a mho or reactance or a combination of mho, reactance and resistance types.

Phase Fault Units:-

These measuring units are fed with line to line voltages (such as Va, Vb) and difference between line currents (Ia-Ib). They measure the positive sequence impedance from the relay location to the fault point. Three such relays respond correctly to all possible single line to ground faults line to line faults, double line to ground faults and 3-phase faults. They however do not respond correctly to earth faults.

Earth Fault Units: -

These measuring units utilize line to neutral voltage (Van, Vbn Vcn) and phase currents (Ia, Ib, Ic). In order to make these units measure the positive sequence impedance correctly, a zero sequence current compensation is to be provided which is obtained by:

KN = (Z0-Z1)/ 3*Z1 (where Z1 = positive sequence impedance of line. Z0 =Zero sequence impedance of line)
In the current circuit (1+KN) Ia will be fed for the above measurement.

iii) Timers: Timer relays when initiated by starters provide the time lag required for zones. They also will be used for zone extension purpose whenever required.

iv) Auxiliary relays: Distance scheme comprises of several auxiliary relays, which perform functions such as flag indications, trippings, signaling, alarm etc.

Additional Features in distance schemes: -

i) Power Swing blocking relay
ii) VT fuse failure relay.
iii) Switch onto fault relay
iv) Fault locator
v) Auto-reclosing scheme.
vi) Carrier communication scheme

i) Power Swing blocking:

Distance relay which respond to balanced 3-phase changes in the impedance will be affected by power swings. These swings or oscillations occur following a system disturbance such as major load change or a dip in voltage due to delayed fault clearance.

As generators in the system strive to find a stable operating angle relative to each other, the distance relays enroute on the line may see these conditions as three phase fault and falsely operate to trip their breakers. To avoid such operation, power swing blocking relays is used.

In case of fault, the transition from period of impedance locations (25 to 33% of starter impedance) to fault impedance (starter impedance) is sudden whereas during power swings, the transition to swing impedance is slow; the PSB relays use this difference to block the tripping during swings.

While the old schemes have blocking in all three zones, new static / Numerical schemes have the feature of blocking any particular zone of our choice.

ii) VT fuse failure relay:

The distance relays being voltage restraint O/C relays, loss of voltage due to main PT fuse failure or inadvertent removal of fuse in one or more phases will cause the relay operation. The fuse failure relay will sense such condition by the presence of residual voltage without residual current and blocks the relay.

iii) Switch onto fault:

Under normal service conditions, a close- by 3-phase fault will be seen by the relays in zone-1 and clear the fault instantaneously. But when the line is switched on to a close by fault (say after line clear with earth switch closed), the voltage at the relaying point will be zero. Faults of this type will normally be cleared by backup zones.

The voltage applied to the relay is low and this condition occurring simultaneously with the operation of starter will cause instantaneous trip by SOTF relay. This SOTF feature will be effective only for about 1-2 seconds after the line is charged. Faults occurring after this time will be measured in the normal way.

iv) Fault locator:

It measures the distance between the relay location and fault location in terms of Z in Ohms, or length in KM or percentage of line length.

This relay gets same inputs as the distance relay (connected in series with one of the main relays). The measurement is initiated by trip signal from distance relays.

While the distance relay provides general idea of the zone in which fault has occurred, the fault locator gives the exact location of the fault, thereby reducing the time of restoration.

Auto Reclosing Schemes:-

Types of faults:-

i) Transient Faults: These are cleared by the immediate tripping of circuit breakers and do not recur when the line is re-energized

ii) Semi-Permanent Faults: These require a time interval to disappear before a line is charged again.

iii) Permanent Faults: These are to be located and repaired before the line is re-energized

About 80-90% of the faults occurring are transient in nature. Hence automatic reclosure of breaker (after tripping on fault) will result in the line being successfully re- energized, thereby

a) Decreasing outage time
b) Improving reliability
c) Improving system stability

Dead Time: The time between auto-reclose scheme being energized and the operation of the contacts which energize the circuit breaker closing circuit.

Reclaim Time: The time following a successful closing operation measured from the instant the auto-reclosing relay contacts make which must elapse before the auto-reclosing relay initiates another reclosing attempt. In other words, it may be said to be the time between first and second auto-reclosure.

Types of Auto-reclosing schemes (based on phase):

a) Three Phase Auto-reclosing:-

This type of auto-reclosing causes an immediate drift apart of the two systems and hence no interchange of synchronizing power can take place during the dead time.

b) Single Phase Auto-reclosing:-

In this, only the faulty phase (which already has tripped on SLG fault) is reclosed without causing interruption in interchange of synchronizing power between two systems through other two healthy phases.

Types of Auto-reclosing schemes (based on attempts of reclosure)

a) Single shot Auto-reclosing:-

In this scheme, breaker is reclosed only once on a given fault before lockout of circuit breaker occurs. High speed auto-reclosing for EHV system is invariably single shot.

b) Multi-shot Auto-reclosing:-

In this scheme, more than once reclosing attempt is made for a given fault before lockout of the circuit breaker occurs. Repeated closure attempts with high fault level would seriously affect the circuit breaker, equipment and system stability. Factors that must be taken into account:-

i) Circuit Breaker Limitations:

Ability of circuit breaker to perform several trip close operations in quick succession.

ii) System conditions

If the percentage of the semi-permanent faults (which could be burnt out) is moderate, for example on the lines through the forest, multishot auto-reclosing is followed.

Types of Auto-reclosing (depending on speed)

i) High speed Auto-reclosing

This aids in fast restoration of supply but should be done, taking into account the following factors:-

- System disturbance time can be tolerated without loss of system stability
- Characteristics of protection schemes and circuit breaker.

ii) Low speed or Delayed Auto-relcosing:-

This is suitable for highly interconnected systems where the loss of a single line is unlikely to cause two sections of the system to drift apart and loose synchronism.

For EHV Systems

1) **Choice of Dead time:**

Lower limit is decided by de-ionising time of circuit breaker.
Upper limit is decided by transient stability and synchronism
Long transmission lines require longer dead time for single phase faults.
The dead time for high speed auto-reclosing scheme with EHV system is 0.3-0.8 Sec.

2) Choice for reclaim time:-

This should not be set to such a low value that the operating cycle of breaker is exceeded when two fault incidents occur close together. The reclaim time will be in the range of 10-30 Secs. depending on the breaker opening and closing mechanisms.

3) Carrier Communication Schemes

The main disadvantage of conventional time-stepped distance protection is that the instantaneous zone-1 of the protective scheme at each end of the protected line is set to cover 80% of the line and hence faults in the balance 20% of the line (at each end) are cleared in zone-2 time, which is undesirable.

The desirable scheme is the one wherein the relays clear the faults on the 100% of the protected line instantaneously and also provide backup for uncleared faults on adjacent lines. This can be achieved by interconnecting the distance relays at each end of the line by a signaling channel (which can be either pilots, a power line carrier communication channel, a radio link or a microwave channel).

The purpose of the signaling channel is to transmit the information about the system conditions at one end of the protected line to the other end and initiate or prevent tripping of the remote circuit breaker. The former arrangement is referred to as a "Transfer trip scheme" while the latter is known as a "blocking scheme".

a) Transfer trip scheme

In this scheme, the distance relay at one end of the protected lines sends a carrier signal to the relay at other end of the line for inter-tripping, thereby clearing the faults on entire line instantaneously. Transfer trip schemes are of two types:

i) Under-reaching scheme:

The scheme in which the zone-1 relay (set to cover about 80% of ZL) is used to send a signal to the remote end of the feeder for inter-tripping is termed as transfer trip under- reaching scheme. To avoid mal-operation due to receipt of false signal, the receiving end relay operation is inter-locked with its Zone3 / starter operation i.e., the scheme operates either by its own Zone-1 relay operation or by receipt of carrier command and its Zone-3 / Starter operation.

ii) Over-reaching scheme:-

This scheme is suitable for short lines where an under-reaching zone-1 would be too short to be of any practical use. In this scheme the relay set to reach beyond 100% of the line, is used to send an inter-tripping signal to the remote end of the line. It is essential that the received relay contact be monitored by a directional relay to ensure that tripping does not take place unless the fault is within the protected section. The disadvantage of this scheme is that there is no independent Zone-1 tripping. The fast tripping therefore realize entirely on signaling channel.

The disadvantage of these schemes is that the signal is transmitted over the faulty line section. Distortion of the signal may occur due to attenuation introduced into the line by the fault.

b) Blocking schemes:-

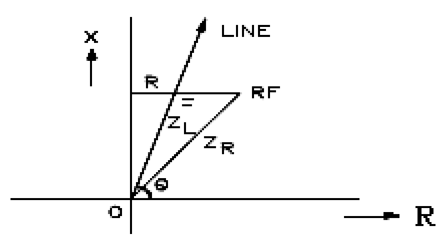
In this scheme, a blocking signal is sent by the reverse looking directional unit ZR toprevent instantaneous tripping for Zone-2 & Zone-3 faults, external to the protected line. Here ZR must operate faster than forward looking Zone-3 units and the signaling channel must also be extremely fast in operation.

Factors affecting distance relay operation:-

i) **Fault resistance.**
ii) **Infeed effect.**
iii) **Branching-off effect.**
iv) **Load encroachment.**

i) Fault resistance: Fault resistance has two components:
a) Arc resistance. b) Ground resistance.

In a fault between phases, only arc resistance is involved.



EFFECT OF FAULT RESISTANCE

For a fault at F, the actual line impedance = R + JX = ZL

Due to the presence of fault resistance, the impedance measured by the relay = R + JX + RF = ZR (where ZR > ZL)

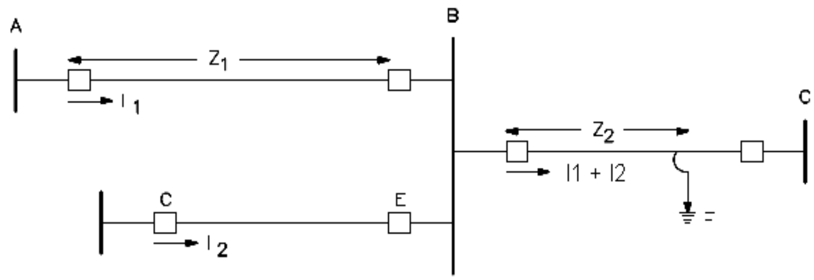
Fault arc resistance is given by Warrington's formula:
$R_{arc} = 8750 \text{ xL} / I^{1.4}$

whereL = length of arc in ft, I = fault current in Amps

The arc resistance has little effect on accuracy of zone-1 unit as it operates instantaneously before the arc can stretch appreciably except in case of short lines. Reactance relays are therefore used for short lines where the fault resistance may be comparable with that of the protected lines and also for ground faults where the ground resistance is high.

The arc resistance will have greater impact on accuracy of backup zones (time delayed) as the arc stretches appreciably.

ii) Infeed effect: The effect of intermediate current source between relay location and fault point is termed as infeed effect. Consider the following example:



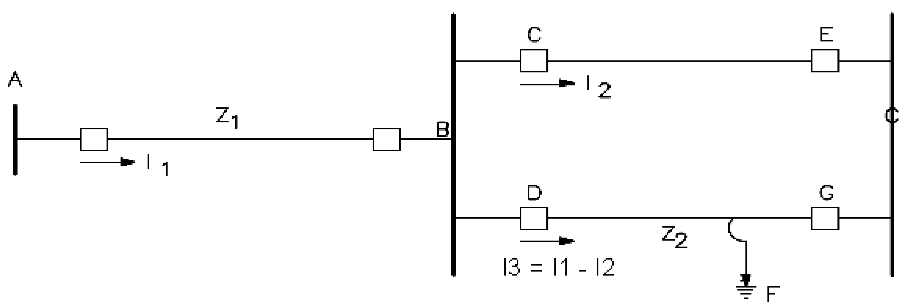
INFEED EFFECT

A fault at F on the line BC is at a distance of Z1+Z2 for the relay at station A. But when current I2 flows from bus D, the impedance to the fault as seen by the relay at A is Z1 + Z2 + Z2 x (I2/I1).

Thus the fault is seen by the relay as farther than what it really is, i.e. distance relay under reaches due to the infeed effect.

The effect of infeed becomes more pronounced with more interconnections at station- B.

iii) Branching-off effect: Consider the following example:



BRANCHING OFF EFFECT

A fault at F is at the distance of Z1+Z2 for the relay at station A. But when current I1 gets distributed as I2 & I3 at station B, the impedance to fault seen by the relay at station A will be (Z1 + I3/I1 * Z2) which is less than (Z1+Z2).

Then the fault is seen by the relay as nearer than what it really is i.e. distance relay overreaches due to branching-off effect. This overreaching tendency will cause the relay to loose its selectivity.

iv) Load encroachment: While protecting long lines the necessary reach may be so large that the minimum service impedance (or load impedance) falls within the region of the starter. This would result in tripping without there being any fault. The two conditions i.e. operation at heavy load and

short circuit differ by virtue of phase angle between voltage and current. For the load impedance, the phase angle will be within +30 to - 30 Deg. While during short circuits, the fault impedance has a phase angle of 60 to 80 deg. (i.e. line angle).
Load encroachment problem is more pronounced in case of under impedance starters and gets lessened in case of mho, elliptical, lens etc, type of starters. Relays with suitable characteristic on R-X diagram have to be carefully chosen to protect long and heavily loaded lines, and this becomes easily possible with microprocessor based numerical relays.

Non-switched scheme vs. Switched scheme:

In an ideal Non-switched scheme, there will be 6 starters, 3 for phase faults and 3 for ground faults. There will be independent measuring units for both phase faults and earth fault for each phase, for all three zones, totaling to 18 units. This scheme is faster and more accurate but is costly.

In the switched scheme, only one measuring unit will be used for all types of faults. This single measuring unit is switched to the correct fault loop impedance by switching-in the respective voltages and currents by the starter.

The reach of the measuring element gets extended to zone-2 and zone-3 after the elapse of corresponding timings through zone extension process. Switched scheme is relatively slow in operation and has the risk of total scheme failure in the event of failure of the only one measuring unit available.

Zone extension schemes:

As a via media between non-switched and switched schemes, there are schemes with zone extension facility (such as EE make MM3V & MR3V relays). These schemes consist of 3 measuring units for phase faults and 3 measuring units for earth faults (apart from 3 starters).

The reach of the measuring unit gets extended to zone-2 and zone-3 after elapse of corresponding timings through a zone extension process.

2.1.5.5 Development in Relay technology

Till 1980 almost all the relays available were electromechanical. Later 80s static relays were introduced. Early 90s Microprocessor based relays came into existence. Numerical relays are in extensive use from later 90s.

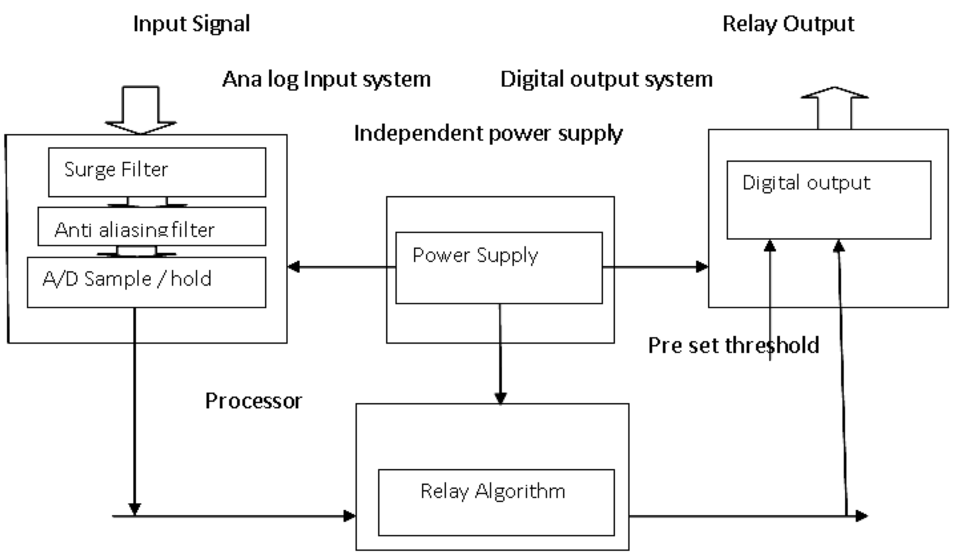
STATIC RELAY: In the solid state relays current signals get converted to voltage signals. Inputs to the relay are fed through the electronic circuits. Output features depend on the rectified DC output. No moving parts are available in these relays. They consume less power to operate and are very fast during switching operations when compared to the Electro mechanical relays.

These relays may malfunction due to transients if present in the inputs. Electronic components may drift due to high ambient temperatures and aging. The switches in the relay have leakage currents irrespective of the switches position.

DIGITAL RELAYS: Filtered signals are converted into wave forms, Calculations are done based on the phase angle comparison and either logics or microprocessors are used in the relay. High speed processors made the relay very fast in its operation. Protection, metering, communication and indication can be integrated in a single chip. Commissioning is easy due to less wiring and few components. Outage time of Feeder/ Transformer gets reduced because of fault locators integrated inside. These relays are small in size and easy to replace.

NUMERICAL RELAYS: Filtered signals are converted into numerical values at each sampling point. Calculations are made in real time using microprocessors.

Block diagram of a typical numerical relay



The numerical relay is a multi function device which supports numerous features like protection, control and communication. Analog inputs (Current and/or Voltages) fed to the relay are converted into digital signals and these signals are filtered in the anti-aliasing filter to eliminate any transients present in the signals. The signal i.e. sampling frequency of analog signal is more than 2000 Hz apart from the electric net work frequency. The processor containing the relay algorithm is the controller of the numerical relay. All features like control, computation, self test, communication etc. are carried out by the Relay algorithm unit. The signal from the input unit is compared with the pre -threshold value in the digital output system.

Numerical relays are normally self-test relays, occupy less space, fast acting when compared with the electromechanical relays. They can store data on Pre-fault as well as post-fault condition. Any CT primary/secondary ratios can be matched. They have less aging problems, better flexibility and number of auxiliary relays can be reduced. Storage of Fault Disturbances is available to study the fault levels as well as status of the CB (values of the current and voltage). The disturbances can be downloaded for analysis. Any change in any digital input signal or protection element output signal is recorded.

Relay settings can be entered through front end panel with a Laptop or HMI. The keypad is normally provided with arrows for menu navigation and for changing the settings. Front port is normally provided with 9-pin straight or cross cable RS 232 serial port for laptop communication. Settings can be saved in 4 to 5 groups and any group can be kept in service. PSL (Programmable and fixed scheme logics) and Topology algorithms needs laptop and soft ware for any modifications. The numerical relays can communicate with other relay or device through Ethernet / Optical fibre cable. These relays can be tested with normal ZFB / OCB or Universal test kits.

SETTINGS AND TESTING OF DISTANCE SCHEME

Distance Relay settings are communicated by the Power Systems wing by considering length of the line, Conductor parameters, loading of the line, instrument transformers available ratios and the distance schemes. After adopting the settings communicated by the Power Systems wing, the schemes will be tested by the MRT wing with a Universal Relay testing kit.
Three phase voltage and current sources are required to test the distance scheme .As per the relay manual and settings communicated by the power systems wing all zone values of Phase to Phase & Phase to ground Faults will be calculated before simulating the fault conditions. Relay characteristics given by the manufacturer will be verified with universal testing kit.

The following points should be observed while testing.

1. Reach check for all zones including reverse zone if provided.
2. Switch on to fault, power swing blocking, Stub Protection, Fault locater initiation, Fuse failure, LBB relay operation and Auto reclose functioning.
3. Trip and annunciation check.

DISTANCE RELAY TESTING

In testing high speed distance relays, it is important to apply simulated fault conditions suddenly; otherwise the behavior of the relay in service may be different from its behavior in test. Checking the relay characteristic by reducing the voltage or increasing the current until the relay operates is not realistic, as the voltage and current change instantaneously in magnitude and phase angle when a fault occurs in service. This causes transient mechanical, electrical and magnetic conditions in the relay which may cause it to over- reach unless its operating time exceeds 4 cycles, during which time the conditions will have disappeared.

Distance relay testing equipment (EE make type ZFB)/ Universal relay test kit is commonly used for testing the distance relays.

Caution: Wherever Main-II relays are being tested, the LBB relay for that breaker should be disenabled lest it would operate the busbar protection.

2.1.5.6 TRANSFORMER PROTECTION

Differential relays

A simple differential relay compares the current at both ends of a protected element as indicated below:

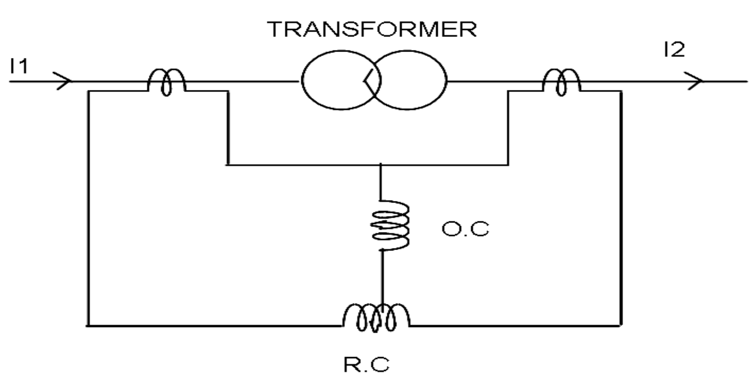
As long as there is no fault within the protected equipment the current circulates between the two CTs and no current flows through the differential element. But for internal faults the sum of the CTs secondary currents will flow through the differential relay making it to operate

PERCENTAGE DIFFERENTIAL RELAY:

Two basic requirements of a differential relay are:

1. It must not operate for load or external faults
2. It must operate for internal faults

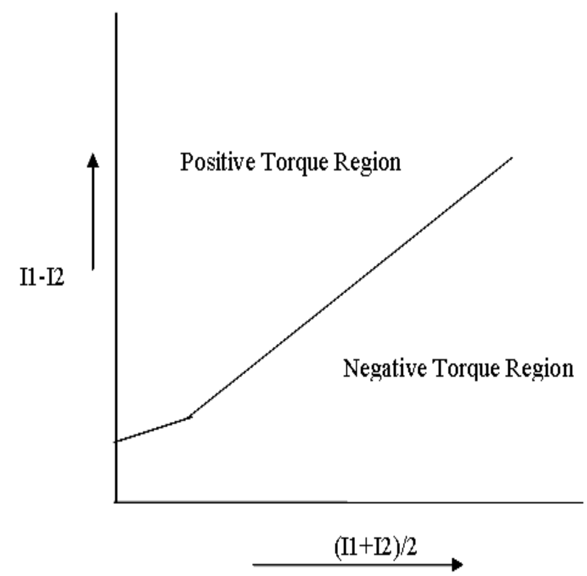
Percentage Differential Relay in a Two Terminal Circuit



As on-load tap change facilities are invariably provided in the grid transformers, any variation from the nominal tap position will result in spill currents in the relay circuits. Further, the CTs are often of different types and have dissimilar magnetization characteristics, again resulting in spill current during heavy through fault conditions.

To avoid unwanted relays operation under the above two conditions a “Percentage bias” differential relays is used.

The operating characteristic of percentage bias differential relay is shown in following figure



In general the transformer primary currents do not equal their secondary current and the connections of the secondary winding do not correspond to those of the primary. In order that the current flowing through the relay should nearly equal zero during normal operating conditions and when external short circuit appear, it is necessary to do everything to have secondary current of the current transformers on the transformer primary and secondary sides of equal order and coincide in phase. This is achieved by accordingly selecting the current transformer ratios, having the method of connection of CTs made in conformity with the vector group of the 3-phase power transformer and by the use of additional auxiliary CTs in the scheme.

SETTINGS AND TESTING OF DIFFERENTIAL RELAY

Differential Relay settings are communicated by the Power Systems wing by considering Power transformer rating, Percentage and number of taps available, current transformers available ratios and the Differential scheme. After adopting the settings communicated by the Power Systems wing the relay will be tested by the MRT wing with a Universal Relay testing kit.

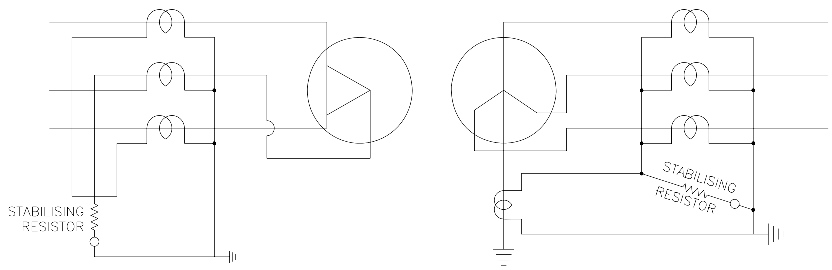
Three phase or Single phase current source is required to test the differential relay.
As per the relay manual and settings communicated, the relays will be tested after simulating the fault conditions. Two numbers single phase/three phase current sources are required to test the relay stability. Current inputs are injected into the differential relay of same magnitude and 180 deg phase shift in the same phase to test the stability of differential relay.

The following points should be observed while testing.

1. Pick up current at the fixed and selected setting
2. Operation of high set element at fixed and selected setting
3. Through current stability check on the existing load
4. Operation of trip and alarm contacts.

Restricted Earth Fault Protection (REF):

An earth fault in the winding is the most common type of transformer fault and is best detected by using a ‘restricted’ form of earth fault protection. In this way time and current setting can be made independent of other protection systems, thus low settings and fast operating times can be achieved. The restricted scheme is a balanced system of protection and can be applied to either Star or Delta windings. The scheme connections of either types of winding are shown in figure.



RESTRICTED EARTH FAULT PROTECTION OF TRANSFORMER

For the star winding, three line current transformers are balanced against a current transformer in the neutral connection; while on the delta side, the three line current transformers are connected in parallel.

An external fault on the star side will result in current flowing in the line current transformer of the affected phase and a balancing current in the neutral current transformer, the resultant current in the relay is therefore zero and hence the relay is stable. During an internal fault, the line current on the line CT gets reversed and hence relay operates.

The arrangement of residually connected CTs on the delta side of a transformer is only sensitive to earth faults on the delta side because zero sequence currents are blocked by the delta winding. For example, an earth fault on the star side transferred through transformer appears on the delta as a phase fault. Therefore the arrangement is an inherently restricted earth fault scheme in this application.

For external faults no current flows through REF unless a CT gets saturated. Hence minimum pickup current setting is adopted (10% or 20% In) on REF relay. Based on the through fault current, the stabilizing resistor is set such that the relay will not operate for external fault when a CT gets saturated. This relay operates only for internal earth faults, instantaneously.

Modern practice is to employ a voltage operated (high-impedance principle) relay for the application. The relay is set to operate with a certain minimum voltage across its terminals. The value of this operating voltage is chosen to be slightly higher than the maximum voltage which can possibly appear across the relay terminals during external fault conditions.

TESTING OF REF Relay: Same as that of Differential Relay.

The following points should be observed while testing.

1. Pick up current at the fixed and selected setting
2. Operation of high set element at fixed and selected setting
3. Through current stability check on the existing load
4. Operation of trip and alarm contacts.

Over fluxing Protection:

Induced EMF in a transformer is given by the equation E = 4.44x Φxfxt
(where Φ = flux generated, f = frequency and t = no. of turns)

Flux **Φ = K (E/f)**

The Over fluxing condition in a transformer can occur during system over voltage and/or under frequency conditions (V/F). This will cause disproportionately great increase in magnetizing current and iron loss. In addition flux is diverted from the laminated core structure into the steel structural parts. In particular, under condition of over-excitation of core, the core bolts which normally carry little flux may be subjected to large component of flux diverted from highly saturated and constricted region of core along side. Under such condition the bolts may be rapidly heated to a temperature which destroys their own insulation and will damage the coil insulation if the condition continues.

The Over fluxing condition does not call for high speed tripping. The tripping can be delayed for a minute or two by which time, the conditions may tend to normal.

Over fluxing relay : In a typical over fluxing relay, over fluxing withstand time of Transformer is generally found to be varying inversely with the working flux density in the core.

The relay with inverse time characterizing measuring element is designed to detect the over fluxing conditions taking into account the over fluxing withstand capability of the Transformer. The highset element provides protection against severe over fluxing condition (which can be blocked when not required)

Setting ranges:
V/F (inverse) K1 : 1 – 1.25 times rated V/F (highest) K2 : 1.0 to 1.5 times K1

Operating times:
Alarm : 0.5 Sec (Fixed)

Time delayed Unit: It follows inverse time characteristic curve. Typical operating timers are a follows:

V/F	**1.01**	**1.05**	**1.1**	**1.15**	**1.2**	**1.25**	**1.3**
Time in Sec.	605	149	55	24.7	9.3	5.8	4.3

Testing of over fluxing relay: A variable voltage source (Variac) is required to test the over fluxing relay. A variable voltage is applied on the relay with the available frequency V/f ratio characteristics and tested for alarm as well as tripping for the set timings.

2.1.5.7 O/L & E/L RELAYS

Types of O/l relays:-

1) Inverse definite minimum type relays (IDMT)

a) Normal Inverse:-

i) 3.0 sec relay – i.e., 3.0 Sec., at ten times pick-up with T.L of 1.0
ii) 1.3 sec. relay – i.e., 1.3 sec at 10 times pick-up

b) Very inverse relays

c) Extremely inverse relays

2) Definite time relays

Instantaneous highset O/L relay supplementing the above O/L relays.
The O/L, E/L relays are used for line protection (for 11 KV to 132 KV) and for Transformer Protection.

O/C relaying is very well suited to distribution system protection for the following reasons:-

1) It is basically simple and inexpensive
2) Very often the relays do not need to be directional and hence no PT supply is required
3) It is possible to use a set of two O/C relays for protection against inter- phase faults and a separate O/C relay for ground faults.

Relay settings:

i) Pick-up settings: For coordination of the inverse time O/C relays, the pick-up current and time delay settings are to be chosen. The pick-up of the relay must be chosen such that it will operate for all short circuits in its own line and provide back-up for adjoining lines.

In choosing the pick-up of the O/C relay, we must also consider that under minimum fault current conditions, the multiple of pick-up (ratio of actual current to pick-up value) is not less than 1.5 so that the relay will operate reliably under such conditions. The pick- up of the phase O/C relay is selected as:

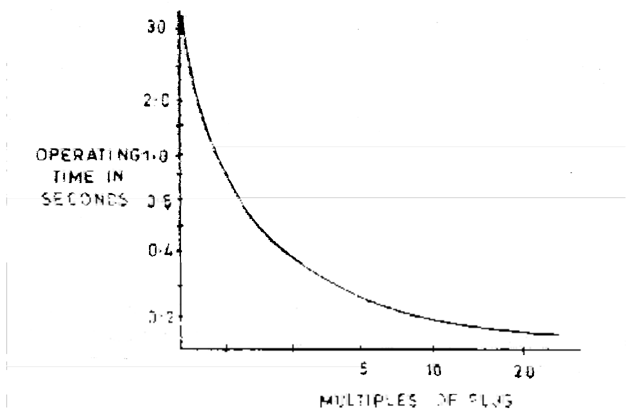
Ip = Ksf x IL (Max) / Kd

Where Ip = Pick up current, IL (Max) = Maximum load current anticipated
Ksf = Safety factor (1.15 to 1.3) and Kd = Drop out to pick up ratio of the relay(0.9 to 0.95)

For the E/F relay, the load current is not a factor in the selection of pickup settings (for the Transformers and EHV lines), and is normally set at 20% of rated current. For distribution lines it is desirable to have higher setting since there will be a ground current normally because of unbalanced load.

ii) Time Setting: The actual operating time of the O/C relay can be varied by proper selection of the "Time Dial Setting" which is selectable from 0.1 to 1.0.

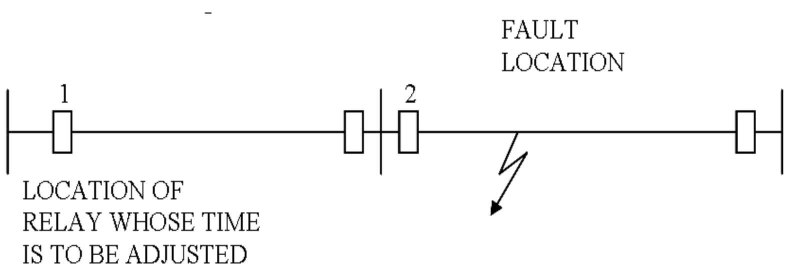
Time Characteristics: A typical time characteristic of an IDMT relay is shown below:



PSM =If (Fault current) / Ip (Pickup current)
Where PSM is plug setting multiplier.

Selective time interval: The time interval between two successive breakers to provide the required selectivity is termed as selective time interval.

Consider the following:



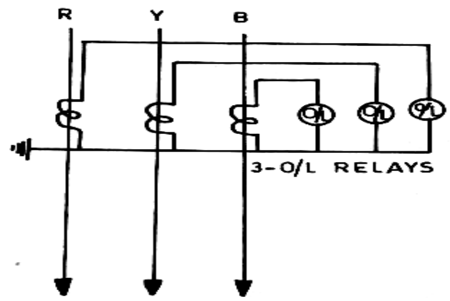
The operating time of the relay at 1 t1 = t2 + b2 + 01 +f
Where t2 = operating time of relay at 2

b2 = breaker operating time at 2
f = factor of safety time
01 = over travel time of relay at 1

The selective time interval S = b2 +01 + f = 0.3 to 0.4 Sec.

Current Transformers and Relay Connections:-

i) Three over current relays for affording protection against both phase and earth faults:-



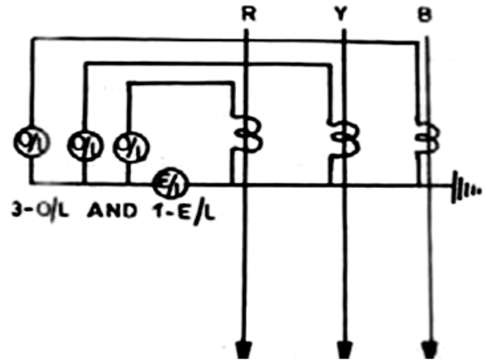
For 3-phase faults the overcurrent relays in all the 3-phases act. For phase to phase faults the relays in only the affected phases operate. For single line to ground faults only the relay in the faulty phase gets the fault current and operates. Even then with 3-O/L relays, the sensitivity desired and obtainable with earth leakage overcurrent relays cannot be obtained in as much as the high current setting will have to be necessarily adopted for the O/L relays to avoid operation under maximum load condition. Overcurrent relays generally have 50% to 200% setting while earth leakage overcurrent relays have either 10% to 40% or 20% to 80% current settings. One important thing to be noted here is that the connection of the star points of both the C.T. secondaries and relay windings by a neutral conductor should be made. A scheme without the neutral conductor will be unable to ensure reliable relay operation in the event of single phase to earth faults because the secondary current in this case (without star-point interconnection) completes its circuit through relay and C.T. windings which present large impedance. This may lead to failure of protection and sharp decrease in reduction of secondary currents by CTs. It is not sufficient if the neutral of the CTs and neutral of the relays are separately earthed. A conductor should be run as stated earlier.

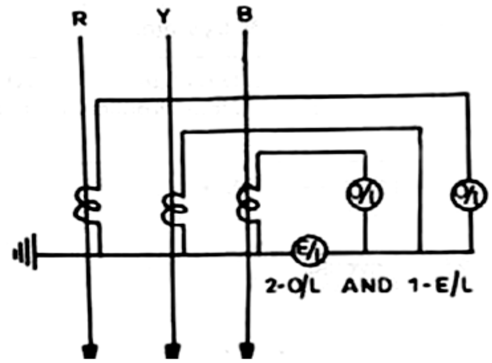
ii) Three overcurrent relays and one earth fault overcurrent relays (3-O/L & 1-E/L):

The scheme of connection for 3-O/L and 1 - E/L relays is shown in figure. Under normal operating conditions and three phase fault conditions the current in the 3-phase are equal and symmetrically displaced by 120 degrees. Hence the sum of these three currents is zero. No current flow through the earth fault relay. In case of phase to phase faults (say a short between R and Y phases) the current flows from R-phase up to the point of fault and returns through ‘Y’phase. Thus only O/L relays in R and Y phases get the fault and operate. Only earth faults cause currents to flow through E/L relay. A note of caution is necessary here. Only either C.T secondary star point or relay winding star point should be earthed. Earthing of both will short circuit the E/L relay and make it inoperative for faults.

iii) Two overcurrent relays and one earth fault relay:

The two overcurrent relays in R&B phases will respond to phase faults. At least one relay will operate for fault involving two phases. For fault involving ground reliance is placed on earth fault relay. This is an economical version of 3-O/L and 1-E/L type of protection as one overcurrent relay is saved. With the protection scheme as shown in Figure complete protection against phase and ground fault is afforded





2.1.5.8 Directional O/L & E/L relays:

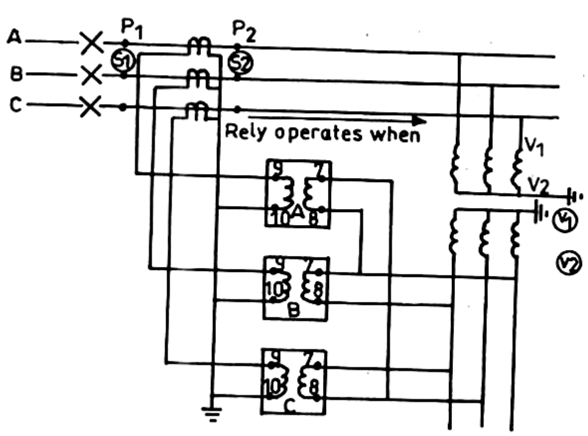
Except at locations where fault power can flow in only one direction, O/C relays must be supplemented by directional elements. They have to be used to discriminate between faults for which a relay should trip and those for which is should not trip according to direction of fault. The tripping direction of the relay is away from the bus, looking into the equipment to be protected.

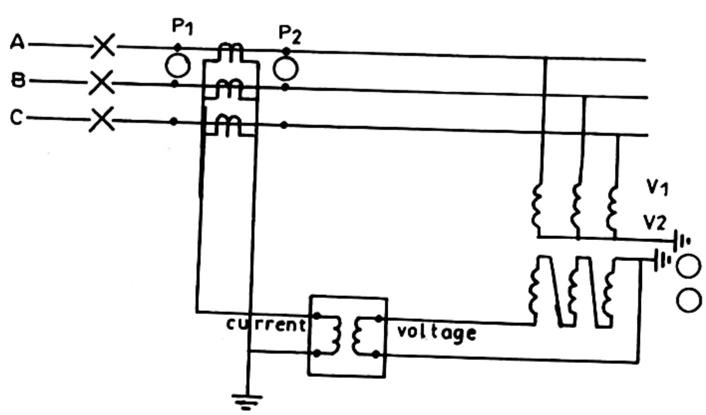
The directional O/L, E/L relays have to be supplied with both current and voltage. Directional O/L & E/L relays are used for all 132 KV lines as a backup protection.

Directional E/L relays are used on HV side of 132/33/11 KV Transformers and on both HV & LV side of 220/132 KV 100 MVA transformers. On 400/220 KV, 315MVA Transformers directional O/L & E/L relays are used on both HV & LV sides.

For all 33 & 11 KV feeders and lower capacity transformers non-directional O/L & E/L relays are used.

The connection diagrams for directional O/L & E/L relays are shown in figure.





Highset (Instantaneous) O/C relay

A highset instantaneous relay is provided in addition to the IDMT relays for the Transformer Protection.

Highset elements in conjunction with IDMT relays may be used on the 33kV and 11 KV feeders for faster clearance of heavy faults.

Testing of O/L and E/L relays

Non Directional O/L & E/L Relays are tested using OCB Kit to check the Pickup value of current and Operating characteristics of relay by injecting the current above the Plug setting value. Relay characteristics also tested with current injection and Timings with Timer.

Characteristics of Standard Inverse (3 secs) relay are given in the table below.

PSM value	**1.35 times**	**2 times**	**5 times**	**10 times**
Time(sec) at TL=1.0	**30**	**10**	**4.3**	**3**

Example: If an Over current relay settings are PSM=100% and TL=0.1

The calculated values are given in the table for checking of relay characteristics.

Current Injected	**Time as per TL**	**Observed Timing**
1.35	**3**	
2.0	**1**	
5.0	**0.43**	
10.0	**0.3**	

For directional O/L & E/L relays voltage source with phase shifter also required for testing of the relay and its characteristics.

The following points should be observed while testing.

1. Starting and Pick up current of the relay as per the plug setting
2. Operation of high set element at fixed and selected setting, if applicable
3. Time of operation as per the relay characteristic
4. Operation of trip and alarm contacts.

2.1.5.9 BUS BAR PROTECTION

Introduction

In olden days, the clearance of busbar faults was done by time delayed distance relays or overcurrent relays, resulting in extension of fault for longer duration of time. In present day's networks, which are highly interconnected, having numerous infeeds and consisting of line sections of varying lengths, clearance of bus faults in zone-2 or zone-3 of a distance relay cannot be tolerated. Also selective tripping becomes a problem on installations having different bus sections. In order to maintain system stability and minimize fault damage due to high fault levels, time delayed tripping for busbar faults is no longer acceptable. It is therefore necessary to detect busbar faults selectively with a unit form of protection scheme.

Busbar protection scheme should possess following:

i) It should be completely reliable
ii) It should be absolutely stable under all types of severe through fault conditions.
iii) It should provide discrimination between sections of the bus bars to ensure that circuits connected to fault busbar alone are isolated
iv) It should be of high speed protection so as to minimize damage and maintain system stability

Advantages of Breaker and a half arrangement: - (One and half Breaker arrangement)

1) It has 3 breakers for two connections. Each circuit is connected to a particular bus.

2) No changeover of line from one bus to the other is required.

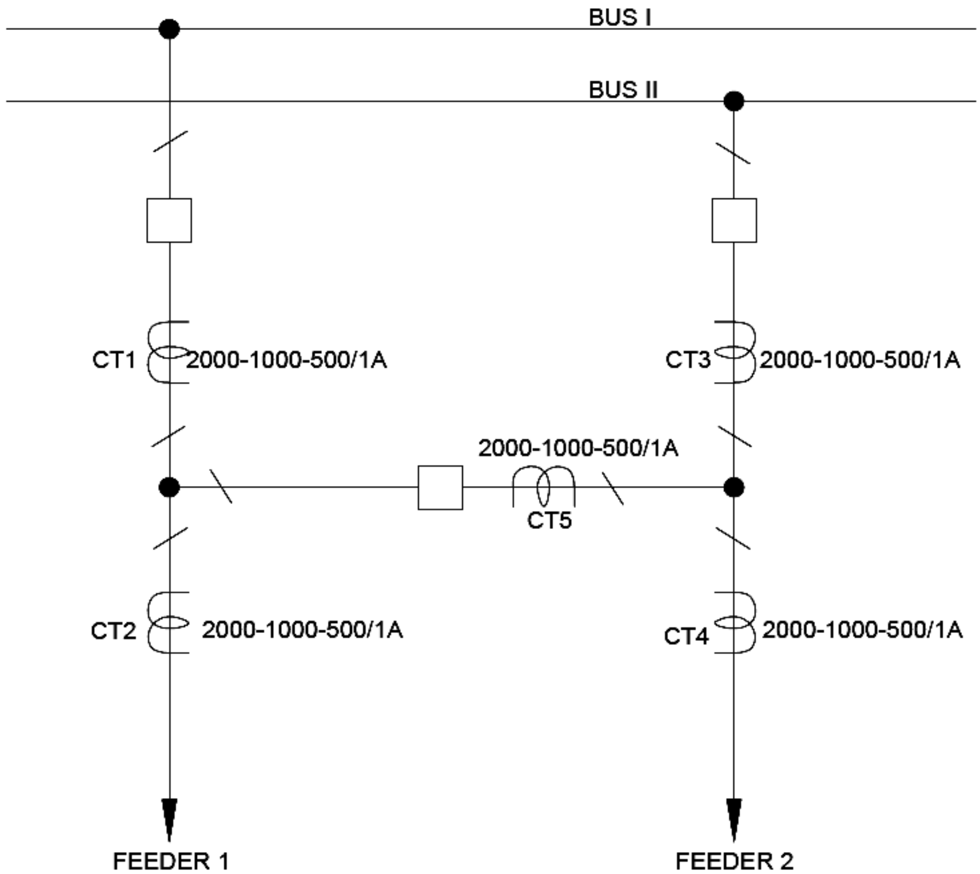
3) This pairing is done such that one is a source and the other a load.

4) For breaker maintenance of any line, the load gets transferred to the other bus.

5) On occurrence of a bus fault or for maintenance all the interconnections will be on healthy bus.

6) Even if both buses become dead, lines can still be in service through the tiebreakers.

ONE AND HALF BREAKER SCHEME WITH 5 CT METHOD



400 KV System Protection:

Generally the 400 KV Substations are provided with breaker and half arrangement. In breaker and half scheme five CTs method or four CTs method will be adopted for protection.

Five CTs Method:

The CTs arrangement is shown in the figure for 5 CTs method in breaker and half scheme.

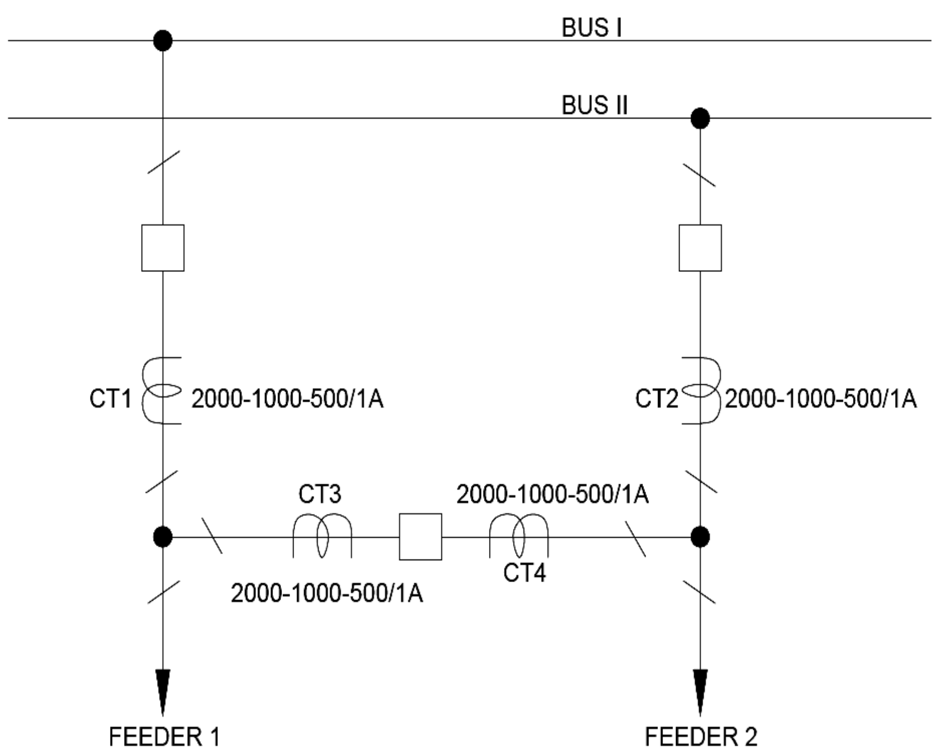
a) Line side CTs will be utilized for Line Protection

b) Bus side CTs will be utilized for bus protection.

c) Teed Protection will be used to cover blind area between bus CTs, Line CTs and Tie Breaker CT.

d) Two differential relays are provided for each T-Section by summating the three concerned CTs i.e. CT1, CT2 & CT5 for T-Section of feeder-1 and CT3, CT4 and CT5 for T-Section of feeder-2.

ONE AND HALF BREAKER SCHEME WITH 4 CT METHOD



Four CTs method:

The CTs arrangement is shown in the figure for 4 CTs method in breaker and half scheme.

a) For feeder protection both bus CT and opposite tie breaker CT will be summated and connected to the relay (CT1 & CT4 for feeder-1, CT2 & CT3 for feeder-2).

b) Bus side CTs will be utilized for bus bar protection.

c) There is no uncovered zone in 4 CTs method.

BUSBAR PROTECTION SCHEMES: Principles & Applications

i) High impedance circulating current scheme
ii) Biased differential or low impedance circulating scheme.

High Impedance circulating current protection

a) Operating Principles:

This is a unit type of protective scheme in which the currents entering and leaving the busbar installations are compared continuously. The objective is to provide fast operation at a low fault setting for internal faults and yet retain stability up to the highest possible value of short circuit current on through faults. Current transformers on each circuit of the busbar are connected in parallel (phase-segregated), which will provide a resultant current to operate a relay for faults internal to the bus bars installations only.

Theoretically, such a system is unaffected by through faults, but in practice, the associated current transformers may not behave ideally when the current exceeds a certain value. Errors in transformation due to saturation on the CT cores may be sufficient to cause mal operation if special precautions are not taken.

Consider the figures 1 (a) & 1 (b). Assuming that due to external fault on line X, CT X gets saturated (i.e.) produces no output. This is represented by short circuit as indicated in figure (b). This is the worst condition for the relay from stability point of view, since the spill current is maximum. The high impedance principle involves choosing impedance high enough to stabilize the relay for this worst condition.

Assuming that current I**y** flows through the saturated CT only. This will develop voltage Vr given by

Vr = Iy (Rct + Rlx)

Where Iy = Fault current in Amps,

Rct = CT secondary resistance & Rlx = Lead resistance

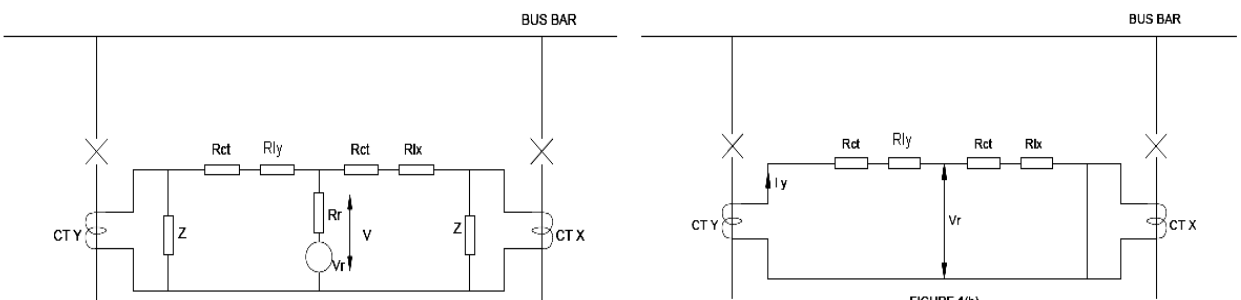


FIGURE 1(a)

FIGURE 1(b)

CIRCULATING CURRENT SCHEME

The relay circuit impedance is then adjusted so that the necessary voltage to operate the relay is greater than the voltage VR.

$Vs = I_r * R$

Where V_s = Setting voltage

I_r = Relay current setting R = Relay branch impedance

To avoid relay operation for inter faults Vs > Vr

For this, an additional resistor called stabilizing resistor Rst is used in series with relay coil resistance Rr **Thus R = Rst + Rr**

During an internal fault the CTs will attempt to transform the full fault current and pass this through relay circuit. This will be many times the setting current and hence voltage output required from CTs will be of the order of many kVs. Practically this is not possible and CTs may get saturated. To enable faster operation of relay, these CTs should have a knee point voltage equal to at least twice the relay setting voltage Vs.

b) Through Fault Stability

The stability limit of the scheme is based on the maximum through fault current. As shown previously, the stability limit is governed by the relay setting voltage. This must not be less than the stability voltage of the system, which is calculated by assuming that maximum through fault current flows through one CT and out through a second one, the latter being the most remote (and hence maximum lead resistance) from the relay associated with the Zone considered. It is further assumed that the DC component of the offset primary current completely saturates the second CT, while the first one continues to transform perfectly.

c) Check Feature

A second line of defence is considered good practice in most schemes of busbar protection, not to give security against mal-operation of the primary protection, but to prevent incorrect tripping due to damage to wiring and equipment from extraneous sources. A check feature is provided by duplication of the primary protection using a second set of current transformers on all circuits other than bus section and bus coupler units. The check system is arranged in a similar manner of the primary protection, but forms one zone only covering the whole of the bus bars and does not discriminate between faults in various sections of the bus bars.

d) Use of Non-linear Resistors

Under internal fault conditions the high impedance relays circuit constitutes an excessive burden to the CTs, leading to development of high voltage. The insulation of CT secondary winding and the relay will not be able to withstand these high voltages, hence it is limited to less than 3 KV peak by use of non-linear resistors called metrosils connected in parallel with the relay circuits

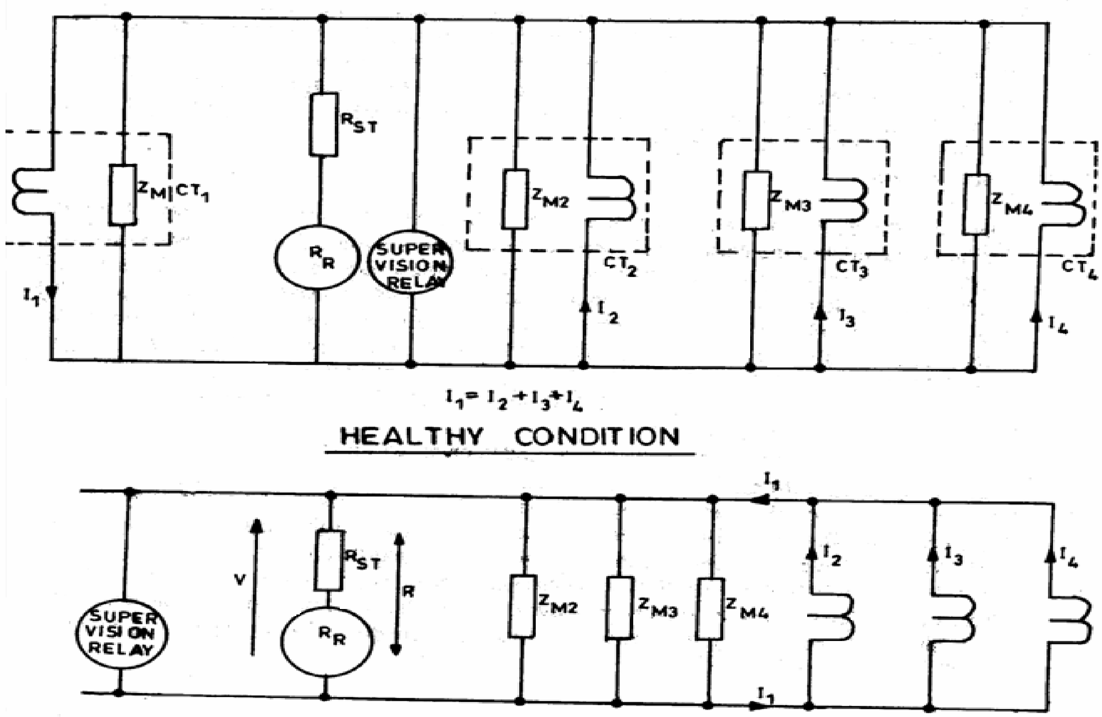
e) Supervision

When a CT secondary winding or connections between CT and the relay circuit get open circuited, the resultant out of balance current will flow through the parallel combination of the relay, metrosil and the CT magnetizing impedance. This may cause unwanted operation of the relay for load or through faults depending on the effective primary setting. This condition of an open circuit can be detected by measuring the voltage across the relay circuit by a sensitive voltage operated relay as shown in Figure. This relay is set to operate when the out-of-balance current equals about 10% of the least loaded feeder connected to the busbar or 25 amperes, whichever is greater.

Operation of the supervision relay is arranged to give an alarm that the busbar protection is faulty, and to short circuit the bus wires for this is necessary to prevent damage to the protective relay and stabilizing resistors.

When the busbar protection has a fault setting below full load of the connected feeders, it is very likely to operate due to an open circuited current transformer. In this case, a check feature is required to prevent tripping. At the same time, it is important that the bus wires are short circuited via the supervision relay to prevent thermal damages to the relay and stabilizing resistors which would otherwise remain continuously picked up under load conditions.

The supervision must be time delayed to avoid a false alarm during genuine fault conditions, typically three seconds is adopted.



CT$_1$ OPEN CIRCUIT, I$_1$ FLOWS THROUGH MAGNETISING IMPEDANCE AND RELAY CIRCUIT IN PARALLEL

FIG(4)

Low impedance biased differential relays: Principle.

An alternative to the high impedance protection described above is the biased differential relay. This type of protection makes use of the fact that during system conditions that give rise to high spill current (namely, heavy through faults), there is high amount of circulating current as well between the in-feeding and out-feeding CT secondaries. The operating quantity in the scheme is the same as before – the secondary differential current. The total value of fault current is usually obtained by means of diodes which route all the secondary currents through the bias circuit. The resultant bias is proportional to the arithmetic sum of all the circuit current, whereas the operating circuit is energized by the vector sum of all the circuit currents. In a biased differential relay, the operating current is arranged to increase proportionally to the load (circulating) current.

Many of the considerations applicable to high impedance schemes are applicable here as well.

For example independent check zone in addition to the main zone and supervision element are provided in this scheme

High impedance vs. Low impedance Schemes:

High impedance as well as low impedance schemes have their own advantages. Both are well-tried, proven methods of providing protection for the busbar.
The most obvious advantage of a high impedance scheme is the fact that it combines sensitivity to internal faults and stability during through faults. The scheme may be made stable to any through fault level, and yet retain sufficient sensitivity for internal faults withweek infeeds.
As it requires only very nominal current for operation, it can deal with internal faults that result in saturation of the CT. The scheme is simple and straightforward to apply.
A true low impedance scheme has the advantage that it can work with CTs of moderate output compared to a high impedance scheme. The scheme does not impose a high burden on the CT.

Also, the scheme can work with CTs of unequal ratio, which is of use in some situations.

In most substations, two nos.class PS cores per feeder are used for busbar protection – one for the main zone and the other for the check zone. Whenever two cores are available, a protection scheme that utilizes both the cores must be employed for busbar protection. Otherwise, one is compromising the security of the protection, as well as underutilizing available resources. A scheme that uses only one core has an inherent disadvantage - its setting must be such that no mal-operation occurs when there is an open circuitry of the CT secondary or the secondary leads.

Under this condition, the concerned zone will see an unbalance current equal to the load current flowing in the relevant feeder. To avoid unnecessary operation of the scheme, the zone settings or the setting of the check relay must be more than the maximum expected load current on any feeder in the substation. Thus, in the case of schemes that utilize only one CT core, the basic sensitivity is poorer than the load current.

When the scheme involves two CT cores, one feeding the main zone and the other feeding the check zone, the above problem does not arise. Open circuiting will affect only on the zones, and the tripping will not be through since the other zone remains stable. The chances of open circuitry occurring in two CT cores simultaneously is very remote. Hence in such a scheme, setting much lower then load current is possible.

In the same connection, it must be pointed out that schemes have check zone fed off
Independent CT cores are clearly superior to schemes that do not have check zones or those that cannot accommodate separate inputs for the main and check zones. First and foremost, a check zone contributes significantly to the security of the scheme.

Testing of Busbar Protection:

A Current source is required to test the Bus bar differential relay. Stability test also conducted on the bus bar differential relay similar to normal differential relay. ABB Make RADSS Differential relay requires variable voltage source (0-400 volts) for testing of the relay.

2.1.5.10 BREAKER FAILURE PROTECTION

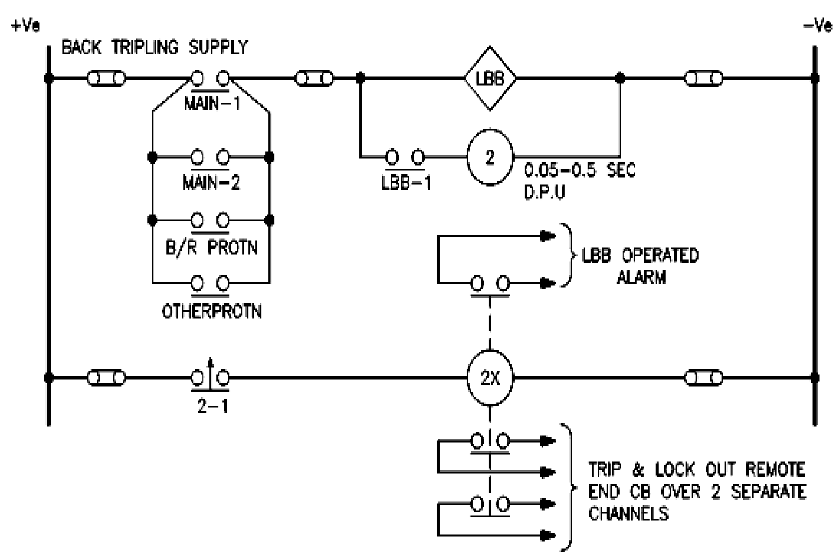
Main protective schemes provided for the line/transformer/generator are required to operate and clear the fault immediately, isolating the faulty section of the system. It is then important that the circuit breaker operates correctly, clearing the fault quickly by tripping. However, if a breaker does not trip in time or fails to trip (either due to mechanical sluggishness or due to inability to interrupt heavy fault current), then the fault gets cleared by backup relays at remote stations.

Increasing power system complexity demands shorter fault clearing times. It is therefore necessary to provide breaker failure relay (also called "Local breaker backup relay" or "stuck breaker protection"). This scheme will isolate the bus to which the stuck breaker is connected, faster. It comprises of O/L & E/L relays with a timer. The LBB relay is energized by trip command of main protection schemes and thus initiate busbar protection scheme after lapse of specified time. Then all the breakers connected to the bus get tripped, thus isolating faulty element.

The general practice is to set the current setting = 20% of In and Time setting = 200 m Sec. The schematic diagrams for the application of the LBB realy (type CTIG) are indicated in the figure (a) below.

Even if the busbar protection scheme is not available, the LBB scheme can be made use of by providing special trip circuit and trip relays similar to that of bus protection trip circuits for each line. A schematic for such applications is indicated in figure (b) below.

BACK TRIPPING LBB THROUGH BUSBAR PROTN, CKTS.



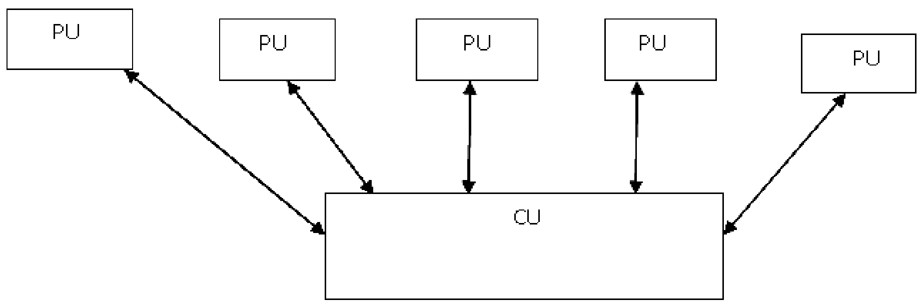
Testing of breaker failure relay (LBB):

A current source with timer is required for testing of breaker failure relay. After operating the Master Trip relay, current required for the set value is injected into the LBB relay and the operation of the LBB Relay is verified as per the time setting.

2.1.5.11 NUMERICAL BUS BAR PROTECTION:

Numerical busbar protection relays are compact, having CT switching, check supervision, breaker failure back up and main busbar differential functions all housed in a single unit.

Block diagram of typical numerical bus bar protection



PU - Peripheral unit   CU - Central processing unit

Each Feeder / Transformer connected to the bus has its own processing unit (PU), which collects information on the status of feeder (Currents, voltages, status of CB and isolator etc...) and communicates it over high speed fibre optic data links to the central unit (CU). The PU collects data (i.e. currents, voltages, status of CB and isolator etc) and processes it to digital form and transmits to central unit (CU). Algorithms are carried out in the CU.

In the Numerical bus bar protection internal LBB feature is available, hence external LBB relay can be avoided in the relay panel. Re-trip as well as back-trip features are available. When a Feeder/ Transformer receives trip command on any protection, the same command will be sent to PU through Master trip relay. After a given time lapse if current is available in the PU (after the receipt of signal from the master trip), PU will give the trip command to the particular Feeder/Transformer which is under fault feeding condition. This feature is called re-trip. After lapsing of internal LBB set time, if currents are available in the same PU, then the PU will send the command to the CU. The CU will initiate trip command to all the Feeders / Transformers connected to the bus to which the faulty breaker is connected; through individual PU. Any external damage of external LBB may lead to trip the all Feeders/Transformers in the conventional / static bus bar protections. The same can be eliminated by using internal LBB feature which is available in the Numerical bus bar protection.

2.1.5.12 UNDER VOLTAGE PROTECTION

Under voltage protection is usually provided for Capacitor banks to protect capacitor units from high

charging currents during low voltages. Unlike O/L & E/L Relays (IDMT characteristics) under voltage relay is meant for instantaneous operation.
Under voltage setting can be kept in the range of 70 -100%

Testing of under voltage relays:

Under voltage relays can be tested by using a Variable Voltage Source (Variac).Predetermined under voltage as per the set value on the relay is applied to the relay by Variac & operation of relay is verified.

2.1.5.13 OVER VOLTAGE PROTECTION

Over voltage protection is required to protect the equipment from voltages above the rated value. Over voltage protection is provided for capacitor banks, Power Transformers, Transmission Lines.
Over voltage setting can be kept in the range of 105-135%

Testing of over voltage relay: Same as that of under voltage relay.

<u>The following points should be observed while testing under voltage /over voltage relays.</u>

1. Starting and Pick up Voltage of the relay as per the plug setting
2. Operation of high set element at fixed and selected setting, if applicable
3. Time of operation as per the relay characteristic
4. Operation of trip and alarm contacts.

Testing of Fuse Failure Relay

Remove main fuse of each phase voltage input to the Distance protection one by one in the relay panel, check for the VT fuse fail alarm and distance protection in block mode.

2.1.6 SURGE ARRESTERS (LAs)

Physical checking of all stacks for cracks/ breakages if any should be done. Proper mounting and tightness of bolts between units, support structures and foundations shall be ensured. All electrical connections, position of voltage grading rings, connection to individual earth electrodes should be checked. The following checks should be done.

- Measurement of insulation resistance of each stack separately and then on the complete arrester
- Check for leakage current
- Testing of counter and leakage current meters
- Checking of earth connection between surge arrester, surge monitor and earth

After initial charging, leakage current flowing through the arrester may be checked and compared with factory value. This shall be reference value for future comparisons during maintenance.

2.1.7 DISCONNECTORS (ISOLATORS) / EARTH SWITCHES

Erection of isolators for correct alignment and tightness of the foundation bolts of the support structure to the foundation and tightness of bolts of the unit to the support structure should be ensured. The following checks shall be done.

- Close/Open operations shall be checked manually and electrically both in local and remote positions. Check for simultaneous making/breaking of contacts in all the phases
- Measurement of contact resistance of the moving and fixed contacts in closed position
- Measurement of insulation resistance of phase to body and between phases
- Check for required rotation of drum switch
- Check for correct operation of the auxiliary switch contacts
- Check for interlock between the isolator and the earth switch (Isolator can not be closed when earth switch is in closed position / Earth switch can not be closed when isolator is in closed position)
- Check for start and running of the drive motor on giving a close/open command and stop automatically after completing close/open operation. Correct functioning of limit switches should be checked
- Interlock between the breaker and the isolator should be checked (Isolator can not be opened when breaker is in closed position)
- Check for corona shield condition where provided
- Check for earth connection from blade to earth for earth switch

2.1.8 DC SYSTEM – BATTERIES AND CHARGERS

- Cells should be erected in row and tier system to facilitate working at a comfortable height. Visual observation of the cell containers, electrolyte leakage, battery room ventilation, air and fumes exhaust arrangements etc.
- Inter cell, inter tier and inter row connections should be checked for proper tightness
- Initial charging of the battery to be done
- Test for Battery capacity
- Test for Battery discharge. Measurement of temperature during discharge test
- Check for electrolyte level up to the mark
- Measurement of specific gravity and voltage of each cell
- Check for working of all panel meters, control switches MCBs etc. on battery charger
- Check for proper working of battery charger operations in both float and boost modes
- Testing of DC earth leakage protection
- Check for working of DC lighting system in the control room

Some Guide lines:

(i) When the battery has to be stored for long period before putting into service, necessary care has to be taken for proper storage, other-wise there may be possibility of oxidation which may have adverse impact on the porosity of the plates. The Cells will develop uniform porosity only after repeated charge/discharge cycles and adjustment of specific gravity has to be made thereafter in all the Cells.

(ii) Variation in the quantity of Distilled water while topping up or failure to top up some cells may also contribute to the variations in cell voltage and specific gravity

(iii) After installation of the battery, if each cell voltage and specific gravity is not uniform and varying then equalizing charge shall be made by adjustment of electrolyte, i.e. addition or removal of electrolyte and/or distilled water is made until the specific gravities are uniform. This adjustment may be repeated after some cycles of operation i.e., after 30 or 45 days.

(iv) Batteries should not be kept under continuous Boost Charge. Batteries shall be on float charge only. After sufficient discharge of the Battery (as indicated by the Voltage and specific gravity of the Cell, Battery shall be kept under Boost charge for the required number of hours only to get the normal voltage and specific gravity.

Sealed Maintenance Free Batteries (Valve Regulated Lead Acid Batteries):

VRLA batteries are normally supplied in fully charged condition. They can be installed and put into service immediately. If these batteries are stored for a long time, self discharge due to internal chemical process takes place and if the discharge is not timely compensated by adequate charge, the battery may not pick up charge even in the boost mode later. Life of such battery gets reduced. Delivery of VRLA battery should therefore be so planned that the battery can be commissioned within a reasonable time (say one or two months time) after its receipt from the

works. Alternately the battery may be kept on trickle (float) charge to compensate for the internal discharge and voltage of each cell monitored till the battery is commissioned. VRLA batteries are compact and temperature sensitive. Hence they need to be installed in a temperature controlled area, preferably in control room which is air-conditioned.

2.1.9 CAPACITOR BANKS

Installation:

- Clean capacitors thoroughly
- Tighten up all electrical connections and other screws and nuts
- Measure the IR values with a 500 V megger between terminals and earth. Minimum value shall be 50MΩ. Do not put a u nit with less than 50 MΩ into service
- Ensure free circulation of air around capacitor units. Adequate clearances as per the drawing shall be maintained
- Temperature of atmosphere surrounding capacitor units shall be within their temperature category under steady working conditions.
- Adequate earthing of capacitor banks (structures etc.) to be ensured.
- Neutral of star connected capacitor banks with residual voltage transformer should not be earthed.
- Before commissioning a capacitor bank, capacitance of each capacitor shall be measured with a capacitance meter. These shall be compared with the value obtained by calculation using the formula

$$C = \frac{KVAR \times 10^9}{2 \pi f (V)^2} \quad \text{micro farads}$$

where V is the rated voltage of capacitor and KVAR is the rated KVAR of capacitor. As per IS the tolerance in the capacitance value for a capacitor unit is + 10% to - 5%

Operating Instructions: The following points may be checked before energizing the capacitors:

a) Supply voltage, frequency and temperature of the area
b) Ensure no hardware or tools are left inside the rack assembly. This may cause short circuit and breakdown.
c) Ensure proper ventilation
d) Ensure all electrical and mechanical connections are done properly and tightly.
e) Ensure that there is no oil leakage from terminal at collar of the bushing and welded seam of the capacitor unit

After charging the capacitors, the following checks shall be made:

a) Voltage : Within 110% of rated voltage especially during light load periods
b) KVAR : Operation KVAR is within 130% of the rated KVAR at the highest system voltage
c) Temperature rise: Container temperature should not exceed 75 Deg. C. This should be measured by having a thermometer fixed with the wall of the container, keeping the bulbs at one quarter of height of capacitor box down from the top edge.
d) Fuse: ensure correct type and rating of fuse
e) Light Load: At light load capacitors cause voltage rise in the system exceeding the permissible value some times. They may have harmful effects on capacitor or on other electrical equipment. Voltage at no time should go beyond the rated voltage by more than 10%.

For capacitor banks operated with series reactors, operating the bank with less number of units than originally supplied may cause the capacitor with series reactor tuned to fifth harmonics.

Best way to check the healthiness of a capacitor is to check the capacitance with a capacitance meter, partial or complete failure of a capacitor can be established from this. Shorting of one internal series group on a capacitor results in a predictable increase in the capacitance level. This is the basis for the capacitances of partially failed capacitors.

2.1.10 GENERAL CHECKS

General checks to be made on various other equipment/ items before commissioning of a substation are given hereunder.

Earthing: Check for earth mat spread covering the entire yard as per the drawing and the mat is buried at least 500mm below the ground surface. Check whether all the joints between horizontal and vertical strips are welded. Check each earth pit for the size and materials used as per the drawing.

Ensure that metal structures, metal boxes/kiosks, bodies of the equipment, neutrals of power and station transformers, surge arresters etc. are properly connected to the earth mats and earth electrodes with adequate size GI/MS flats as per the drawings. Measure the earth resistance of individual earth electrodes and the combined earth resistance of the station and record these values for future reference. Ensure that the combined resistance is less than 1 ohm.

Control Cables: Check for proper laying of cables in the cable trenches and providing of identification tags on the cables at either end. Ferrules must be provided on each core of the cable at both ends for easy identification during maintenance.

Statutory Clearances: Spacing between adjacent equipment in the switch yard shall be checked for adequacy as per standards and as shown in the drawings. Clearances between live part to ground and between phases shall be measured for adoption as per standards. Phase to phase and phase to ground clearances of main and auxiliary buses should be checked.

Lighting: Yard lighting distribution in the switch yard, in the control room and in the other areas of the substation premises should be checked for adequacy and for proper working, including control and protection.

Fire Protection System: Correct working of Compressors should be checked. Oil level, condition of valve plates, gaskets etc should be checked. Working of Diesel Engine, Jockey pump, V-belt drive should be ascertained. Check the healthiness of battery and working of fire alarm system. Auto start of Hydrant pumps, Diesel Engines etc. to be checked. Operation of Deluge system, outlet pressure, alarms, starting of diesel/electrical pumps etc. to be checked.
CO_2, Foam and any other type fire extinguishers installed in the substation should be checked for the weights of gas, operation of regulating valves etc.

Standby Diesel Generator set: Check for oil leaks, and all gasketted joints. Air intake system, cooling system, fuel system, Exhaust etc. should be checked for proper working. Main Generator's condition and IR values to be checked. Control and protective relays of generator to be tested.

2.1.11 COMMUNICATION:

Power Line Carrier Communication (PLCC) cubicles/ Optic fibre Termination Equipment (OTE) and other electronic equipment intended for Automation should be installed in an air-conditioned room and should work in a dust free environment. Proper connections to the equipment to be checked. Battery (48V/24V) for communication can be installed in the main battery room housing the station battery. Proper working of other accessories such as Exchanges, battery and chargers, Motor-Generator sets etc. should be checked.

Apart from the above public telephone, either a land line or a cell phone to be provided in the substation. Working of the entire communication system well before the commissioning of the substation should be ensured. Communication should be established with Load dispatch centre and the controlling stations and should be working before the SS is programmed for commissioning. This helps in receiving directions from load dispatch and concerned control wings at head quarters for compliance and carrying out control and relays operation requiring on line communication.

Any defects/omissions noticed during checks and testing of relays should be reported to construction unit (EE/SE TLC). The TLC unit shall arrange for rectification of all such defects/ omissions through the supplier/contractor as the case may be and report compliance to the TL&SS unit. After ensuring every thing in a fit shape, the SE (TL&SS) shall inform the TLC unit, zonal CE, CE (Transmission), CE (Construction/head quarters) and the Grid operation unit (CE G.O) for arranging charging of the new Substation/bay/transformer duly giving the programme. The programme should be coordinated with the service personnel of the manufacturers/ contractors for testing and commissioning of the transformers/other equipment as per the provisions of contract.

On receiving the intimation for charging a new installation from the field, the Grid Operation Unit, will arrange to coordinate with other concerned units (Power systems, Communication, construction etc.) in preparing the charging instructions and communicate to field. Charging operations shall be carried out strictly in accordance with the charging instructions communicated by the Grid Operation Unit.

Communication between the LD center and the new installation should be ensured before charging. Steps indicated in the charging instructions should be followed in correct sequence with due intimation to the load dispatch center. In case of an interconnected substation, it is desirable to charge the Power transformer from the low voltage side.

Power transformer should be initially charged on no load (idle charge), preferably at rated or reduced voltage and the noise from the transformer (humming) should be observed. It should be uniform from all sides of transformer. Oil and winding temperatures should be monitored at regular intervals. It is likely that during filteration at site in the pre-commissioning stage air might have got trapped inside the transformer. It is prudent to switch off the transformer after a few hours of idle charge (4to6 hours) and open the air release valves provided on the equalizer pipes and on the top of main tank to allow the trapped air to escape. This is indicated by oil gushing out freely from the valves without any bubbles, after which the air valves should be closed tightly. After release of air the transformer may be charged and kept under idle charge for few more hours (say 8 hours) and temperatures monitored. Transformer may be loaded after ascertaining normal temperature rise.

2.2 LINES

2.2.1 Checking of lines

During the last stages of completion of the line or immediately after completion of construction, statutory inspection of the line should be arranged by DE/SE (O&M) through the maintenance staff to check the fitness in all aspects for charging the line. Any defects/omissions noticed should be immediately reported to the construction unit [EE/SE (TLC)]. The SE/EE (TLC) should arrange for rectification/replacement of defects/omissions through the contracting agency/through the construction staff, in the shortest possible time before the contractor winds up the work, and make the line fit in all respects for charging.

Various checks to be done during statutory inspection are mentioned below:

i) Right of way/way leave/electrical clearance

ii) Foundation and Revetments/Protection Work

iii) Tower and Tower accessories

iv) Hardware Fittings

v) Insulators

vi) Conductors and Earthwire

vii) Accessories for conductor and Earthwire

viii) Aviation Warning Signals (Lights/globules/painting)

2.2.1.1 Right of way/Way leave/Electrical clearance:

Minimum right of way (in metres) for lines of various transmission voltages, Electrical clearances for power line crossings as per the standards and as given in the tables already should be inspected and ensured for compliance with the standards.

Check that Jumpers in the tension tower are properly intact with conductor and form a parabolic shape in order to achieve adequate clearance from support steel structure.

Ground clearance

Normally at the time of construction adequate clearance is provided between lowest conductor and ground, but due to delay in charging/commissioning there arc chances of dumping/heaping soil, earth and concrete etc. or stacking bricks etc. which may cause reduction in ground clearance. In such cases the stored materials shall be removed.

Ensure that there is no temporary or permanent construction of houses or shades below the line. If the same has been constructed and are found to create clearance problem they shall be removed before charging.

Ensure that all clearances as per the approved drawings are adopted.

The ground profile at the time of commissioning shall be checked with the profile approved at the time of check survey.

Ground clearance of lowest conductors at critical points/where ever the lowest conductor is touching the ground shall be checked in the field from any of the prevalent method and the values of ground clearance at these critical points shall be recorded in the prescribed format.

In case of hilly Terrain and for building clearance, the side clearance from conductors and jumpers at critical points shall also be checked and recorded for all phases of conductor/earthwire towards hill/ building side.

2.2.1.2 Foundation and Revetments/Protection work:

Foundation:

There shall not be any damage/uneven settlement of foundations. For this, tolerances in levels of all four stubs should not exceed the criteria provided in the Annexure-C of IS -5613 (Part -3/Section 2):1989.

It is to be ensured that back filling of foundation is properly done. Soil shall be filled over all legs up to ground level.

Extra surface earth after foundation back filling shall be removed from legs of the tower beyond a lead distance of 30 mtrs.

Any crack or break in chimney, if found, shall be repaired.

Revetments/Protection:

Cracks/damages to revetments shall be repaired. Weep holes shall have slope such as to flush out the deposited water away from tower platform.

In case of hilly terrain, the benching area should be leveled properly. The area around tower shall have proper slope for drainage of rain water.

2.2.1.3 Tower and Accessories:

Normal Tower

After completion of a transmission line, all the towers shall be thoroughly checked before charging the line. Special attention shall be given to the points as mentioned below:-

Deformed/Buckled/missing/Rusted Members and Nuts and Bolts

It is to be ensured that no members bent, deformed or rusted have been used in towers and if so, the same shall be replaced.

If any members is found missing, a new member shall be Fixed as per erection drawing of Towers.

Nuts shall be sufficiently tightened for the required Torque. Minimum 2 to 3 complete threads shall be projected outside the nut. All bolts shall have their nuts facing outside of the tower for Horizontal connection and Downwards for Vertical connections.

Nuts & bolts shall be properly tack welded/punched as per the specification and proper zinc rich paint shall be applied. It shall be ensured that the circular length of each welding shall be at least 10mm.

It shall also be ensured that all extra blank holes provided on tower members are filled with correct size of nuts & bolts.

Special Towers

In addition to the above checks for towers, ladders and platforms provided in special towers shall be properly tightened and no foreign material shall be left out on such platforms.

Earthing of Towers

Ensure that proper earthing of tower has been done and earthing strip is neither damaged nor broken and is properly fixed to the stub.

In case of counter poise earthing, it is to be ensured that earthwire is sufficiently buried in the ground and no where it has drag out during cultivation. The length of counter-poise is normally 30 mtrs as per specification.

Before charging of the line, ensure that resistance is below 10 ohms. If the value (before stringing) has been recorded higher than 10 ohm earthing shall be changed to counterpoise type.

Earthing of special towers shall be verified as per approved drawings applicable for special towers/special foundation. (In case of anchor foundation bolt/anchor plate welded with last leg of special tower.)

2.2.1.4 Tower accessories

All the danger plates, number plates, circuit plates, and phase plates shall be in position & and as per the specification.

All plates shall be properly tightened.

It shall be ensured that phase plates are fixed in correct phase sequence, especially at transposition towers, the phase plates in the correct phase sequence shall be provided at each tower or end tower as per the specification.

It shall be ensured that the anti-climbing device (ACD) is provided, at suit-able height of tower. In case of barbed wire ACD, barbed wire shall be tightly fixed. In case of spike type ACD, all spikes shall be properly fixed and oriented towards outer face of tower.

It shall be ensured that the step bolts (for normal towers) are provided up to the peak of tower. Any missing step bolts shall be replaced.

Fixing of birds guards (up to 220 kV/wherever applicable) shall be ensured.

2.2.1.5 Hardware Fittings:

Tightening of all bolts and nuts are to be checked up to specified torque.

Check the fixing of all security clips (W/R type clips).

Surface condition of corona control rings and distance/alignment between Tower side arcing horn (wherever applicable) and line side arcing horn/corona control ring to be checked as per approved drawings.

Ensure that, no. of insulators per string is lesser by one number as compared to no. of discs in normal string (up to 220 kV) at approach spans to the terminal ends (approx last 1.5 KM).

To restrict the swing of jumpers, the provision of Pilot strings in case of Tension Towers shall be verified from the approved drawings.

2.2.1.6 Insulators:

All the damaged/broken insulator discs shall be replaced.

Unusual deflection in suspension strings if observed shall be rectified.

The insulators shall be cleaned before charging.

IR value of individual disc of at least 5 insulators at random shall be checked by 5/10 kV Megger.

2.2.1.7 Conductors and Earth wires:

Surface of the conductors shall be free from scratches/rubs

Ensure that conductor strands are not cut and opened up. Wherever strands are found cut/damaged/scratched, they must be repaired with repair sleeves/repair protective rods in case the nos. of damaged strands are within specified limits (normally up to $1/6^{th}$ nos. of strands in the outer layer).

2.2.1.8 Accessories for Conductor and Earth wires:

Joints

All joints on conductor/earthwires shall be away from the tower at a distance of at least 30 metres or as provided in the Technical specification.

Ensure that not more than one joint in a conductor is provided in one span.

Ensure that no mid span joint is provided in major crossings for main roads, railway crossing and major rivers etc. or as provided in specification.

Ensure that all mid span joints on conductors/earthwire and repair sleeves of compression type are free from sharp edges, rust and dust.

Clipping

Ensure that conductor is not over tightened in the suspension clamps.

Spacers, vibration dampers and copper bonds

Placement and no. of dampers on each phase shall be verified as per damper placement chart.

Spacing of Vibration dampers from the tower and spacing between damper to damper in case two Vibration Dampers (VD) were provided, shall be verified as per the damper placement chart. All loose/ displaced VD shall be properly tightened/relocated and missing VDs shall be provided. Ensure that no copper bond is loose/missing.

Jumpers

Verify Electrical clearance of jumpers to tower body as per design. All the jumpers shall be checked properly. In case, jumpers (conductor/earthwire) are found loose, they shall be tightened sufficiently.

Foreign material

Ensure that all foreign materials viz dead bird. fallen tree branches, bird nests etc. on conductors, earthwires, Jumper, insulator string, cross arms are re-moved.

Others

It shall be ensured that all temporary/local earthing, guys, T&P (Tools and Plants), foreign material and other loose material which were used during stringing/tower erection have been removed.

In case there is any change in the ground profile before commissioning of line from the approved profile, the extra earth/obstruction/temporary sheds/any other construction shall be removed.

2.2.2 Pre-commissioning Testing and Charging Procedure

First the construction unit should ascertain that the transmission line to be energized is ready for operation and has been properly handed over (released) in writing. This will include all safety aspects, Electrical inspector clearance, Statutory clearance, and final inspection, if any.

All the concerned authorities shall be informed before commissioning the lines and their approval obtained in accordance with Indian Electricity Act, 1910 and Indian Electricity Rules, 1956. Electricity Supply Act 1948 and Electricity Act 2003. Before charging of the line PTCC approval from P&T Dept. shall be obtained.

Line charging instructions received from CE/Grid are clearly understood by the project in charge and DE/SE (O&M) and doubts, if any, are to be got clarified prior to the energization of the line.

Once the line is handed over for charging no work shall be permitted without a valid **Line Clear (Work Permit).**

When the whole system has been energized, including the AC line, it will be kept in this state for 8 hours or more for "soaking" with continuous inspection and monitoring. However recommendations of CE/Grid may be checked. Otherwise it may be put into continuous operation.

2.2.2.1 Safety Procedures:

Energization implies an abrupt and serious change of the working conditions in the plant.

In order to avoid serious accidents, thorough information must be given to all personnel involved in the construction of transmission line. EE/SE, construction concerned with the project, must ensure that due publicity has been made to the public in all the villages/areas along the line route cautioning them against climbing the towers etc. and intimating about the date on which the line will be charged. It is also to be confirmed that the Contractor shall not carry out any job on the said line without a valid line clear.

It shall be ensured before charging that all men, material, Tools and plants and any temporary earthing on any part of the entire length of line are removed.

It must be ensured that any power supply / low voltage charging used as anti-theft measure must be disconnected and isolated to avoid accidental connection.

All equipment tests and pre-commissioning tests must have been completed, reconnected (in case cables were isolated for testing purpose) and documented.

The system must be formally declared ready for energization and handed over for operation in writing.

2.2.2.2 Handing over:

The transmission line shall be inspected prior to energization and a formal handing over document to be jointly signed by the representative of SUPPLIER (if available), Contractor , and EE construction concerned. However all contractual taking over has to be resolved separately as per the terms and conditions of the contract. This Handing over shall be limited to the extent of completion of erection and readiness for energization.

Any balance activities remaining to be done, are to be listed jointly by EE (construction) and contractor and signed jointly. These documents are also to be retained at field with a copy to Head Quarter. These balance works are mentioned in the following category.

i) List of balance works in any part of the line

ii) A list of temporary arrangements introduced.

iii) Check list records properly documented, completed and signed.

iv) Original tracing of Profile, Route Alignment, Tower Design, Structural Drawings, Bill of Materials, Shop Drawings, Stringing charts (initial and final as applicable) etc. of all towers/line submitted to APTRANSCO.

Whether the balance activities mentioned above are solved or whether any minor points which do not influence charging of the line remain shall be recorded. In case of such minor issues, handing over of the transmission line shall be accepted by the pre-commissioning team. This handing over only for energization with or without remaining activities shall be made by the EE/SE construction to the SE (O&M) and the CE zone concerned in writing.

2.2.2.3 Control and Protection System:

Before energization it must be ascertained that all control and protective systems for the unit to be energized are operative. This includes confirmation that the protections have been properly tested and that the tests have been documented.

It also includes verification by inspection or otherwise, if necessary by repetition of trip test, that the protections are actually functionally enabled, as counter check.

2.2.2.4 Despatch Procedures:

All operational activities (switching etc.) must be coordinated and communicated with the State Load Despatch Centre.

2.2.2.5 Switching Procedures:

For each activity the instructions to the operators and the communications to the dispatchers will be made in writing or by confirmed telephone messages. The switching procedures first to be properly documented step by step and understood by everybody involved in the switching operation prior to the energization. Any clarification required in the procedures must be resolved.

The implication of this is that each and every activity must be listed and described, so that complete information is available for detail investigation, if required in future.

2.2.2.6 Testing and Measurement Procedure:

Before commissioning of the line following tests may be carried out

Earth Resistance Measurement: Prior to the testing of soil resistivity and earth resistance the operation manual of the testing instrument available at site may be referred and procedures to be adopted for measurement of soil resistivity and earth resistance followed.

Insulation Resistance Test: This test may be carried out with the help of a 10 or12 KV megger preferably power driven to ascertain the insulation condition of the line. In case 5 kV megger is used, it shall be ensured that the induced voltage (CVT reading) is LESS than the instrument withstanding capacity otherwise it is likely that the instrument may be damaged.

This Test is to be carried out First prior to the continuity test.

Conductor Continuity Test: The objective of this test is to verify that each conductor of the overhead line is properly connected electrically (the value of electrical resistance of line does not vary abnormally from that of a continuous conductor of the same size and length). The electrical resistance of the conductor shall be measured with a Wheatstone bridge or other suitable instrument, if available taking the safety aspects of Equipment as well as testing Engineer.

A simple method of continuity test is illustrated below :

Once the insulation test is completed and the results confirm no short circuit check the following :

Sending End	**Receiving End**	**Results**
CLOSE R-Ph GS	MEGGER R- Ph	ZERO/LOW
OPEN Y – Ph GS	MEGGER Y-Ph	HIGH
OPEN B-Ph GS	MEGGER B-Ph	HIGH
OPEN R-Ph GS	MEGGER R-Ph	HIGH
CLOSE Y – Ph GS	MEGGER Y-Ph	ZERO/LOW
OPEN B-Ph GS	MEGGER B-Ph	HIGH
OPEN R-Ph GS	MEGGER R-Ph	HIGH
OPEN Y–Ph GS	MEGGER Y-Ph	HIGH
CLOSE B-Ph GS	MEGGER B-Ph	ZERO/LOW

(ALL GS OPEN CONDITION)

GS means GROUND SWITCH

Test results as above indicate continuity of the line.

The continuity Test of the line with proper phase indication or phase marking can be checked by continuity test as described below:

Sending End	Receiving End Megger between	Results
CONNECT R&Y PHASE B-PHASE & ALL GS OPEN	R PHASE & Y PH Y PHASE & B PH B PHASE & R PH	ZERO OR LOW HIGH HIGH
CONNECT R & B PHASE Y PHASE & ALL GS OPEN	R PHASE & Y PH Y PHASE & B PH B PHASE & R PH	HIGH HIGH ZERO OR LOW
CONNECT Y & B PHASE R-PHASE & ALL GS OPEN	R PHASE & Y PH Y PHASE & B PH B PHASE & R PH	HIGH ZERO OR LOW HIGH

Test results as above indicate it correct marking of the phases.

Phase Sequence

Once the line is charged from one end, without closing the Breaker at the other end the Phase sequence is to be checked from the CVT output by the help of Phase Sequence Meter. In case there is other feeder/feeders available Phase sequence is to be rechecked by the measurement of secondary voltage of both the Feeders (New line & existing charged line).

Let the secondary Voltage of CVT be 110 volts (ph to ph) for both the Circuits. In case of correct Phase Sequence the voltage reading shall be as follows:

NEW CIRCUIT	EXISTING CIRCUIT	VOLTAGE
R-Phase	R-Phase	0
R-Phase	Y-Phase	110
R-Phase	B-Phase	110
Y-Phase	R-Phase	110
Y-Phase	Y-Phase	0
Y-Phase	B-Phase	110
B-Phase	R-Phase	110
B-Phase	Y-Phase	110
B-Phase	B-Phase	0

In case the results are not matching the phase sequence is to be rechecked and reconfirmed before closing the breaker.

Signature Analysis: There could be in-homogeneities on the line due to improper joints in the conductor, loose jumpers, leakage points, electrical path to ground due to disc puncture etc. To check the condition of the line, signature analysis of the line may be carried out using an off-line fault locator. Signature analyzer indicates the degree of faults from the minimum to the major fault in progressive numbers. A no fault line or uniform line is indicated as "-". All types of fault can be detected with an accuracy of +/- 100mtrs.

After attending to rectification of all defects noticed, the condition of the line may be verified using the fault locator and the signature so obtained may be recorded as reference for comparison with the values observed during maintenance later.

Before conducting the signature analysis, isolators should be kept open at both ends. Earth switch should be closed. After connecting the fault locator unit to system ground, connections to the overhead lines should be given. Before commencing the test, the line earth switch should be opened. All safety precautions such as wearing gloves, rubber shoes etc. should be taken.

2.2.2.7 Energization:

After completion of all the required tests and checks satisfactorily, the SE/DE (O&M) will fix programme for charging the line in consultation with the EE/ SE (Construction), who will arrange to get the service persons from contractor/supplier for supervision of testing and commissioning of the line as per the provisions of contract. Test reports and the programme for charging should be intimated well in advance to zonal CE, CE (construction), and CE (GO). The Grid operation unit will prepare charging instructions in consultation with communication, power systems and construction units, and communicate the same to SEs TL&SS and TLC. Suitable charging instructions will be prepared depending on the type of line to be charged, viz. radial line/ inter connecting line/ power evacuation line etc. Charging instructions shall be strictly followed in correct sequence while charging the line.

2.2.2.8 Observation and Duration:

The line may be charged on no load at power frequency voltage preferably for 24 hours and monitored for any abnormalities.
Visual and audible inspection of the relevant equipment and reading of permanent instrumentation will be made.
The system shall be idle charged at least for 8 hours. During this time continuous monitoring and inspection will be done in control room, auxiliary systems areas and switch yards.

This will include frequent, scheduled inspection of all equipment and reading of all permanent instruments and recorders, and surge arrester counters, especially system parameters.

2.2.2.9 Passing Criteria:

Neither insulation breakdown nor actuation of protective system must occur. Observe for equipment behavior, noise, vibration, temperature rise etc. Any abnormalities should be noted and corrected.

Corona discharges may not be "unreasonable". Local discharges that may be attributable to sharp points shall be carefully located and recorded. After termination of the energization the equipment shall be closely inspected and the points rounded or covered.

No unscheduled changes of system nor of equipment is permitted during the 8 hour energized condition.

2.2.2.10 Documentation:

Switching and operational activities and all readings of permanent instruments will be recorded in a regular manner in the operator's log. Copies of this log, notes on special observations from inspections and other measurements will constitute the test records.

MANUAL ON MAINTENANCE OF EHV SUBSTATIONS AND LINES

MAINTENANCE PROCEDURES:

Introduction:

Proper maintenance of electrical systems helps in minimizing/preventing unwarranted breakdowns of equipment/ lines improving the reliability and generating revenue. Periodical or preventive maintenance is normally followed to keep the equipment continuously in service for desired output. Condition based maintenance is the most accepted and adopted concept in maintenance now a days which helps in providing advance information about the health of the equipment to take corrective action in advance.

As the system is growing, it is getting more and more complex. Due to stringent regulations the utility cannot afford to have breakdowns in the system resulting in interruption of power supply to the consumer. On the other hand equipments are getting older and are more prone to failure. Equipment overhaul and major maintenance are also expensive and need to be planned based on the condition of the equipment rather than on a periodic basis as a routine.

3.1 SUBSTATIONS

3.1.1 PREVENTIVE MAINTENANCE PROCEDURES:

3.1.1.1 General Instructions for Maintenance of Switch Yard Equipment:

External Cleaning: The insulators of the transformer bushings; circuit breaker; CT; CVT; isolator shall be cleaned from salt and dirt/dust deposition together with the cleaning of the other insulators in the substation. Frequency of this cleaning depends on the polluting atmosphere. For installations with higher atmospheric/saline pollution, cleaning frequency may be increased and these may be suitably protected against pollution.

Rust Protection: All steel enclosures such as marshalling kiosks, boxes parts of the operating mechanism are made of steel and are surface treated against rust. In spite of the good rust protection, minor corrosion will occur after some years, especially when these are standing in strong corrosive surroundings. The rust stains shall be sand papered away and new rust protection shall be painted or sprayed on. As rust protection, grease G or Tectyl 506 is recommended.

Lubrication: For lubrication, the lubricants recommended by manufacturers shall primarily be used. This is especially important in cold climates with temperatures below - 25°C. The bearings of the breaker and operating mechanism of isolator and breaker are to be lubricated with grease G although these normally do not need lubrication before the major overhauls. Plain bearings in mechanism details such as arms, links and link gears are also to be lubricated with grease G. These bearings shall be regularly lubricated with a few drops of oil B. The teeth in the gear shall be lubricated with grease G. Dryness of driving mechanism may lead to mal-operation and failure.

Treatment of Contact Surfaces: The contacts of breaker / isolator / ground switch shall be treated according to the following directions:

- Silvered contact surfaces: Silvered contact surfaces shall be cleaned, if necessary, with a soft cloth and solvent (Trichloroethane). Steel brushing or grinding is not allowed.

- Copper surface: Copper surfaces shall be clean and oxide free. If necessary, they shall be cleaned with cloth and solvent (Trichloroethane) or steel brushing. After steel brushing, the surface shall be cleaned of loose particles and dust.

- Aluminum surface: Aluminum contact surfaces shall be cleaned with steel brush or emery cloth. After making the surface dry and free of dust by wiping with a dry cloth, a thin layer of Vaseline shall be applied. The joint shall be assembled within 15 minutes.

Moving Contact Surfaces:

- Silvered: Cleaned if necessary, with soft cloth and solvent (trichloro ethane). No steel brushing.

- Non-silver coated: Cleaned as silvered surfaces, can be steel brushed. After steel brushing they shall be thoroughly cleaned of loose particles and dust

- Lubrication: Lubricant – grease K is applied in a very thin layer on the surfaces of the male contact and the puffer cylinder. The superfluous grease is carefully removed.

Safety: Before taking up any work in close proximity of live equipment or any work on a top of transformer where safety clearance is not sufficient, proper line clear (permit to work) shall be taken. Person authorized to issue such clearance and the authorized person who receives it shall independently ensure that proper isolation has been carried out and earthing provided at appropriate locations. Whenever earthing needs to be removed to conduct any test on equipment, the same shall be done after obtaining the permission from the person issuing line clear.

Precautions: Maintenance shall be carried out by skilled persons having adequate knowledge and experience on the equipment. Maintenance Engineer shall be aware of the concepts of condition monitoring tests and update himself with the developments in condition monitoring methods. Maintenance Engineer should have knowledge of the equipment and the testing instruments used so as to safeguard the equipment, testing instrument and more important, human life. The boundary of work area shall clearly be identified and caution to be exercised not to inadvertently contact the live neighboring components. Proper isolation of AC and DC power supply shall be ensured to avoid electric shock. Always ensure using proper ladder and other safety equipments while climbing to higher places. Make shift arrangements may lead to accident.

Analysis of Test Results: All test results are to be carefully analyzed and preferably compared with earlier test results and pre-commissioning test results to arrive at conclusion. A trend analysis is more important to identify the evolving defects and to take corrective action.

3.1.1.2 TRANSFORMERS AND REACTORS:

In order to provide long and trouble free service, it is important that a careful and regular supervision and maintenance of the transformer and its components is carried out. The frequency and extent of such a supervision and maintenance is dependent on the experience, climatic conditions, environment, service conditions, loading pattern etc. All work done on transformers should be recorded in history register for future reference.

General Supervision:

Dirt and Dust: The external transformer surfaces shall be inspected regularly; and when required cleaned of dust, insects and other air borne dirt. Transformers/reactors installed near polluting industry/cement plants, etc., need special care and more frequent cleaning of the bushings and other components. All Marshalling Boxes and OLTC cubicle are to be kept properly closed so that there will not be entry of dust inside, which is difficult to clean.

Rust and Treatment: A regular inspection is to be done on the external surface of the transformer tank and radiators. Possible rust damages shall be removed and the surface restored to original state by means of the primer and finish-paints of the transformer to minimize the risk of corrosion and its subsequent spreading. These checks also include looking for signs of oil leaks on gasket areas and welded areas containing oil. The touch-up paint' as and when required as per site condition and re-painting is to be done once in five years. However transformers in coastal areas and more corrosive atmosphere may require more frequent painting.

Steel wire brush and abrasive/emery paper no.100, 150/180 and 320 general purpose thinner, synthetic enamel paint of approved shade (IS: 2932), Zinc chromate primer (IS: 104) and paint brush may be required for the above work.

Using a wire brush, remove all loose flakes of paint, ensuring that the surrounding areas are given attention. Using the abrasive paper, rub the damaged areas so that all contours to the edges are smooth. Prominent dent marks and pits on external surfaces are to be filled up with knifing putty. When putty is dry, smoothen it with emery paper and clean with clean rag. Clean the local area with a suitable solvent like methyl alcohol that contains no salts.

Depending upon the extent of the damage, i.e., depth, apply the necessary number of coats of paint to build up .the overall thickness (min. 80 microns). One undercoat and one top coat after two coats of primer are to be given.

Paint should be applied so that the layers feather in with each other and there should not be any steps in layers. For radiators, spray painting (50-60 psi) should only be applied.

Allow each coat of paint to dry before the next coat. This procedure must only be carried out either in warm, dry weather or while under cover with clean plastic sheet.

Mechanical Damage: Checks must be carried out for mechanical damage to the fabrications and associated equipment. Particular attention should be given to vulnerable areas such as radiators. If damage is seen on the equipment, a decision must be taken as to its seriousness. It may be necessary to take corrective actions such as replacement of an item of equipment.

Check out all Joints for Signs of Leakage: All joints, both welded and gasketed, must be checked for signs of oil leakage. If there is any doubt of a leak, the area must be cleaned of oil, using a suitable solvent (methyl alcohol) and sprayed with liquid chalk. This will promote the flow of the leak and give a good indication as to the exact location of the leak, if there is one. If a leak is suspected on a gasket, the joint must be tightened until such time that it can be changed with a new gasket. If a leak is apparent at a welded joint once again clean the area and apply liquid chalk and allow to dry. This will highlight the point exactly if there is a leak. It must be properly repaired with welding procedures when convenient. Prior to leaving the leak, it must be highlighted with a marker, or something similar, so that it is not lost when permanent repair takes place.

Other areas commonly associated with oil leaks are drain plugs in radiators, valves in the oil management and cooling system and the gas and oil actuated relay.

Check for Oil Level: All oil levels associated with the equipment including oil conservator and all oil filled bushings shall be checked. Also the oil in the oil seal should be maintained. Some bushings in transformers will be below the conservator oil level and some above. If there is leakage in bushing at the oil end, the level will be low or high depending upon the level of conservator. External leak on bushing will lead to indicate low oil level. This is to be observed accordingly and if there is leak, action is to be initiated immediately as bushing failure may lead to failure of entire transformer.

OLTC oil conservators are always kept at lower level compared to the main conservator tank so that OLTC oil will not mix with main tank oil. An increase in level of oil in OLTC conservator tank indicates internal leakage and action is to be taken accordingly. After energizing of the transformer, a certain settling may appear in sealing joints. This applies especially to sealing joints with plain gaskets that are not placed in grooves. These should therefore be re-tightened. For correct torque for tightening the bolt, the manufacturer's recommendations are to be followed.

After completing all the checks ensure that all materials or tools, used for maintenance work, have been removed. All clothes and other debris must be disposed off. The transformer compound should be left in a clean and tidy condition.

Silica Gel Breather: In open breathing transformer, the breather plays active role in maintaining- the transformer dry by admitting dry air when transformer breathes. In transformers having air cell or diaphragm, the breather ensures dry air inside the air cell or above the diaphragm. The silica gel inside the breather becomes pink from bottom to top over a period of time.

Any de-colorization at top or sides indicates leakage in container and needs to be attended immediately. In order to prevent severe deterioration of the silica gel, it is recommended that it is replaced when half to two thirds of the silica gel has become pink in color. Failure to do so will severely retard the drying efficiency of the breather. The silica gel can be reactivated by heating it to

130°C-140°C in a ventilated oven until it has achieved bright blue color. Check that the oil level is correct in the Oil Cup at the breather base and fill oil if the level is found low.

Note: Do not exceed the temperature stated above, otherwise the color impregnation will be destroyed and the silica gel will turn black.

Immediately after re-activation the loose silica gel must be placed in a sealed container to prevent absorption of moisture on cooling. The silica gel should be stored in sealed condition until required for use.

Self indicating (blue) silica gel contains the dye cobalt chloride which has been classified carcinogenic by a European Commission directive and is a banned substance because of its potential health hazards. In Europe the silica gel breathers are to be disposed in 'Class l' disposal locations for hazardous waste products or incinerated.

Drycol Breather Check: Drycol breathers are provided in some transformers where air cell is not provided. It condenses the moisture inside the conservator and brings it out as water droplets. Silica gel breather will also be provided for these transformers.

The following checks need to be carried out for Drycol breathers:

Operation of counter reading: Check on a regular basis that the counter is functioning. Record the figures each time a check is made so that a progressive check is recorded.

Defrost current condition indicates that water is still being ejected from the breather

Press the test button and check that a defrost current is being indicated. Check that the two red neon lights are ON and the amber neon light is OFF.

Release the test button and check that the counter has advanced one count and that freeze current is indicated.

Checks for conservator:

Visual Check for Conservator Oil Level: The transformer oil conservator is provided with an oil-level indicator indicating "low" to "full" with grading. These indications are relative to temperature of the operating equipment. The oil level indicated should be recorded along with top oil temperature.

If corrected oil level is normal, no additional action is required, whereas if it is above or below the normal level, it may be necessary to remove or add some oil. The correct oil-filling level is specified on an information plate that is placed on the transformer rating plate panel. At an oil temperature of + 45°C, the conservator should be half filled; if the level exceeds the "full", oil must be drained off. If the value is "low" or "min", oil must be filled in.

Leakage Test for Air Cell:

Normally leakage test for air cell fitted inside the conservator is carried out before installing the conservator in its position or at the time of major overhaul. During service, the leakage in the cell or in the sealing of the conservator can be detected by the oil level in the prismatic oil level indicator, if provided, on the conservator. If there is no leakage, the prismatic oil level indicator will show "Full" oil level. However, in case of leakage, the oil level in the prismatic oil level gauge shall be lower than "Full" level.

For releasing air from Conservator fitted with Air Cell: Pressurize the Air Cell up to the maximum pressure specified by the manufacturer and open the air vent valves provided on the top of the conservator until oil starts coming out. Then close the valves. Release pressure from the Air cell and refit breather.

For releasing air from Conservator fitted with Diaphragm type Air Sealing: Open the air release valve provided on the top of the diaphragm and start filling oil into the conservator, preferably from the valve provided at the bottom of the conservator. Filing of oil from oil filling valve at the bottom of transformer tank is avoided because it may result in entry of air into the transformer and may get trapped and result in unnecessary accumulation of air in the Buchholz relay at a later stage.

Continue filling oil into conservator until it is full and oil starts coming out of the air release valve. Close the air release valve after ensuring that entire air has come out from the oil portion below the diaphragm.

Slowly drain the oil from the conservator until the oil level as indicated on the oil level gauge corresponds to the transformer oil temperature.

Before making the leakage test of air cell for the transformer in service, oil should be drained out to the lower level of conservator. Apply pressure as specified by the manufacturers to inflate the air cell. Adjust the pressure after 6 hrs, if required. Check temperature and maintain the air cell at almost the same temperature for 24 hrs. If there is no loss of pressure during 24 hrs, it means the air cell is not having leak.

Any heating process like welding, grinding etc. are not allowed on the assembled conservator fitted with air cell diaphragm as it is highly sensitive to heat.

Marshalling kiosks/Cubicles: Checks on physical parameters like condition of paint, condition of door seal, lights and heaters, cable tightness etc shall be done.
Operation of alarms and indicating lamps to cover all system functions shall be ensured.

Valve Operational Checks: Transformer and associated equipment must be out of service, isolated and earthed while carrying out these checks. Valve operational checks are done at the time of erection or at the time of major overhaul.

The checks include checking each valve for free operation, adequate greasing and for padlocking wherever provided.

Each valve shall be returned to its "in service" operating position (open or closed) and locked after the checks have been completed.

Checks for Auxiliaries

Cooling System: The cooling surfaces of radiators shall be inspected regularly and cleaned of dust and dirt. The cleaning is suitably carried out by means of water flushing at high pressure. Precaution should be taken to cover the fan-motor so that water may not go inside. Alternatively cleaning can be done with cleaning solution and cloth.

The fan-motors are provided with permanent - lubricated bearings and double sealing rings. The motor bearings are axially clamped with spring-washers. If the sound level of the fan increases, then first tighten all mounting supports and in case any abnormal sound is noticed in fan motor, then action should be taken for repair/ replacement.

Cooling System-Fans-Controls: Fan controls are designed to operate both manually and automatically with set temperature. Manual, Control is to be turned 'ON' to operate cooling system for checking. Oil pumps need to be checked by observing their flow gauges. Measurement of pump current reveals any abnormality. Any significant imbalance of current between the terminals greater than 15-20% is indicative of the problem with the pump motor. Checking for correct rotation of fans and pumps to be ensured as reverse rotation may not provide desired result.

Calibration of OTI/ WTI: Temperature indicators in transformers are used for both indication purpose and as protective device. The accuracy of these devises is to be ensured for correct operation of alarm and tripping and also to prevent mal operation. The Indicator temperature bulb is to be removed from its well on the side/ top of transformer. Using a temperature controlled calibration instrument in oil bath the temperature of the bulb should be slowly raised in steps of 5°C and observed for temperature reading. If the temperature deviation is more than ±5°C compared to the standard thermometer reading, the thermometers are to be replaced with healthy one.

Checking of Cooler Control, Alarm and Trip Settings: Setting of temperature should be as per approved scheme. Access the local winding / oil temperature indicator and rotate the temperature indicator pointer slowly to the first stage cooling value (say 65°C). Check that the fans of those coolers set to first stage are operating. Continue rotating the pointer to the second stage cooling value (say 80°C). Check that the fans of those coolers set to second stage are operating. Continue rotating the pointer to the alarm value (say 110°C). Continue rotating the pointer to the trip value (say 125°C). Observe for alarm and trip signals in the panel.

Pressure Relief Device: The Pressure Relief Valve (PRV) is mounted at the transformer top body. Internal arcing in oil inside transformer generates excessive gas pressures that can severely damage equipment and cause extreme hazards to personnel. The pressure relief device is intended to minimize the extent of damage by quickly operating and venting out the pressure. It will reset when the pressure becomes normal. A pointer is provided to indicate the operation of this relay and the relay is connected for tripping the transformer on operation. There will be oil spillage whenever the relay operates. Smaller transformers are provided with explosion vent where the diaphragm will rupture due to heavy internal pressure and releases the pressure. The diaphragm needs to be replaced when it operates. There are some transformers fitted with sensitive sudden pressure relay, which operates on rate of change of differential pressure and trips the equipment.

Buchholz Relays: The use of gas-operated relay as protection for oil-immersed transformers is based on the fact that faults as flashover, short-circuit and local overheating normally result in gas-generation. The gas-bubbles gathering in the gas-operated relay affect a float-controlled contact that gives an alarm signal.

For testing of the contact functions, buchholz relays are provided with a test knob on the cover. Unscrew the protective cap and press down the knob by hand. The spring loaded knob with a pin inside the relay actuates first the alarm device and then the tripping device. After testing, screw on the protective cap again.

Checking the operation of Buchholz relay in case of low oil level is carried out by closing step valve in both sides of the relay and draining of oil through oil drain valve provided in Buchholz relay. First alarm and then trip contact should operate to indicate healthiness.
To check the relay for oil surge, manufacturer's recommendations for particular relays have to be followed.

Bushings: Bushings are most failure prone in any transformer/ reactor. Failure of bushings could lead to the fire in transformer and total damage. For uniform voltage distribution across capacitance graded bushings, bushing porcelains shall be cleaned from dust and dirt during shutdown maintenance. In areas where the air contains impurities such as salt, cement dust, smoke or chemical substances, shorter intervals are required.

On Load Tap Changer: To enable operation of taps during service, On- Load Tap Changers (OL TC) are provided in EHV transformers. OLTCs may be located either on the high voltage winding or the low voltage winding, depending on the requirements of the user, the cost effectiveness of the application and tap changer availability. OLTC being a current interrupting device requires periodic inspection and maintenance. The frequency of inspection is based on time in service, range of use and number of operations.

Precautions: Testing of OLTC shall be done under shutdown i.e. after de-energizing the transformer by isolating the transformer from all sides.

Tap Changer Hand Operation: Check hand operation of the tap changer up and down the full range before electrical operation is attempted and that the handle interlock switch does not allow electrical operation while the handle is inserted. In addition where single phase tap changers are employed check their tap positions agree and are reached simultaneously at motor drive unit head. Continuity check should be done for any discontinuity during tap changing operation by connecting an analogue multi meter across HV and IV bushing in case of auto transformers and relevant winding in case of two winding transformers and change the tap positions from maximum to minimum.

Check for proper operation of out of step relay, tap changer surge relay and remote operation and tap indication of tap changer.

Inspection and Maintenance of OLTCs: Normally the temperature of the OLTC compartment may be few degrees Celsius less than the main tank. Any tep1perature approaching or above that of the main tank indicates an internal problem. Prior to opening the OLTC compartment, it should be inspected for external symptoms of potential problems. Such things as integrity of paint, weld leaks, oil seal integrity, pressure re1ief device and liquid level gauge are all items which should be inspected prior to entering the OLTC.

Following de-energization, close all valves between oil conservator, transformer tank and tap-changer head, then lower the oil level in the diverter switch oil compartment by draining of oil for internal inspection. Upon opening the OLTC compartment, the door gasket should be inspected for debris that might indicate abnormal wear and sliding surfaces should be inspected for signs of excessive wear.

Finally, the tap selector compartment should be flushed with clean transformer oil and all carbonization which may have been deposited, should be removed. Minimum BDV should be 50kV and moisture content should be less than 20 PPM.

3.1.1.3 CIRCUIT BREAKERS:

Main parts of a circuit breaker are interrupting chambers and the operating mechanism. The interrupting chambers normally do not require routine preventive maintenance other than cleaning but operating mechanism does require proper upkeep.

Interrupting Chamber: Interrupting chamber is an enclosed unit mostly filled with oil or SF6 gas. 33kV and below Circuit breakers have vacuum interrupting chambers also. There is stress on the contacts during fault current interruption and damages may happen to arcing contacts or main contacts. The breaker interrupting chamber is recommended to be opened only based on condition monitoring tests or as per advice of the manufacturers.

In SF_6 circuit breaker, whenever there is fault interruption, there is formation of metallic fluoride inside the arcing chamber. This fine white/ gray powder has high dielectric strength when it is dry. Moisture absorbent material is provided in circuit breaker to keep the gas dry. The absorbent material is to be changed as per advice of manufacturers. The absorbents are normally packed in air tight sealed container and it should not be exposed to atmosphere for long time (not more than 15 m) as it may absorb moisture from air. SF_6 pressure and dew point also should be monitored since these parameters are vital for successful fault clearance by the breaker. If there is loss of SF6 gas pressure, then leakage test with halogen leak detector is to be carried out to identify the leak area for rectification.

In minimum oil circuit breakers, breather is provided to keep the breaker free from moisture. Breather silica gel need to be monitored and changed when ever required. The level and quality of oil are also to be monitored.

Operating Mechanisms: Normally circuit breakers have pneumatic, hydraulic and spring operating mechanisms. As operating force is required for closing and tripping of circuit breakers there can be combination of these mechanisms in one circuit breaker. Since operating mechanisms have a number of moving parts, they need more maintenance such as greasing, lubrication, cleaning, setting of limit switches, etc. Compressors/ oil pumps/ spring charging motors also require maintenance. Other maintenance on particular operating mechanism such as air compressor maintenance, nitrogen priming pressure checking in hydraulic mechanism, checking of over travel, checking of gaps in operating plunger of close/ trip coils etc. are to be carried out as specified by the manufacturers.

SF6 Gas: The density of SF_6 gas is about five times that of air and heat dissipation is also much more than air. At atmospheric pressure, dielectric strength of SF 6 gas is about 2.4 times that of air and at 'about 3 kg/cm^2 it is same as that of oil. As SF_6 is Green House gas, it needs to be handled carefully and should not be let in to the atmosphere.

Emptying and Re-filling of Gas: The breaker is evacuated by means of the gas treatment equipment that purifies and also compresses the gas for storage, so that it can be reapplied. For economic and ecological reasons, SF_6 contained in electrical equipments, should not be vented into atmosphere. Prior to the gas removal, the quality of the SF_6 gas should be tested.

Operational contamination should be absorbed with suitable filter unit provided in the gas handling plant. Such filters/ sieves should already be installed into the SF_6 gas maintenance/ handling unit. When SF_6 is suctioned from a gas compartment, the gas is passed automatically through filters, which dry and purify the gas.

After maintenance/ overhaul of the circuit breaker, it should be evacuated by vacuum pump before filling in the SF_6 gas so that SF_6 gas does not mix with ambient air and also humidity and dust particles are removed from the Breaker. With vacuum pump a final vacuum must be reached less than 5 mbar.

Grading Capacitors: Grading capacitors are provided in multiple break Circuit Breakers to equalize potential difference across the breaks. If grading capacitors are provided, it is to be ensured that they are properly connected and there is no leakage of oil from the grading capacitors. The insulator porcelain should be kept clean and condition monitoring tests are to be carried out to identify the healthiness.

Pre-insertion Resistors: Pre-insertion Resistors (PIR) are provided in circuit breakers to limit surges during switching. Unless any abnormality is noticed during condition monitoring tests, no internal inspection of the PIR contacts of resistors is required. The insulators are to be kept clean and proper tight connection with the circuit breaker has to be ensured.

3.1.1.4 CURRENT TRANSFORMERS:

Visual Inspection: Current transformers are normally filled with oil and have oil impregnated paper insulation for both primary and secondary .winding. Careful inspection is to be made for any trace of oil leakages. Oil leakages are more prone through cemented joints or secondary terminal box due to improper sealing of terminal studs. As CTs have less oil quantity small leakage may lead to exposure of paper insulation and subsequent moisture absorption.

If bellows are provided in CTs, the position of bellow indicates either leakage of oil or expansion due to internal gas generation. Both the conditions are serious for the life of the CTs and immediate action to be initiated for rectification.

Visual inspection is also to be carried out on the healthiness of terminal connections, condition of porcelain, development of cracks, chippings, cleanliness of insulator surface etc.

Maintenance of Gaskets: Marshalling boxes, CT terminal boxes are to be properly sealed to prevent any dust, rain water and insects. Door gaskets are to be changed periodically to give proper sealing. All door bolts/ latches are to be properly tightened and never left loose.

Secondary Terminals Connections: Stud type terminals are preferred in Marshalling box cable terminals. This gives better grip even if more than one wire is connected to one terminal. But pin type terminals are also provided in some cases. Since wires may get loose due to vibration, climatic condition, it is required to check tightness of terminals periodically to avoid mal-operation/ non-operation due to improper contacts. All terminals of unused CT secondary terminals are to be properly shorted to avoid development of abnormal voltage and subsequent failure of CTs in case they are left open. The tan∂ test tap is to be properly earthed to avoid damage to insulation.

Primary Terminals: Thermo vision scanning indicates proper connection of primary terminal. If thermo vision is not carried out, physical checking of terminal connection is to be done with proper torque. All corona shields are to be provided and any damaged corona shield to be replaced with new one. As CT primary carries heavy current, any loose joint may lead to arcing and welding of terminal connectors.

In coastal and industrial areas where pollution levels are high, due to saline atmosphere/ chemical contamination, porcelain insulators of electrical equipment shall have higher creepages.

3.1.1.5 CAPACITOR VOLTAGE TRANSFORMERS/ POTENTIAL TRANSFORMERS/ COUPLING CAPACITORS:

Visual Inspection: The bellows provided in most of the CVTs are not visible from outside. CVTs/ PTs and CC are also oil filled equipments and oil leak is to be observed. If oil leak is observed in anyone stack, the entire CVT is to be replaced. CVTs are tuned units and replacement of anyone stack is not recommended to avoid phase angle errors.

Electro-Magnetic Unit: Electro-Magnetic Unit (EMU) of CVT houses the secondary transformer, Compensating reactor and Ferro resonance suppression circuit. The colour of oil indicated through the gauge glass gives some indication of the healthiness of the internal components. Any abnormal heating may also be observed through Thermo vision scanning.

Secondary Voltage: Deviation in secondary Voltage of CVT is clear indication of failure of capacitor elements. Action shall be taken to replace CVT if secondary voltage in any one CVT is abnormal (may be +2volts and - 4volts). Continuing the equipment in service beyond this stage may lead to failure/ bursting of CVTs.

Other Maintenance: Maintenance of Marshalling box gaskets, tightening of secondary terminal connections and tightening of primary terminal connections, etc., are also to be ensured for healthy operation. It is to be ensured that all extra holes at Marshalling boxes are properly plugged and the boxes made vermin proof. The anti--condensation heater and the thermostat are to be kept in working condition to keep inside of the panel dry.

3.1.1.6 DISCONNECTORS:

Disconnectors have main current carrying arms and operating mechanism for connection and disconnection. Being off-line devices, they are normally air break type. Normally horizontal double break, Horizontal center break, Pantograph, Vertical break Disconnectors are in use in EHV substations.

The alignment of Disconnectors is very important for smooth operation. The limit switches, the healthiness of auxiliary contacts needs to be checked periodically. The main contacts are to be inspected and made smooth if any pitting marks seen. The corona shields are to be kept smooth and shining and checked for tightness of fitting. Damaged corona rings should be replaced. All moving parts are to be lubricated for smooth operation. The gear mechanism and motor normally do not require any maintenance and manufacturer's' recommendation should be referred for maintenance of gears.

Earth Switches: The earth switch is a safety device and smooth operation is to be ensured by proper alignment. The earth blade contacts are to be cleaned properly for proper contact and contact resistance to be measured to ensure healthiness. The earth connection from blade to earth is to be carefully checked. All the joints should be tightened. Flexible copper braid connections are provided and healthiness ensured. All moving parts should be lubricated for smooth operation.

3.1.1.7 LIGHTNING (SURGE) ARRESTERS:

Surge arresters are to be maintained to give protection to other connected switch yard equipments. Cleaning of porcelain insulators is necessary for uniform voltage distribution. Voltage grading rings are to be properly positioned and checked for tightness and any damaged rings to be replaced. Healthiness of surge monitors is to be checked and if found defective the same may either be replaced with healthy one or shorted to minimize earth resistance. Healthiness of earth connection is to be checked as it plays a vital role on the operation of the surge arrester. Failure of one stack causes over stressing of remaining stacks. Whenever one stack fails, it is better to change the entire arrester as otherwise the stressed stacks will start failing along with the new stack.

3.1.1.8 BATTERY AND BATTERY CHARGERS:

Substations generally use Lead Acid batteries / Nickel-Cadmium batteries for DC supply. Valve regulated lead acid batteries (maintenance free batteries) are also in use for substation applications.

Cell containers are to be kept always clean to avoid surface leakage. Any leakage is to be attended immediately. Vaseline J white petroleum jelly is to be applied on battery terminal and inter-cell connectors, nuts and bolts to avoid sulphate deposit. The rubber seal at the base of the terminals and on cell lid is to be fitted properly and to be replaced if damaged. All connections are to be checked for tightness. Maintaining level of electrolyte in flooded cells is very important to avoid sulphation and permanent damage of the cells. Distilled water is to be added to make up to the level.

VRLA batteries need controlled temperature. Where VRLA battery is used, the battery room temperature is to be maintained -using air conditioner as the temperature plays vital role on the performance of the battery.

Battery Chargers: Battery charger is to be maintained for keeping the battery always charged and also to supply normal DC load for operation. If the charge / discharge ammeter does not show current on the charge side, then the float charger is not giving output. Defect should be located and corrected. In case of failure of float charger, the boost charger may be used as float charger as per design.

Charger panel is to be kept clean, free from dust and all terminals to be checked periodically for tightness. The battery maintenance and condition monitoring is to be carried out as per schedule to keep the DC system in healthy condition.

Battery Capacity Testing:

Initial Requirements: The following list gives the initial requirements for all battery capacity tests except as otherwise noted.

a) Equalize the battery if recommended by the manufacturer and then return it to float for a minimum of 72 h, within 30 days, prior to the start of the test.
b) Check all battery connections and ensure that all connections are proper and clean.
c) Record the specific gravity and float voltage of each cell just prior to the test
d) Record the electrolyte temperature of 10% or more of the cells to establish an average temperature.
e) Record the battery terminal float voltage
f) Take adequate precautions (such as isolating the battery to be tested from other batteries and critical loads) to ensure that a failure will not jeopardize other systems or equipment.

Discharge Test: The ampere-hour capacity of a battery varies with the rate of discharge. The capacity is more at slower rates of discharge and less at higher rate of discharge. The Indian Standards adopt 10 hr. rate as the standard rate of discharge for specifying the AH capacity of stationary batteries.

a) Disconnect the charging source, connect the load bank to the battery, start the timing, and continue to maintain the selected discharge rate.
b) Maintain the discharge rate until the battery terminal voltage decreases to a value equal to the minimum average voltage per cell as specified by the design of the installation (e.g. 1.75 V) times the number of cells.
c) Read and record the individual cell voltages and the battery terminal voltage. The readings should be taken while the load is applied at the beginning of the test, at specified intervals, and at the completion of the test. The readings are to be taken on hourly basis.
d) If one or more cells is approaching reversal of its polarity (+ 1 V or less) and the test nears the 90-95% expected completion time, continue the test until the specified terminal voltage is reached.
e) If earlier in the test an individual cell is approaching reversal of its polarity (+ 1 V or less) but the terminal voltage has not yet reached its test limit, the test should be stopped, and the weak cell should be disconnected from the battery string and bypassed with a jumper of adequate conductor capacity. The new minimum terminal voltage should be determined based on the remaining cells. The test should then be continued in order to determine the capacity of the remaining cells. The time required to disconnect the cell, install the jumper, and restart the test shall not exceed 10% of the total test duration or 6 min, whichever is shorter. This "downtime" shall not be included in the test discharge period (i.e., the capacity determination shall be based on the actual test time).

   Note: IEEE recommends not more than one "downtime" period when a battery is being tested. The battery may show higher than its normal capacity (especially during short-duration testing) if the battery is subjected to more than one "downtime period".

f) Observe the battery for inter-cell Connector heating and if possible do thermo scanning of the Connectors during test to establish healthiness of inter-cell connection.
g) At the conclusion of the test, determine the battery capacity as per the formula given below: capacity = (Ta / Ts) x 100

   Where Ta - is actual time of test to specified terminal voltage, Ts - is rated time to specified terminal voltage

   Note: If after the test one or more of the reversed cells are replaced, the benchmark capacity of the battery can be reestablished by either retesting the battery or by analysis. If the problem that caused the cell to reverse is identified and corrected, the cell can be reinstalled into the battery and the battery can be retested to establish the benchmark capacity, or the cell can be discharged independently, recharged, reinstalled into the bank and the benchmark capacity reestablished by analysis.

Determining Battery Capacity: % capacity at 25°C (77°F) = (Ta /Ts) x 100

Ta is actual time of test to specified terminal voltage, Ts is rated time to specified terminal voltage.

The discharge rate and test length shall be taken as 10% of the rated capacity and 10 hrs duration for substation batteries.

Effect of Temperature on Discharge Rate: The rated AH capacity of lead acid battery is specified corresponding to a reference temperature of 27°C. The capacity is reduced with lower temperature of the electrolyte and increased with increase in temperature at the rate of 0.43% for tubular and Plate cells per °C variation in temperature for 10 hr discharge rate.

Capacity at 27 °C = C_t + [Cx R x (27-T)]

Where C_t - Observed capacity at t° C
R - Variation factor of 0.43% for 10 hrs discharge
T - Average electrolyte temperature

Although capacity of battery increases with increase in electrolyte temperature, higher electrolyte temperature accelerates corrosion of the grids and deterioration of separators, there by affecting the battery life.

3.1.2 CONDITION BASED MAINTENANCE PROCEDURES

As untimely equipment failure is a cause of concern for the reliability of the system, it is prudent to assess the health of the equipment to take corrective action in advance. Over a period various techniques have been developed and are being adopted in condition based maintenance.

While doing condition monitoring tests, proper precautions as demanded by those tests are to be strictly taken into consideration, since any compromise of the requirement may lead to wrong test results and wrong conclusion.

Testing instruments play vital role in condition monitoring. If working in charged switchyard, equipments which are not tested for Electro Magnetic interference/Electro Magnetic Compatibility (EMI/EMC) for such level may not give reliable test results. Calibration of Testing Instruments is also to be ensured for reliability of assessment. A thorough knowledge on the testing is required for carrying out any assessment. Test results are always to be compared with the pre-commissioning/ Factory test results to assess the present condition. A complete data base of the test results and history of the equipment are to be maintained for proper evaluation of the results. Computer Software is also available for evaluation of condition monitoring test results which are to be used with proper knowledge.

3.1.2.1 TRANSFORMERS AND REACTORS:

Measurement of Insulation Resistance: Insulation resistance (IR) measurement is the basic test to check the soundness of transformer solid insulation. This test generally reveals the condition of insulation (i.e., degree of dryness of paper insulation), presence of any contaminants in oil and also any gross defect inside the transformer. IR value measurements of EHV transformers shall preferably be done with 5 kV motorized megger. This will help constant application of voltage for a longer period for evaluation of Polarization Index.

Precautions: Jumpers are to be disconnected for performing this test so that lightning arrestors and associated equipments are not connected with the transformer. As any dirt on bushings may result in erroneous results, the bushing porcelains are to be cleaned by wiping with a piece of dry cloth. When using a megger, observe the usual accident preventive rules as it operates on High Voltage Direct Current. Transformer windings possess a substantial capacitance and therefore, the current carrying parts can only be touched after discharging them. If moisture condensation is suspected on porcelain surface, provide aluminum foil taping below the lower most porcelain shed. (Esp. for small bushings like Neutral Bushing) Connect the foil to the guard terminal of megger. Lead wires from the bushing line lead and tank earth to megger shall be as short as possible without joints and shall not touch tank or each other.

Testing Procedure: IR measurements shall be taken between the windings to body (i.e. to earthed tank). Windings on each side HV, IV and LV shall be connected together. Following measurements shall be taken.

Auto-transformer	Shunt Reactor	Two winding transformer	Three winding transformer
HV+IV to LV	Winding to E	HV to LV	HV+IV to LV
HV+IV to E		HV to E	HV+LV to IV
LV to E		LV to E	HV+IV+LV to E

HV- High voltage, IV -Intermediate voltage, LV -Low voltage/ Tertiary voltage windings, E-Earth

Date and time of measurement, Sl.No. Make of megger; oil temperature and IR values at intervals of 15 seconds, 1 minute and 10 minutes should be recorded.

Min insulation resistance values for one minute measurements for transformers may be determined by using the following empirical formula:

$IR = CE / \sqrt{KVA}$ where IR = Insulation Resistance, in MΩ

C = 1.5 for oil filled transformers at 20 ^{0}C, assuming that transformer oil is dry, acid free and sludge free.
= 30.0 for un-tanked oil-impregnated transformers

E= Voltage rating, in V, of the windings (ph-to-ph for delta connected and ph-to-neutral for star connected transformers)

KVA = Rated capacity of the winding under test (If the winding under test is three-phase and the three individual windings are being tested as one, rated capacity of the three phase winding is used).

IR test results below this minimum value would indicate probable insulation breakdown. A zero or a very low value of ohms would indicate a grounded winding, a winding-to-winding short or heavy carbon tracking.

The following IR values as a thumb rule may be considered as the minimum satisfactory values at 30°C (one minute measurements) at the time of commissioning. Even if the insulation is dry, IR values will be low if the resistivity of oil is poor.

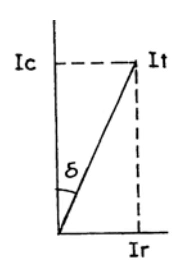
11kV = 300M Ω, 33kV = 400 MΩ, 66kV and above = 500 MΩ

With the duration of application of voltage, **IR** value increases. The increase in insulation resistance is an indication of dryness of insulation. The ratio of 60 seconds insulation resistance to 15 seconds insulation resistance value is called Absorption Coefficient and the ratio of 600 seconds insulation resistance to 60 seconds insulation resistance value is called Polarization Index. The following table gives a general guideline for evaluation of insulation.

Polarization Index	Insulation Condition
Less than 1	Wet
1.0-1.1	Poor
1-1.25	Fair
1.25-2.0	Good
Above 2.0	Dry

Tan ∂ and Capacitance Measurement:

Dielectric Dissipation Factor: Dissipation or loss factor (tan ∂) is defined as the ratio of the resistive component of (Ir) of current to the capacitive current(Ic) flowing in an insulating material (see figure below). The more the resistive component of current, the more is the dissipation of dielectric indicating deterioration of insulation.



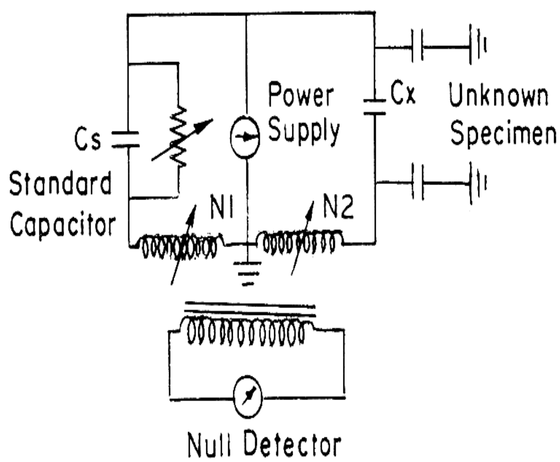
Power factor is the ratio of resistive current to that of total current. For very low value of resistive currents, the capacitive current will be almost equal *to* the total current and hence values of dissipation factor and power factor are same Insulation power factor or dissipation factor (Tan delta) and capacitance measurement of bushings provide an indication of the quality of the insulation in the bushing.

Adverse Effects of Moisture in Paper Insulation: Dielectric strength of insulation decreases with increase in moisture content. And also, moisture in cellulose insulation can lead to bubble formation under high load conditions. Moisture accelerates the ageing of paper insulation. If moisture content in paper insulation increases from 1 % to about 2%, it will lead to increase in ageing of the insulation by almost two times.

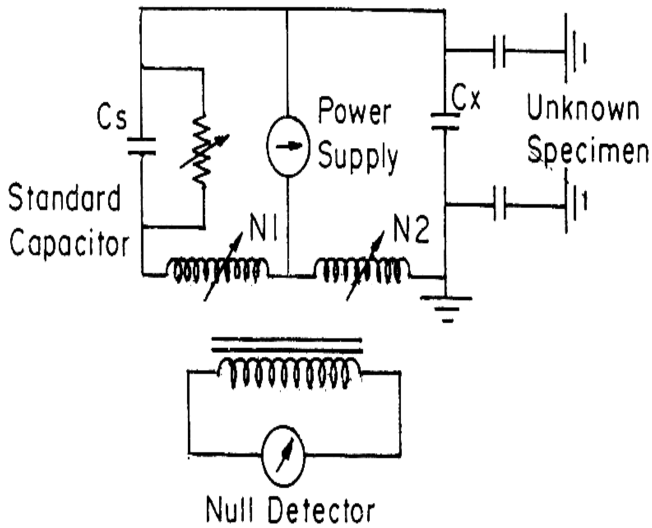
At high temperature, moisture is pushed out of the paper insulation into the oil. As insulation cools down, water begins to migrate slowly from the oil into the paper. The time for the temperature drop in the oil may be much quicker than the water can return to the cellulose insulation. Hence depending upon these conditions, dissipation factor also changes.

Modes of Selection for Tan∂ Measurement:

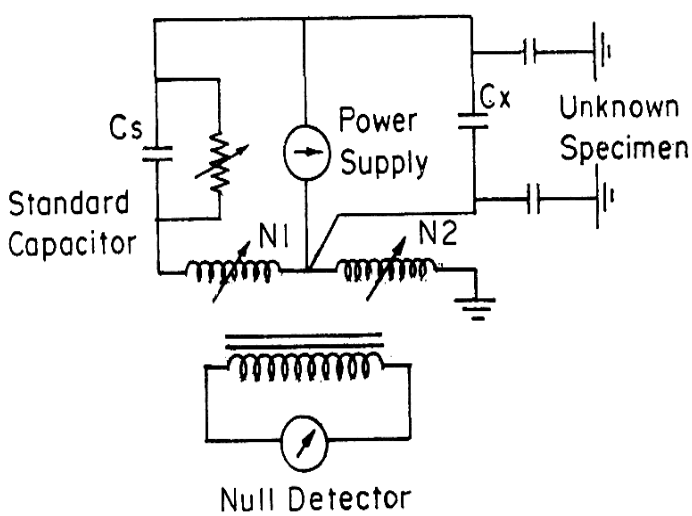
(a) Ungrounded Specimen Test (UST): Test set connected for ungrounded specimen test mode. This is used when specimen is isolated from earth, e.g., Transformer bushing, CTs with test tap, CVTs, etc. In this mode of measurement, the current which flows to the ground will not enter the measurement winding (N2) and directed straight to the source as shown in Fig. below. For UST mode of measurement, removal of jumpers from the termination of the equipment has less influence compared to the other mode of tan∂ and capacitance measurement.



(b) Grounded Specimen Test (GST): Test set connected for grounded specimen test mode. This is used when specimen do not have two specific points isolated from ground for Tan∂ measurement, e.g., Transformer/ Reactor windings, CTs without test tap etc. Here Capacitance and tan∂ is measured using GST mode. As shown in Fig. below, during GST mode operation, all current which flows to ground shall pass through the measurement winding and -influence the reading. In GST mode measurement, it is necessary to isolate the measuring portion from other parallel ground path by-removing the connected terminal jumper connections. In this measurement capacitance for the parallel combination of HV to earth and between the windings shall be obtained.



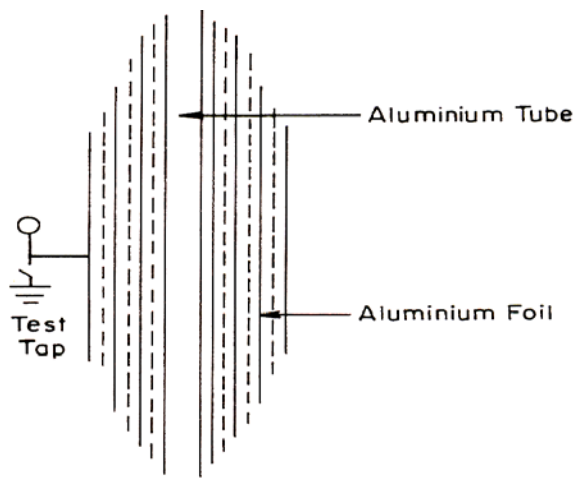
(c) Grounded Specimen Test with guard (GSTg): Grounded Specimen Test mode is used whenever a portion of the test specimen is required to be eliminated from the measurement. It also separates the total values of a GST test into separate parts for better analysis. The connection in the measurement kit shall be as shown in fig below. The current flowing through the guarded portion is directed towards the source and it will not influence the measurement. In GSTg measurement, HV to Earth Capacitance is measured. By interchanging the HV and LV leads of the kit LV to earth capacitance can be measured directly.



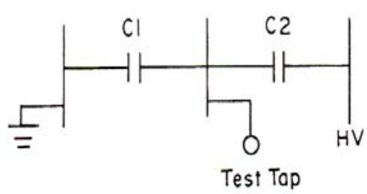
The three capacitors shown in unknown specimen in the above figures are generally HV winding to ground, HV winding to LV winding and LV winding to ground. For measurement on transformers with more than two windings, the figure shall be made accordingly for proper measurement. Measurement of capacitance and Tan∂ between windings is carried out in UST mode and measurement of capacitance and Tan∂ from windings to ground is measured in GSTg/ GST mode.

Interference Suppresser: This circuit permits suppression of power frequency interference signal to the bridge signal. There are measurement kits that operate at other than power frequency to avoid interference, but compute the capacitance and tan∂ at power frequency using software. If interference is more in the switch yard, balancing of the kit at highest sensitivity will be difficult and readings may not be accurate.

Tan∂ and Capacitance of Bushings: In bushing, conducting layers are arranged within the insulating material for the purpose of uniform distribution of the electric field in the bushing as shown in the figure. Bushing test tap is a connection to the last of the conducting layers of a capacitance graded bushing to ground, with a disconnector for measurement of partial discharge, power factor and capacitance values of the bushings.



The main Capacitance, C2, of a bushing is the capacitance between the high-voltage conductor and the test tap. The tap capacitance C1, of a capacitance-graded bushing is the capacitance between the test tap and mounting flange (Ground) as shown in Fig.



The capacitance C of a bushing without a voltage or test tap is the capacitance between the high-voltage conductor and mounting flange (ground).

For measurement of tan∂ and capacitance of bushings it is strongly advised to short HV terminals of all bushings of the same winding and all other winding bushing terminals be shorted and grounded to avoid influence of capacitance of other windings.

Measurement of C1 capacitance and tan∂: HV lead of the test kit to be connected to the shorted bushing top and LV lead to be connected to the test tap of the bushing under test: Test is to be carried out in ungrounded specimen test mode at the rated test voltage of the kit.

Measurement of C2 capacitance and tan∂: HV lead to be connected to the test tap of the bushing under test (if required additional crocodile type clip may be used) and LV of the kit to be connected to the ground. HV of the bushing is to be connected to the Guard terminal of the test kit. Test to be carried out in GSTg mode at 1.0 kV.

Precautions: The test set is a source of high voltage electrical energy and operator must use all practical safety precautions to prevent contact with energized parts of the test equipment and related circuits. The ground cable must be connected first and removed last. It should also be ensured that test specimen is de-energized and grounded before making any further connection and no person may come in contact with HV output terminal or any material energized by the output.

All the jumpers connected on the bushings are to be removed to have proper isolation and removal of parallel paths in case of measurement in GST and GSTg mode. In case tertiary is also connected, ensure the isolation of the same prior to commencement of test.

Tan∂ and Capacitance of Winding Insulation: Dissipation factor/ Loss factor and capacitance measurement of winding is carried out to ascertain the general healthiness of the ground and inter-winding insulation of transformer and reactors.

Measurement Combination: The combination for tan∂ measurement of winding is same as that of measurement of IR value. The probable combination is given below:

Auto-transformer (Two winding)	Test mode	Shunt reactor	Test mode	3 winding transformer	Test mode
HV + IV to LV	UST	HV to E	GST	H V to LV I	UST
HV + IV to E	GSTg			H V to LV 2	UST
LV to E	GSTg			LV I to LV 2	UST
				HV to Ground	GSTg
				LV I to Ground	GSTg
				LV 2 to Ground	GSTg

Test Voltage: Normally C and Tan∂ measurement can be performed at site at about 10 kV to 12 kV. It is a good practice to have tan∂ and capacitance tested at factory at these voltages to have reference. Testing shall be done under shutdown. Transformer/Reactor shall be isolated from service and isolators opened on all sides. Test shall not be carried out when there is condensation on the porcelain. Tests shall not also be carried out when the relative humidity is in excess of75%.

Effect of Ambient Temperature: At 20° C, value of tan delta (Dissipation Factor) should not be more than 0.007. If tan delta measurement is carried out at temperature other than 20°C, then correction factor furnished by manufacturer are to be applied. It is however advisable to carryout the test between 20°C to 40°C of winding temperature as ,in this range the values are almost constant and do not vary much.

Evaluation of Test Results: An increase of Dissipation Factor accompanied by a marked increase in Capacitance usually indicates excessive moisture in the insulation. Increase of DF alone may be caused by thermal deterioration or by contamination other than water. The changes in C and Tan ∂ values are caused by deterioration of the insulation, contamination or physical damage.

Maximum values of Dissipation Factor (Tan delta) of class A insulation, e.g., oil impregnated insulation is 0.007. Rate of change of tan delta and capacitance is very important. Comparison of test results with earlier results and that of pre-commissioning test results shall give desired information for trend analysis. Winding temperature correction to be applied only if indicated by the manufacturer. It is always desirable to test at about same temperature for better comparison.

Winding Resistance Measurement: Winding resistance is measured at site in order to check for any abnormalities due to loose connections, broken strands and high contact resistance in tap changers as a pre-commissioning check and compare the measured values with the factory test values.

Precautions: As the transformer windings have low resistance, measurement shall be done with Kelvin Double Bridge/Transformer ohm meter. To reduce the high inductance effect it is advised to use a sufficiently high current to saturate the core. This will reduce the time required to get a stabilized reading. It is essential to note the temperature of the windings as the resistance varies in proportion to temperature.

Care shall be taken to ensure that direct current circulating in the windings has settled down before the measurement is done. In some cases this may take several minutes depending on the winding inductance.

Test Procedure: For star connected winding with neutral brought out, the resistance shall be measured between the line and neutral terminal and average of three sets of readings shall be the tested value. For star connected auto-transformers the resistance of the HV side is measured between HV terminal and IV terminal, then between IV terminal and the neutral. For delta connected windings, such as tertiary winding of auto-transformers, measurement shall be done between pairs of line terminals and resistance per winding shall be calculated as per the following fom1Ula:

Resistance per winding = 1.5 x Measured value

Winding temperature to be calculated at 75°C using the following formula:

$R_{75} = R_t (235+75)/ (235+t)$

R_{75} = Resistance at 75°C;

Rt = Resistance at measured temperature

t = Measured Winding temperature

Evaluation of Test results: Since it is difficult for precise winding temperature measurement at field, the expected deviation for this test with respect to the factory test result is about 5%. The values obtained also should not be more than 5% of other phases. As winding resistance are temperature sensitive, it is to be measured when equipment is stable in temperature and the values to be converted to 75°C.

Magnetic Balance Test: Magnetic Balance Test is conducted only in three phase transformers to check the imbalance in the magnetic circuit and to evaluate its healthiness. No winding terminal should be grounded; otherwise results would be erratic and confusing.

Test Procedure: Transformer shall be in normal tap position, and neutral disconnected from ground. Single phase 230 V is applied across one phase of Intermediate Voltage (IV) winding terminal and neutral (call it V1) then voltage to be measured in other two IV terminals across neutral (call them V2 and *V3* respectively). Test to be repeated for each of the three phases. Test to be repeated for the HV winding also.

Evaluation of Test Results: From the measurement carried out ensure that, VI = V2 + V3 respectively. Zero voltage or very negligible voltage induced in any winding should be investigated.

Also the applied voltage may be expressed as 100% and the induced voltages as percentage of applied voltage. This will help in comparison of two results when applied voltages are different.

Magnetizing Current Measurement: Excitation/ magnetizing current test is performed to locate defect in magnetic core structure, shifting of windings, failures in turn to turn insulation or problems in tap changers.

Magnetizing current measurement should be taken before measuring DC Winding resistance to have better results which are not influenced by the residual magnetism.

Test Procedure: Transformer tap position is to be kept at the lowest position and IV and LV terminals open. 3-phase 415 V is applied on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV terminals and Current in each phase of HV terminal. Repeat the measurement for Normal and Highest tap position. It is advisable to do measurement at all taps during thorough investigation of the transformer. Test to be repeated for IV winding keeping HV and LV open.

Evaluation of Test Results: The set of readings for current measurement in each of the tap position are to be equal. Unequal currents shall indicate possible short circuits in winding.

Results between similar single-phase units should not vary more than 10% .The test values on the outer limbs should be within 15% of each other, and values for the centre leg should not be more than either on the outer limbs for a three-phase transformer. Results compared to previous tests made under the same conditions should not vary more than 5%. The comparison of the test values of healthy condition with the faulty condition help in locating the trouble spots.

If a reading beyond permissible tolerance is observed when turns ratio, winding resistance, and impedance tests are normal, it may be due to residual magnetism. Residual magnetism may be eliminated or reduced by applying a dc voltage to the windings through a voltage divider. The voltage should be raised from zero to a maximum value that will yield a current of no more than 10A through the winding and then return to zero. Care must be taken not to break the circuit while dc current is flowing in thy winding. The polarity should then be reversed and the procedure repeated. The process is repeated several times, each time reducing the magnitude of current and each time reversing the polarity. The excitation current test should then be repeated.

Voltage Ratio Test: Voltage Ratio test is performed to determine the turns ratio of transformers to identify any abnormality in tap changers/ shorted or open turns etc. The voltage should be applied only in the high voltage winding in order to avoid unsafe voltage.

Test Procedure: Transformer tap position is to be kept in the lowest position and IV and LV tem1inals open. Apply 3-phase 415 V supply on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV and IV terminals simultaneously. Repeat test for each of the tap position separately.

The above tests can also be performed by portable Transformer turns ratio (TTR) meter. They have an in built power supply, with the voltages commonly used being very low, such as 8-10 V and 50 Hz. Two windings on one phase of a transformer are connected to the instrument, and the internal bridge elements are varied to produce a null indication on the detector. Exciting current is also being measured in most cases.

The turns ratio tolerance should be within 0.5% of the nominal ratio. For three phase star connected winding this tolerance applies to phase to neutral voltage.

If there are shorted winding turns, the measured ratio will be affected. Out-of-tolerance ratio measurements could be due to shorted turns, especially if there is an associated high excitation current. Out-of-tolerance readings should be compared with previous test results, because in some instances, the design turns ratio may vary from the nameplate voltage ratio on some taps because of the need to utilize an incremental number of winding turns to make up the taps while nameplate voltage increments may not exactly correspond. This error may combine with measurement error to give a misleading out-of-tolerance reading.

Ratio measurements must be made on all taps to confirm the proper alignment and operation of the tap changers.

Open turns in the excited winding will indicate very low exciting current and no output voltage. Open turns in the output winding will be indicated by normal levels of exciting current, but very low levels of unstable output voltage. The turns ratio test also detects high resistance connections in the lead circuitry or high contact resistance in tap changers by higher excitation current and a difficulty in balancing the bridge.

Vibration Measurement on Oil Immersed Shunt Reactor: Movement of the core-coil assembly and shielding structure caused by the time-varying magnetic forces, results in vibration of the tank and ancillary equipment. These vibrations have detrimental effects such as excessive stress on the core-coil assembly. The shunt reactor shall be energized at rated voltage and frequency and these values to be noted down during measurement for future reference.

The vibration of shunt reactor shall be measured using transducers, optical detectors or equivalent measuring devices. The measuring equipment should be accurate within ± 10% of 2nd harmonic of the exciting frequency. The peak-to-peak amplitude shall be determined by direct measurement or calculated from acceleration or velocity measurement.

Readings are to be taken in as many points as possible. The points of measurement are to be marked permanently on the wall of reactor for taking measurement at the same location subsequently.

The average amplitude of all local maximum points shall not exceed 60 µm (2.36 mils) peak to peak. The maximum amplitude within any individual reading shall not exceed 200 µm (7.87 mils) peak to peak.

Testing of Buchholz Relay: The use of the gas detector relay (Buchholz relay) in oil immersed transformers/ reactors is based on the fact that fault in the transformer, such as arcing, partial discharges or local overheating, normally result in generation of gas. This gas is collected in the relay housing and actuates an alarm contact.

The gas detector relay also includes a device, which responds to the abnormally high gas flow from the main transformer tank to the conservator, which occurs when the transformer develops a serious fault. This device actuates a trip contact, which is connected to the trip circuit of the transformer.

If the transformer suffers a loss of oil causing oil level to drop below the level of the relay, alarm as well as trip contacts close and the transformer is tripped.

An inspection window is fitted on either side of the relay and is graduated in cubic centimeters to measure the volume of the gas accumulated.

While conducting testing on the buchholz relays, trip circuit shall be disconnected. Since 220 V DC is available at the relay while carrying out the test, it should be ensured that there should not be any accidental contact with DC.

Test Procedure: For testing of the contact functions, the Buchholz relay is provided with a test knob. With the help of the test knob we can actuate both alarm and trip contact. First actuate the alarm contact and check whether the auxiliary relay operates and gives annunciation in the control room. Then actuate the trip contact, which in turn should operate the trip relay as well as gives annunciation in control room.

The relay shall also be tested by injecting air into the relay from the pet valve provided at the top of the relay using a foot pump or compressed air to simulate gas accumulation. The annunciation of the relay to be checked in this way and after the test the air should be released and the pet cock to be closed or connected to the gas-collecting device.

The annunciation and tripping of the relay be tested by draining of the oil from the relay after closing the gate valves provided on both the sides of the relay in the connecting pipeline. The pet valve as well as the drain valve is opened to drain the oil. When the oil level in the relay falls, the annunciation will appear and further draining the oil will operate the trip contact of the relay.

Testing of Pressure Relief Device (PRD) / Sudden Pressure Relay (SPR): Pressure Relief Device / Sudden Pressure Relay is intended to protect power transformers/ reactors from excessive pressure that may develop inside due to internal fault.

If a short circuit occurs inside a transformer, the arc vaporizes the transformer oil and a heavy pressure is built up. If the pressure is not released immediately (within a few milli seconds), the transformer tank will get bulged and ruptured with oil spreading everywhere creating a fire hazard.

When pressure inside the transformer tank rises above pre-determined safe limit, a spring mounted diaphragm lifts from its seat for releasing the oil, vapor or gases to reduce the pressure. The diaphragm restores to its original position as soon as the pressure in the tank drops below set limit.

The lifting of the diaphragm also operates a flag indicator and a micro switch which is connected for annunciation /tripping. The flag and the micro switch remains operated until they are manually reset.

The pressure limits are set at factory. The flag unit is very delicate and care must be taken while handling the same. Gasket to be changed when cable terminal box is fitted back after the test is over. Read the manufacturer's instruction before any operation.

Test Procedure: Only operation of the micro switch and the associated cabling and correct operation of the relays are tested during routine maintenance. Actuating the flag by lifting the operating rod manually tests the functioning of the switch operation or as advised by the manufacturer and the annunciation in the control panel as well as the extension of the trip command to be monitored.

The Sudden Pressure relays (SPR), provided in some of the equipments, are to be tested in the same way as we test the pressure relief device during routine maintenance. Normally the mechanical flag indication is not provided in the SPR. The terminals are shorted to activate the trip and annunciation relays and the whole scheme is tested. The gas release valve can also be used for pressing air into the gas detector relay to simulate gas accumulation. A pump with a check valve or a container with compressed air is recommended. Release the air after testing.

Dissolved Gas Analysis (DGA): Transformer undergoes electrical, chemical and thermal stresses during its service life which may result in slow evolving incipient faults inside the transformer. The gases generated under abnormal electrical or thermal stresses are Hydrogen (H2), Methane (CH_4), Ethane (C_2H_6), Ethylene (C_2H4), Acetylene (C_2H_2), Carbon monoxide (CO), Carbon dioxide (CO_2), Nitrogen (N2) and Oxygen (O_2) which get dissolved in oil. Collectively these gases are known as **fault gases**, which are routinely detected and quantified at extremely low level, typically in parts per million (ppm) in dissolved Gas Analysis (DGA). Most commonly used method to determine the content of these gases in oil is using a vacuum Gas Extraction apparatus/ Head Space Sampler and gas chromatograph.

DGA is a powerful diagnostic technique for detection of slow evolving faults inside the transformer by analyzing the gases generated during the fault which get dissolved in the oil. For Dissolved Gas Analysis to be both useful and reliable, it is essential that sample taken for DGA should be representative of lot, no dissolved gas be lost during transportation and laboratory analysis be precise and accurate. Effective fault gas interpretation should basically tell us first of all, whether there is any incipient fault present in the transformer, and if so what kind of fault it is. It should also indicate the seriousness of the fault warranting taking out the transformer from service for further investigation.

DGA can identify deterioration of insulation oil and hot-spots, partial discharge, and arcing. The health of oil is reflective of the health of the transformer itself. DGA analysis helps the user to identify the reason for gas formation and materials involved and indicate urgency of corrective action to be taken.

The evolution of individual gas concentrations and total dissolved combustible gas (TDCG) generation over time and the rate of change (based on IEC 60599 and IEEE C 57-**104** standards) are the key indicators of a developing problem. Some of the recognized interpretation techniques are explained below.

Individual Fault Gases Acceptable Limits: When no previous DGA history of transformer is available, the DGA results are compared with the gassing characteristics exhibited by the majority of similar transformers of normal population. As the transformer ages and gases are generated, the normal levels for 90% of a typical transformer population can be determined. From these values and based on experience, acceptable limits or threshold levels have been determined as given in table (as per IEC 60599) below:

Transformer Type	**Fault Gases (µl/l)**						
	H2	**CH4**	**C2H6**	**C2H4**	**C2H2**	**CO**	**CO2**
Non communicating OLTC	**60-150**	**40-110**	**50-90**	**60-280**	**3-50**	**540-900**	**5100-13000**
Communicating OLTC	**75-150**	**35-130**	**50-70**	**110-250**	**80-270**	**400-850**	**5300-12000**

"Communicating OLTC" means that some oil and /or gas communication is possible between the OLTC compartment and the main tank or between the respective conservators. These gases may contaminate the oil in the main tank and affect the normal values in these types of equipment.

However it is improper to apply threshold level concept without considering the rate of change of the gas concentration in Dissolved Gas Analysis. When an abnormal situation is indicated by above table, a testing schedule is devised, with increased sampling frequency.

Total Dissolved Combustible Gas (TDCG) Limits: The presence of an incipient fault can also be evaluated by the total dissolved combustible gas (TDCG) present. Limits for TDCG are as given in table below based on IEEE standard C-57.1 04-1999. An increasing gas generation rate indicates a problem in transformer.

TDCG limits, PPM	Action
< or = 720	Satisfactory operation. Unless Individual gas acceptance values are exceeded
721 - 1920	Normal ageing/slight decomposition. Trend to be established to see if any evolving incipient fault is present
1921 -4630	Significant decomposition. Immediate action to establish trend to see if fault is progressively becoming worse
<4630	Substantial decomposition. Gassing rate and cause of gassing should be identified and appropriate corrective action such as removal from service may be taken

TDCG includes all hydrocarbons, CO and H_2 and does not include CO_2 which is not a combustible gas.

Evaluation of Gases: Relationship with temperature of different fault gasses is given below

Methane $CH_4 > 120°$ C   Ethane (C_2H_6) > 120^0 C
Ethylene (C_2H_4) > 150°C   Acetylene (C_2H_2) > 700^0 C

Faults Associated with Different Gases

Oil Overheating	C_2H_4, C_2H_6, CH_4
Overheated Cellulose Traces of acetylene with smaller quantity of Hydrogen may be evolved. Large quantity of Carbon-Di-oxide (CO2) and Carbon Monoxide (CO) are evolved from over heated cellulose. Hydro carbon gases such as Methane and Ethylene will be formed if the fault involves oil impregnated structure.	CO
Partial discharge in Oil (Corona) Ionization of high stressed area where gas / vapour are present or 'wet spot' produces Hydrogen and methane and small quantity of other hydrocarbons like ethane and ethylene. Comparable amounts of carbon mono-oxide and di-oxide may result due to discharges in cellulose.	H_2, CH_4
Arcing in Oil Large amount of Hydrogen and acetylene are produced with minor quantities of	C_2H_2, H_2

methane and ethylene in case of arcing between the leads, lead to coil and high stressed area. Small amounts of carbon mono-oxide and di-oxide may also be formed, if fault involves cellulose.	

It is to be understood that there is no definite interpretation method available, which can indicate the exact location and type of the fault. The different interpretation methods only provide guidelines to make expert interpretation about the equipment. Apart from the DGA results various other factors are taken into consideration such as past history of the transformer, grid condition, loading patterns, voltage and frequency profile, etc.

Ratio Methods: Several well- known methods/criteria (like Rogers ratio, IEC 60599, Dornenberg, Key gas etc.) are being used by utilities to interpret the DGA results, based mostly on the relative concentrations (i.e. ratios) of the constituent gases. These ratios generally give an indication of the existence and nature of a problem. Some of the interpretation methods used for DGA is discussed here under:

(i) IEC 60599 method

This method is applicable only when the fault gas results are ten times the sensitivity limit of the Gas Chromatograph (GC). As per IEC 60567 the sensitivity limit for the GC should be maximum 1 ppm for all the hydrocarbons and 5 ppm for Hydrogen. In this method three ratios viz. C_2H_2/C_2H_4, CH_4/ H2 and C_2H_4/C2H_6 are used for interpretation. Various combinations of the ratios are used for diagnosis of type of fault such as PD, Discharge of low energy, Discharge of high energy, Thermal fault < 300^0C, Thermal fault 300 - 700^0 C and Thermal fault> 700^0 C. The table (as per IEC 60599) showing different type of faults depending upon the three key ratios is given below:

DGA Interpretation Table

Case	Characteristic fault	C2H2/C2H4	CH4 /H2	C2H4 / C2H6
PD	Partial discharges	NS	<0.1	<0.2
DI	Discharges of low energy	>1	0.1-0.5	>1
D2	Discharges of high energy	0.6-2.5	0.1 -I	>2
Tl	Thermal fault T < 300°C	NS[1]	>1 but NS[1]	<I
T2	Thermal fault 300°C < I < 700°C	<0.1	>1	1-4
T3	Thermal fault	<0.22	>1	>4

(Source IEC60599 – 1999)

Note l: In some countries, the ratio C_2H_2 / C_2H_6 is used, rather than the ratio CH_4 /H_2. Also in some countries, slightly different ratio limits are used.

Note2: The above ratios are significant and should be calculated only if at least one of the gases is at a concentration and a rate of gas increase above typical values.

Note3: CH4 / H2 <0.2 for partial discharges in instrument transformers. CH4/H2 0.007 for partial discharges in bushings.

Note4: Gas decomposition patterns similar to partial discharges have been reported as a result of the decomposition of thin oil film between over-heated core laminates at temperatures of 140 °C and above

NS = Non- significant whatever the value

An increasing value of the amount of C_2H_2 may indicate that the hot spot temperature is higher than 1000^0C

Though this method is quite comprehensive, still there are cases where it does not fit into any of the cases listed in the diagnosis table. These cases should be dealt through trend analysis and other interpretation methods. Again interpretation through the above method is meaningless unless it is correlated with the earlier sample results.

(ii)IEEE method-C57-/04/1991

(a) Key gas method: Characteristic "Key Gases" have been used to identify particular type of fault. Laboratory simulations and comparison of results of DGA tests combined with observations from the tear down of failed transformers have permitted the development of a diagnostic scheme of the characteristic gases generated from thermal and electrical (Corona and arcing) deterioration of electrical insulation. Table given below lists the key gases for the conditions of arcing, corona, overheating in oil and overheating in paper in the order of decreasing severity.

Key gases associated with typical fault

Fault type	Key gases
Arcing	Acetylene(C2H2), Hydrogen(H2)
Corona	Hydrogen (H2)
Overheated Oil	Ethylene (C2H4), Methane(CH4)
Overheated Cellulose	Carbon Monoxide (CO) and Dioxide(CO2)

(b) Ratio Method: These methods help in assessing the type of fault by comparing ratios of characteristic gases generated under incipient fault conditions. The advantages to the ratio methods are that they are quantitative, independent of transformer capacity and can be computer programmed. The disadvantages are that they may not always yield an analysis or may give an incorrect one. Therefore it is always used in conjunction with other diagnostic-methods such as key gas method.

(i) The Doernenberg ratio method is used when prescribed normal levels of gassing are exceeded. It provides a simple scheme for distinguishing between pyrolysis (overheating) and PD (corona and arcing). In this method four ratios viz CH4 /H2, C2H2 /C2H4, C2H6 /C2H2 and C2H2 /CH4 are used.

Ratios for key gases – Doernenburg

Suggested Fault Diagnosis	Ratio 1 (R1) CH4 / H2	Ratio 2 (R2) C2H2/C2H4	Ratio3 (R3) C2H2/CH4	Ratio4 (R4) C2H6/C2H2
1-Thermal Decomposition	> 1.0	< 0.75	< 0.3	> 0.4
2-Corona (Low Intensity PD)	0.1	Not Significant	< 0.3	> 0.4
3-Arcing(High Intensity PD)	> 0.1	> 0.75	> 0.3	< 0.4

Concentrations of Dissolved Gas

Key Gas	Concentration LI (in ppm)
Hydrogen(H2)	100
Methane (CH4)	120
Carbon Monoxide (CO)	350
Acetylene (C2H2)	35
Ethylene(C2H4)	50
Ethane (C2H6.)	65

In Doernenburg's method for declaring the unit faulty at least one of the gas concentrations (in ppm) for H_2,, CH_4,, C_2H_2 and C_2H_4 should exceed twice the values from limit LI and one of the other three should exceed the values for Limit LI. Having established that the unit is faulty, for determining the validity of ratio procedure at least one of the gases in each ratio Rl, R2, R3 or R4 should exceed limit LI. Otherwise the unit should be re-sampled and investigated by alternative procedures.

(a) The Rogers Ratio method is a more comprehensive scheme using only three ratios viz.CH4/H2, C2H2/C2H4and C2H4/C2H6, which details temperature ranges for overheating conditions based on Halstead's research and some distinction of the severity of incipient electrical fault conditions. Table below lists the ratio for key gases. A normal condition is also listed.

(b) Rogers Ratio for Key Gases

Case	**R2 (C2H2/C2H4)**	**RI (CH4/H2)**	**R5 (C2H4/C2H6)**	**Suggested Fault Diagnosis**
0	**<0.1**	**>0.1**	**<0.1**	**Unit normal**
I	**<0.1**	**<0.1**	**<0.1**	**Low-energy density arcing -PD (See Note)**
2	**0.1-3.0**	**0.1-1.0**	**>3.0**	**Arcing - High energy discharge**
3	**<0.1**	**>0.1 <1.0**	**1.0-3.0**	**Low temperature thermal**
4	**<0.1**	**>1.0**	**1.0-3.0**	**Thermal<700°C**
5	**<0.1**	**>1.0**	**>3.0**	**Thermal > 700°C**

Note: There will be a tendency for the ratios R2 and R5 to increase to a ratio above 3 as the discharge develops in intensity.

IEEE C57.104 - 1991 gives an elaborate way of analyzing the type of fault using Doernenberg, Rogers's method and TDCG limits.

However, it is again emphasized that DGA is likely to give misleading results unless certain precautions are taken. These are proper sampling procedure, Type of sampling bottle, cleanliness of bottle, Duration of storage, method of gas extraction, good testing equipment and skilled manpower.

Trend Analysis: Transformers from same manufacturers and of same type some time exhibit initially specific pattern of gas evolution which subsequently slows down (or plateau's) is called Fingerprints or Normal characteristics, which are characteristic to the transformer and do not represent an incipient fault condition.

When a possible incipient fault condition is identified for first time, it is advised to determine gassing trend with subsequent analysis giving information such as which gases are constantly being generated and rate of generation of these gases. The level of gases generated in subsequent analysis provides a baseline from which future judgment can be made. In the examination of trends, Key gases, TDCG, CCVCO ratio, rate of gas generation and fingerprints (of normal trends) of particular transformer should also be considered.

The ratio of gas generation is a function of load supplied by the transformers and this information is vital in determining the severity of fault condition and decision of removal of the equipment from service for further investigation. Two methods have been suggested in literatures for assessing the gassing rate:

- Change of concentration of gas in ppm
- Determination of actual amount of gas generated

General guidelines for rate of gas generation in case of removal of transfom1er from service are 100 ppm/day and 0.1 cub feet (0.003 m^3) gas per day.

Furfuraldehyde Analysis: Degradation of insulating paper can be ascertained by direct or indirect methods. Direct method employs measuring Degree of Polymerization (DP), which requires a physical paper sample from the winding. However this being destructive to transformer cannot be employed as a routine condition monitoring method.

It is known that in addition to CO and CO_2 the ageing process of the paper produces several oil soluble by-products, most notably the furanoid compounds (FF A). The monitoring of furanic compounds by sampling of the oil and its analysis using High Performance Liquid Chromatography (HPLC) has been used for condition monitoring on a routine basis for some years.

Generally FF As are extracted from the oil either by solvent extraction or solid phase extraction and measured by HPLC by UV detector. The major FFA in oil is 2-Furfural and others are present in very low or undetected levels. 2-Furfural can be measured colorimetrically using spectrophotometer. This method is rapid and accurate and measures only 2-Furfural in oil. This technique is useful for quick screening of FFA in transformer oil. The relationship between the generation of these by-products and condition of in service paper is not well established. However, it has generally been seen that there is a linear relationship between FFA and DP. FFA may be used as a complimentary technique to DGA for condition monitoring.

Recovery Voltage Measurement:
Recovery Voltage Measurement (RVM) is being carried out on transformers for estimating the moisture content in solid insulation.

Test Principle: 2 kV DC voltage is applied on the solid insulation of the transformer for a pre determined time (tc). After the application of the voltage the terminal is shorted for half of the tc time (td). Then shorting is removed and the recovery voltage is measured till building up of the peak voltage using a recovery voltage meter. Then after a relaxation time, voltage is again applied for a time (tc_1) which is more than tc. Then again the process of shorting for half the time of tc_1, that is td_1 and measuring of recovery voltage is continued.

This process is continued for about 2000 to 5000 sec of tc. And at each interval of time the peak recovery voltage is plotted in a graph against tc. The peak in the graph represents the peak recovery voltage. If the insulation is wet, the time constant for the peak is more. Software is used for computing the recovery voltage based on the values obtained.

Test Procedure: Before carrying out RVM, all terminals of each winding are to be shorted together. One of the winding combinations is grounded along with transformer tank. To avoid interference effect, voltage is injected from the low voltage winding and high voltage winding is earthed. If LV winding is more susceptible to interference, then LV could be connected to ground and voltage is applied through HV winding. It is recommended that no forced cooling is applied during the application of the test voltage. Bushings should be clean. It is recommended to start the test after about 8-10 hrs after taking shut down on the transformer to have uniform heat distribution and winding resistance test is recommended to be conducted after R VM test. As there should not be any interruption of power supply during the test, an uninterrupted power supply to RVM kit is ensured. The test kit automatically applies voltage (2 kV) for time tc and Short for time td and measure peak recovery voltage (Ur max). The time interval of tc is automatically increased and plot of tc vs Ur max is plotted by the software.

Evaluation of Test Result**:** RVM estimates the polarization spectrum of oil-paper insulation. The qualitative evaluation of the insulation is primarily focused on the state of ageing represented by a single peak in the curve of tc vs. Ur max. The more the time constant the better is the insulation. RVM software also indicates the percentage moisture of the paper insulation based on the curve. The results

could be well validated using 'relative saturation' measurement of transformer oil or using the standard curve as stated in IEEE C –57 to evaluate water content in paper insulation based on water content in oil at different temperatures. The correlations may not equate one to one but an expert analysis of the result is required before taking further action.
The appearance of more than one peak indicates an inhomogeneous state of ageing or inhomogeneous distribution of moisture in paper. New transformers have limited reasons for inhomogeneous RVM spectrum. The cause may be mainly due to inadequate drying of transformers. Used transformers show a wider variety of causes for inhomogenities due to hot spots, de-polymerization, non equilibrium of paper and oil moisture etc.

Frequency Response Analysis: Frequency Response Analysis (FRA) is done to assess the mechanical integrity of the transformer. Transformer while experiencing severity of short circuit current looses its' mechanical property by way of deformation of the winding or core. These changes cannot be detected through conventional condition monitoring techniques such as Dissolved Gas Analysis, Winding Resistance Measurement, Capacitance and Tan Delta Measurement etc. Some times even transportation without proper precaution may cause some internal mechanical damages. FRA measurement, which is signature analysis, provides vital information of the internal condition of the equipment so that early corrective action could be initiated.

Test Principle and Measurement: Short circuit forces can cause winding movement and changes in winding inductance or capacitance in Power Transformers. Recording the frequency response with these changes gives information regarding the internal condition of the equipment. Frequency Response Analysis (FRA) has proved to be an effective tool to detect such changes.
Sinusoidal signal output of approximately 2 V rms from the Frequency Response Analyzer is applied and one measuring input (R1) is connected to the end of a winding and the other measuring input (T1) is connected to the other end of the winding. The voltage is applied and measured with respect to the earthed transformer tank. The voltage transfer function TI/R1 is measured for each winding for five standard frequency scans from 5 Hz to 10 MHz and amplitude and phase shift results are recorded. While the low frequency analysis reveals the winding movements, the high frequency analysis reveals the condition of joints.

Pre-caution should be taken to see that winding which is not under test is kept in open condition in order to avoid response difference among the three phases. The same procedure is followed on subsequent tests on the same or similar transformer, to ensure that measurements are entirely repeatable.

The voltage transfer function Tl/Rl is measured for each winding for four standard frequency scans from 5 Hz to 2 MHZ and amplitude and phase shift results are recorded for subsequent analysis.

Analysis of Measured Frequency Responses: As FRA is signature analysis, data of signature of the equipment when in healthy condition is required for proper analysis. Signatures could also be compared with unit of same internal design or with other phases of the same unit. Normally measured responses are analyzed for any of the following:

- Changes in the response of the winding with earlier signature.
- Variation in the responses of the three phases of the same transformer.
- Variation in the responses of transformers of the same design.

In all the above cases the appearance of new features or major frequency shifts are causes for concern. The phase responses are also being recorded but normally it is sufficient to consider only amplitude responses.

3.1.2.2 CIRCUIT BREAKERS:

Capacitance and Tan∂ of CB Voltage Grading Capacitor

Circuit Breaker grading capacitors have oil filled paper capacitor elements. 'The healthiness of the capacitor elements could be checked by measurement of Capacitance and Tan∂.

Test Procedure: Connect LV cable to the middle of the double interrupter. Connect HV cable to the other end of the Grading capacitor to be tested. The opposite ends of the grading capacitor have to be grounded using earth switch. Before applying HV, interference is to be nullified using Interference suppression unit (ISU). Measurements have to be taken in UST Mode only. Disconnect the HV cable and connect the same to the other grading capacitor and ground the previous grading capacitor. Now the second grading capacitor is ready for testing. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/induced voltage conditions should be followed. Carry out the measurements in main and reverse mode/polarity and then compute the average value.

Evaluation of Test Results: Increase in the value of tan ∂ will indicate Chemical deterioration due to age and temperature, including certain cases of acute deterioration due to localized overheating, Contamination by water, carbon deposits, bad oil, dirt and ,other chemicals or ionization. The acceptable value is 0.007 but any increase in tan∂ and any change in capacitance value is to be analyzed.

Dew Point Measurement of SF 6 Gas/ Operating Air for CBs

Dew Point: Dew Point is the temperature at which moisture content in SF_6 gas/air starts condensing.

Dew Point when measured keeping regulating valve in service at the outlet of dew point kit to allow required flow rate of gas/air, is called dew point at rated pressure of CB. Dew point when measured by regulating the gas flow at the inlet of dew point kit and keeping outlet regulating valve (if provided) in fully open condition so that flow rate of gas/air is maintained as required, is called dew point at atmospheric pressure.

Test Procedure: Dew point measuring kit with associated accessories is used for testing. All the joints/connectors should be dust and moisture free. Dry the joints and pipe by dry air. Make the connections to the kit from CB pole ensuring that regulating valve is fully closed at the time of connections of the Dew point kit. By regulating the flow rate of SF_6 gas (0.2 liter/min to 0.5 liter/min - ref. IEC 480), the value of dew point is observed till it becomes stable. If the regulating valve is provided at outlet of the dew point kit, then dew point for rated pressure is to be monitored.

Evaluation of Test Results: Dew point measurement of SF_6 gas in a CB indicates the change in the value of dielectric properties of SF_6 gas. The dielectric properties of SF_6 gas do get changed with time due to mixing of impurities like moisture; decomposition products of SF_6 gas. There are two sources of moisture ingress in SF_6 gas after it is filled in CB. Exudation of moisture contained during manufacturing from insulation materials used in Circuit Breakers and permeation of moisture through sealed sections, i.e., gaskets, O-Rings, etc.

Sulphur Hexafluoride Gas: During Arc interruption in CBs, decomposition of SF_6 gas takes place which in presence of moisture, may result in deterioration of Organic Insulating materials inside interrupting chamber and also corrosion of metals due to formation of hydro fluorides. Therefore, in order to avoid dielectric failure of CBs, monitoring of moisture content in SF_6 gas is very important.

Dew Point of SF_6 gas varies with pressure at which measurement is being carried out. This is due to the fact that Saturation Vapor Pressure decreases with increase in Pressure of the SF_6 gas. Hence, dew point of SF_6 gas at higher pressure is lower than dew point at atmospheric pressure. Therefore, if measurement is done at a pressure other than the atmospheric pressure, same is to be converted to the atmospheric pressure. Dew points as recommended by manufacturers are given in Table below:

S1.No	Make of CB	Dew point at rated pressure	Dew point at atmospheric pressure	Remarks
1	BHEL	- 15° C	- 36° C	At the time of commissioning
		- 7° C		During O&M
		- 5° C		Critical
2	M and G		- 39° C	At the time of commissioning
			- 32° C	During O&M
3	CGL	- 15°C	- 35° C	At the time of commissioning
		- 10°C	-31 ° C	During O&M
4	ABB	-15°C	- 35° C	At the time of commissioning
		- 5° C	- 26°C	During O&M
5	NGEF	-15°C	- 36° C	At the time of commissioning
		- 7° C	- 29° C	During O&M
		- 5° C	- 27° C	Critical

Measurement of Dew Point of operating air in ABCBs indicates the moisture content in the air being used as insulating and arc quenching medium. The arc quenching/ dielectric properties of dry air do get changed with aging of CB and quality of air deteriorates as moist air travels to the interrupter of circuit breaker. This will result in deterioration of internal insulation which could possibly lead to unsuccessful arc quenching due to poor dielectric strength of interrupting medium. It is therefore, necessary to carry out measurement of Dew Point of air in ABCBs. If the dew point values are low (may be below -40°C) then the reason to be investigated and efforts to be made to keep the dryer in healthy condition.

Measurement of Circuit Breaker Operating Timings including Pre-insertion Timings

Circuit Breaker Operational Analyzer is used to measure Operating Timings of Circuit Breakers to evaluate the operational performance.

Testing Procedure: It is to be ensured that R, Y, B phase marking cables are connected with the proper place in the CB analyzer and colour codes are to be maintained for all the three poles of CB.

Give closing command to closing coil of CB and note down the PIR and main contact closing time. Take the print out from the analyzer. Give tripping command to trip coil-I of CB and note down the main contact tripping time. Give tripping command to trip coil-II of CB and note down the main contact closing time. Note down the timings for 'CO', 'OC' and “OCO' by giving respective commands.

Closing time of EHV CBs should not exceed 200 ms and discrepancy should not be there between main contacts and PIR contacts. Discrepancy in operating times of PIR and main contacts should not exceed the permissible limits.

In any case, main contacts should not close prior to closing of PIR contacts and PIR contacts should not open prior to closing of main contacts. In case, contact bouncing is observed in operating timings for PIR and main contacts, same is to be rectified.

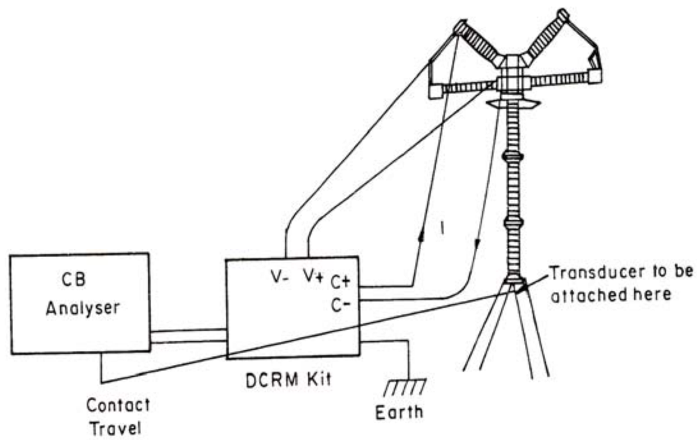
Opening time for EHV CBs should not exceed beyond 35 ms. Discrepancy in operating timings for Pole to Pole and Break to Break should not be allowed beyond permissible limits which is 3.33ms and 2.5 ms respectively.

In case, operating times of different poles/breaks are not within permissible limits, Dynamic Contact Resistance measurement should be made to see the healthiness of main contacts. CO timings should be within permissible limits as specified by different manufacturers.

Measurement of Dynamic Contact Resistance of EHV Circuit Breakers

Measurement of dynamic resistance, with the help of DCRM kit with CB Operational Analyzer is done to monitor condition of CB main and arcing contacts without opening the interrupter.
Testing Procedure: CB should be in open position, Isolator of both sides of CB should be in open position and Earth switch of one side of CB should be in open position. The tightness of connections

at CB flanges is most important to ensure error free measurement. CB during CO operation generates lot of vibrations and failure of connections during this period can dramatically change the dynamic resistance of CB. Typical arrangement of DCRM is given below:



Typical arrangement for DCRM

Incoming and outgoing flanges of CB to be cleaned with polish paper to remove paint, oxidation, etc., at points where current clamps are mounted. Select this point of connection, as close as possible to the end of porcelain insulator to ensure that minimum resistance is offered by flanges, bolts, terminal connectors, etc.

Evaluation of Test Results: Condition of contacts can be monitored by comparing DCRM signatures taken at the time pre-commissioning and during service. If there are wide variations in resistance value from the pre-commissioning value, it indicates erosion of contacts. DCRM is also helpful in monitoring length of arcing contacts by measuring contact travel and dynamic contact resistance. The contact travel from the point of opening of main contacts to opening of arcing contacts is length of arcing contact. During service due to erosion of contacts, length of the same get shortened to the extent that it may lead to commutation failure, hence, monitoring length of arcing contacts is very important.

Measurement of Contact Resistance of Circuit Breaker: Contact resistance of main contacts is measured with a Micro ohm meter of 100A and above with associated accessories.

CB should be in close position and Isolators on both side of CB should be open. The ohm meter operates on four wire measurement principle. To measure the contact resistance connect the respective leads and adjust the variac so that 100 amperes current flows through the CB contacts. Value of contact resistance is directly displayed on the digital LED display screen.

Contact resistance of the CB contacts indicates wear out and misalignment of the main contacts. If the value of contact resistance exceeds the permissible limit, i.e., 150 μohms, this could result in overheating of the contacts. Therefore, the problem of high contact resistance should be attended immediately by making proper alignment of contacts or by replacing arcing/main contacts.

Checking of Pole Discrepancy Relay and Timer for Circuit Breakers

Pole discrepancy is defined as the difference in closing and opening timings of different poles of CB.

For checking the pole discrepancy, Isolators on both sides of CB should be kept open and Earth switch closed.

a) Keep the CB in open position. Extend closing command to close one pole, say R-Pole, of CB. After it is closed, this Pole should automatically open after 2.5 seconds (as per pole discrepancy timer settings). Repeat the test for remaining two poles of CB.

b) Keep the CB in closed position. Extend Tripping command to trip one pole, say R-Pole, of CB. Remaining Y and B- Poles of CB should automatically open after 2.5 seconds. Repeat the same test for remaining two poles of CB.

c) Timer checking: Connect standard timer in parallel with CB timer. Extend 220 volt DC to both the timers and note down the timings at which output contacts of timer (which are going to pole discrepancy trip relay) gets closed. If there is a difference between timing readings of two timers, adjust the CB timer's settings accordingly.

Permissible value of pole discrepancy between two poles of CB is 3.33 m/sec. However, timer is set to trip the remaining poles taking into consideration the auto reclose scheme adopted by the utilities.

Checking of Operational Lockout for Circuit Breakers

Operational lockouts are provided in circuit breakers to prevent the operation of the breaker during deficiency in the circuit breaker or its operating mechanism. The lockouts provided in CBs are to be tested to check for any drift/ non-function as they are safety devices to prevent improper operation leading to failure.

Low Gas Pressure Alarm: Close isolation valve between CB Pole and density monitor. Start releasing SF_6 gas from density monitor till the low pressure gas alarm contacts are closed which is detected by Multimeter. Note down the pressure and temperature at which the contacts get closed.

Operational Lockout Alarm: Continue releasing SF_6 gas from isolated zone till the operational lockout alarm contacts are actuated which are detected by multimeter. Note down the pressure and temperature at which the contacts get actuated. Gas is to be taken in to gas evacuating unit and after checking, gas is to be filled to the rated pressure in the CB.

Pneumatic Operating System Lockout:

a) Compressor START/STOP Switch: Close the isolating valve of CB. Release air into atmosphere from the compressor. Note down the value of pressure at which compressor starts building up air pressure and pressure at which compressor stops.

b) CB auto reclose (AR) lockout: Close Isolation valve between pneumatic system and pressure switches. Release air from the isolated zone to atmosphere. Note down pressure at which AR L/O contacts of pressure switch get actuated which are detected by multimeter. The leads of the multi meter should be connected to the contactor where the AR L/O of CB is made.
c) CB closing lockout: Release air from the isolated zone to atmosphere. Note down pressure at which CB Closing L/O contacts of pressure switch get actuated which are detected by multimeter.
d) CB operational lockout: Release air from the isolated zone to atmosphere. Note down pressure at which CB Operational L/O contacts of pressure switch get actuated which are detected by multimeter.
e) Mechanical Closing Interlock (MCI) (FOR ABB CBs ONLY): CB should be in closed position. Release air from pneumatic system of CB to atmosphere and observe whether CB poles start opening, if so, note down the pressure at which tie rod starts coming down, the movement to stop after a few millimetres. The MCI is provided to prevent opening of the CB. Non operation of MCI is to be investigated.
f) Hydraulic operating system lockout: By opening pressure release valve, note down the pressure at which pump starts building up oil pressure and pressure at which pump stops.
g) CB auto reclose lockout: Close Isolation valve between hydraulic system and pressure switches. Release oil from the isolated zone to oil tank. Note down pressure at which AR L/O contacts of pressure switch get actuated which are detected by multimeter.
h) CB closing lockout: Release oil from the isolated zone to oil tank. Note down pressure at which CB Closing L/O contacts of pressure switch get actuated which are detected by multimeter.

All the SF6 gas pressure lockout switch settings should be checked and corrected with ambient temperature. Settings should be within ± 0.1 bar/kg/cm^2 of the set value (after taking into account the temperature correction factor).

All the air/oil pressure lockout switches settings should be checked and corrected and should be within ± 0.1 bar/ kg/cm^2 of the set value.

3.1.2.3 CURRENT TRANSFORMERS

Capacitance and Tan∂ Measurement

Capacitance and tan∂ measurement on CTs is done to evaluate the healthiness of solid insulation. As most of the CTs have oil impregnated paper as solid insulation, capacitance and tan∂ measurement indicates the amount of deterioration. The test procedure is similar to the test described under transformer bushings.

CT is to be isolated from supply for carrying out this test. Terminal jumper is to be disconnected from HV side of CT if test tap is not provided. If test tap is provided, test tap should be disconnected from ground before measurement and to be grounded after the measurement is completed. Measurement is to be carried out at 10 kV or 12 kV level with highest sensitivity level. As CTs are in high induction area, testing instrument should be able to suppress the interference.

Test procedure

a) CTs with test tap: High voltage from tan delta test kit should be applied to primary (HV) terminal and LV should be connected to tan delta test tap. Measurements have to be taken in UST mode.

b) CTs without test tap: High voltage from tan delta kit should be applied to primary (HV) Terminal and LV should be connected to the ground/earth. Measurements have to be taken in GST mode.

In both the above cases, before applying HV, interference is to be nullified using interference suppression unit (ISU). Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/ induced voltage conditions should be followed. Measurements are to be carried out in main and reverse mode and then the average value to be computed.

The permissible values of capacitance and dissipation factor of class A insulation, e.g., Paper insulation impregnated in oil is 0.007 at 20°C. Tan delta value should not exceed the permissible limit. A record of the measured values of capacitance and tanδ is to be maintained for monitoring the variation in the values (trend). It is all the more important to monitor the rate of change of Tan delta and capacitance. Tan delta value should not increase by more than 0.1 % per year and capacitance value by 1% per year. So before taking any decision about condition of CT above facts need to be considered. Change in capacitance values can be within + 1 0%, to -5% of the original value.

An increase in only tan∂ value (not appreciable change in capacitance value) indicates deterioration of cellulose insulation whereas increase in both tan delta and capacitance values indicates ingress of moisture in the insulation.

Main reason for increase of tan delta value is because of presence of inherent air voids which are created during manufacturing process. In course of application of high voltage, these voids are ionized which result in deterioration of insulating properties of the insulation.

Insulation Resistance Measurement for Current Transformers

IR values between primary terminals to earth are measured with a 5 kV megger and associated accessories like test leads etc. Motorized insulation tester is preferred for better results.
Before testing, associated Circuit Breaker and the isolators from both sides of CT should be in open position. Earth switch should be open at the time of IR measurement.

Testing Procedure: HV terminal of the megger is to be connected to the Primary terminal of CT by using crocodile clip for firm grip and LV terminal to be connected to ground. A test voltage as specified is applied and successive readings are taken. Values of IR are to be recorded after 15 seconds, 60 seconds and 600 seconds. Ambient temperature and weather conditions are to be recorded.

Changes in the normal IR value of CT indicate abnormal conditions such as presence of moisture, dirt, dust, crack in insulator of CT and degradation of insulation. Changes in the IR value of CT may be due to the weather conditions also. It is advised to carry out IR measurement during sunny and dry weather preferably. Insulation Resistance changes with deterioration in insulating properties. Absolute value of1R is important to monitor but the rate of change is equally important. Minimum value of 1000 M ohms is considered satisfactory.

If readings of IR increase with time, the insulation is good. However, if readings remain same over the time span, insulation is contaminated. This is due to the fact that charging current and absorption currents subside with time and only conduction current remains. This indicates that total current taken by insulation changes with time. However, if there is no appreciable change in the total current drawn by the insulation, it is an indication of domination of conduction current over charging and absorption currents. Factors to be monitored for these abnormalities are briefly given below:

$$\text{Dielectric Absorption ratio} = \frac{\text{IR value after 60 seconds}}{\text{IR value after 15 seconds}}$$

$$\text{Polarization Index} = \frac{\text{IR value after 600 seconds}}{\text{IR value after 60 seconds}}$$

If Dielectric Absorption Ratio is above 1.5 then insulation quality is considered to be good. If Polarization Index is more than 1.3 then also insulation quality is considered to be good.

Measurement of Secondary Winding Resistance for Current Transformers

Secondary winding resistance of CTs is measured with a digital or analogue Ohm meter with leads. While taking the measurement the CB and Isolators from both sides of CT should be in open position. Test links to be opened in the CT MB prior to measurement of secondary resistance. It is to be ensured that associated CTs are not in charged condition. For example, main and tie CTs for differential relays should not be in charged condition. Earth provided if any in the secondary circuit of CT, should be removed prior to measurement.

Leads of ohm meter should be connected between different terminals of CT secondary cores. Select suitable range on ohm meter. Record the winding resistance values.

Value of secondary winding resistance should be within acceptable limits. Extreme low value of resistance indicates turn to turn shorting and a high value indicates loose connection which is to be identified and tightened before repeating the measurement.

Magnetization Characteristics of Cores for Current Transformers

Saturation level is an important magnetization characteristic of CT cores.

Knee Point Voltage: Knee Point Voltage is defined as the voltage at which a 10 % increase in flux density (Voltage) would cause 30% to 50% increase in exciting ampere-turns (current).

Equipment required for testing are Voltage source of 5 kV, Voltmeter of range 0 to 5 kV, Ammeter of range 0 to 100 Amps, testing leads/cables, etc.

CB and Isolators from both sides of CT should be in open position. Test links should be opened in the CT MB prior to test. All the associated CTs shall also be not in charged condition. For example, main and tie CTs for differential relays should not be in charged condition. If any earth is provided in the secondary circuit of CT, same is to be removed prior to measurement. Applied voltage to the CT core should not exceed the rated Knee Point Voltage of the CT.

Voltage is injected in the secondary after making proper connections. Applied voltage is increased from zero to rated Knee Point Voltage in steps of 25%, 50%, 75% and 100%. Measure the Current drawn by the CT secondary core at respective applied voltages and record the test results.

The magnetization test is conducted in order to see the condition of turns of CT secondary. This test gives an indication regarding shorting of turns CT secondary winding. Magnetization characteristic also indicates the healthiness of CT.

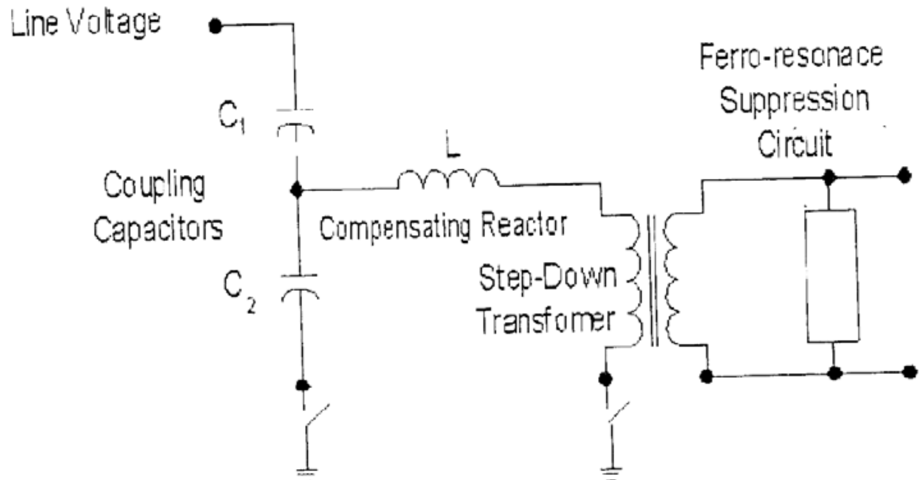
The magnetization current at rated Knee Point Voltage should not be more than the specified/designed value. A curve can be drawn between applied voltage and magnetizing current.

From the curve it can be observed that up to rated KPV (Knee Point Voltage), the VI curve is almost a straight line. However, if this line is not linear, this indicates that the magnetizing characteristics are not desirable. If the slope of the curve starts increasing, it indicates that magnetizing induction becomes low and total primary current is utilized in exciting the core alone. Consequently, output of CT secondary will be erratic.

3.1.2.4 CAPACITIVE VOLTAGE TRANSFORMERS

Measurement of Secondary Voltage

As CVTs are made up of capacitor elements, any puncturing of element will alter the secondary voltage of CVT. Capacitor elements in CVTs are designated as C1 and C2 as shown in the figure below. In 400 kV CVTs, there are about 280 - 300 elements in C1 and C2 out of which C 1 has about 260 to 280 elements and C2 about 15 to 20 elements leaving ratio of C 1/ C2 to about 20 as tap voltage. Puncturing of one capacitor element in C1 side is likely to increase secondary voltage by about 0.35 to 0.45% (0.22 - 0.28 V) and failure of one capacitor element in C2 side is likely to decrease secondary voltage by 5 to 6% (3.2 - 3.8 V)



CVT Basic Circuit

Periodic measurement of secondary voltage is to be done to check the healthiness of the capacitor elements. The measured voltage is to be compared with other phases of the same CVT and in case of doubt, simultaneous measurement to be carried out with another feeder/ Bus CVT. A precision multimeter of accuracy of 0.5 class or better for AC voltage should be used.

Any drift in secondary voltage of CVT has to be analyzed and action taken accordingly. There may be difference in secondary voltage due to unbalance in primary voltage also. This will be marginal and simultaneous measurement with another healthy CVT could help identify the problem. The following table gives a broad guideline for action to be taken to identify the defective CVTs and to eliminate the defect from service.

SI .No.	Drift in secondary voltages	Condition of CVT	Measurement frequency
1.	**Up to ±0.5 volts**	**Healthy**	**Six Monthly**
2.	**±O.5 to ±O.8 volts**	**Needs monitoring**	**Three Monthly**
3.	**+0.8 to + 1.2 volts**	**Needs close monitoring**	**Monthly**
4.	**+ 1.2 to +2.0 volts**	**Needs close monitoring**	**15 days**
5.	**Above +2.0 volts**	**Alarming! Critical**	**Needs replacement*.**
6.	**-0.8 to - 4.0 volts**	**Needs close monitoring**	**l5days**
7.	**Less than - 4.0**	**Alarming**	**Needs replacement***

***Before replacement of CVT, voltage drift is to be reconfirmed by simultaneous measurement of voltage w.r.t. other feeder CVT of same phase.**

Capacitance and Tan∂ Measurement

A large number of equipment insulation failures can be identified in advance by carrying out Tan∂ and capacitance measurement. Changes in the value of capacitance indicate abnormal conditions such as presence of moisture, layer short circuits or open circuits in the capacitor elements of CVT stacks.

Measurement is to be carried out by 10 kV or 12 kV test kit. As there will be induction at switchyard, kits with induction suppression facility must be used.

Jumper is to be disconnected from HV terminal. PLCC connection/earth connection is to be removed from HF point/bushing and earth connection to be removed from neutral point of EMU tank.

Before carrying out the measurement, the insulator petticoats of CVTs should be thoroughly cleaned to remove moisture, sand, dust particles or salt deposition etc. as presence of these may influence the measured values. All safety precautions pertaining to the high voltage kit used to be observed.

HF point should be disconnected from ground/ PLCC. Neutral/ LV of Intermediate voltage transformer should be disconnected from ground. High voltage from tan delta kit should be applied to primary (HV) Terminal and LV should be connected to the HF point of the CVT. Before applying HV, interference is to be nullified using interference suppression unit (ISU). Measurement has to be taken in UST - Mode. Standard procedure (as specified by kit supplier) for measuring capacitance and tan delta in charged switchyard/induced voltage conditions should be followed. Measurements are to be carried out in main and reverse mode/polarity and then the average value to be computed.

Evaluation of the test results:

SI. No.	Parameter	Change of the measurement parameter from the pre-commissioning value	Remarks
I.	Capacitance	Up to ±2%	Normal
		±2% to ±3%	Yearly measurement
		Above ±6 %	Needs replacement
2.	Tan Delta	Up to +0.002	Normal
		+0.002 to +0.003	Yearly measurement
		Above +0.003	Needs replacement

Note: If only Tan Delta values exceeds +0.003 (increase from the pre-commission values) and other parameters like drift in secondary voltages and capacitance values are within acceptable norms, the Test results are to be reviewed for further action by experts.

3.1.2.5 DISCONNECTORS (ISOLATORS)

Contact resistance of disconnector switch main contacts should be measured to check the healthiness of the current carrying parts. Micro ohm meter of 100 A or more current injection capacity with accessories is required for this test.

CB is to be in open position and other side disconnector switch of CB also to be in open position. High voltage plugs should be free from moisture during installation and operation. At the time of connections, both sides of disconnector switch should be earthed by closing earth switches or by temporary earths. After making the connections, earthing is to be removed.

The ohm meter operates on the four wire measurement principle. To measure the contact resistance connect the respective leads and adjust the variac so that app. 100 amps current flow through the contacts. Value of contact resistance is directly displayed on the digital LED display screen. By using four terminal method, we can nullify the resistance of test leads if input impedance of measuring device (IC) is very high.

Contact resistance of the main contacts indicates wear out and misalignment of the main contacts. If the value of contact resistance exceeds the permissible limit, i.e., 300 micro ohms this could result in overheating of the contacts. Therefore, the problem of high contact resistance should be attended immediately by making proper alignment of contacts or by replacing finger contacts.

3.1.2.6 SURGE ARRESTERS

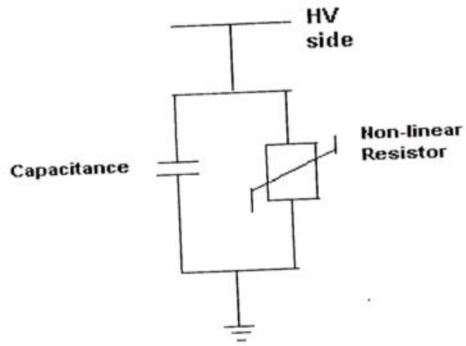
Surge Arrestors installed in the substation are intended to divert surges to earth and thus protect costly switchyard equipments. Proper insulation coordination is necessary for enhancing life span of costly substation equipments.
Surge Arrestors are monitored basically using three tests to evaluate their condition. Leakage current monitoring, Insulation resistance measurement and thermo vision scanning would indicate any deterioration in surge arresters. Out of these, leakage current measurement and thermo-vision scanning are on-line measurement and shut down is required for IR measurement. As system availability is crucial for utilities, more emphasis is to be given for on-line measurements.

Leakage Current Measurement: As per IEC-60099(5), the following condition monitoring techniques for the surge arresters in service are suggested:

- Total leakage current measurement
- Watt loss measurement
- Insulation resistance measurement
- Third harmonic resistive current (THRC) monitoring with compensation for third harmonics in system voltage.

Total leakage current measurement is not sensitive to the deterioration of the arrester discs as this does not indicate severity of ZnO disc degradation as resistive current is only 20-30% of the total leakage current and a sharp increase in resistive current due to degradation of arresters discs do not affect the total leakage current considerably. Watt loss measurement is a useful method but it involves a separate voltage source and test results are affected by phase shifts introduced by CVT/PT. The harmonics present in the system voltage may create capacitive harmonic currents, which may be comparable with the harmonic currents generated by the non-linear resistance of the surge arrester. As a result, the error in the measured harmonic current may be considerable. The error in the measured third harmonic current may be up to 100% with 1 % third harmonic present in the system voltage. Hence, reliable monitoring of surge arresters is possible through such test kits which provide for compensation for harmonics present in the system voltage.

The equivalent circuit of surge arrester is parallel combination of capacitance and variable resistance (as shown in figure). The current flowing through the zinc oxide discs is the total leakage current (h), having capacitive leakage current (Ic) and resistive leakage current (Ir) components. Normal operating voltages causes ageing of ZnO discs whereas switching/ lightning over voltages may cause over loading of all or part of the ZnO blocks. The increase in resistive leakage current (Ir) due to above reasons may bring the arrester to thermal instability and may result in complete arrester breakdown. Hence, monitoring of leakage resistive current (Ir) is very important.

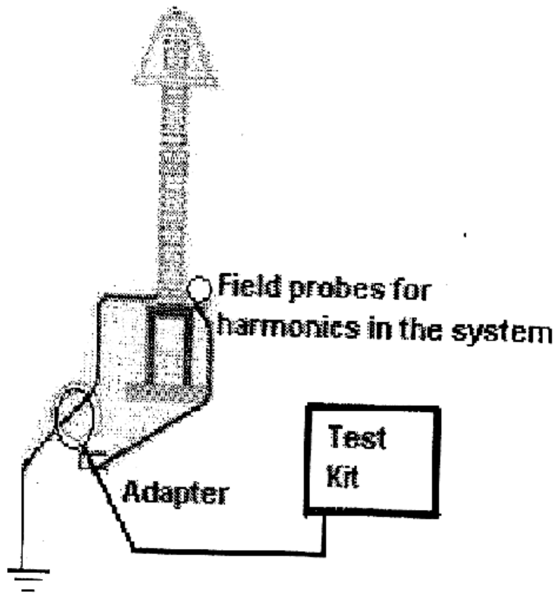


Harmonics are created in leakage current on application of fundamental frequency, due to non-linear voltage-current characteristic of surge arresters. Third harmonic is the largest harmonic component of the resistive current. Third harmonic in system voltage creates capacitive harmonic currents which affect the measured value. Error in the measured values may be considerable. As reported, 1% third harmonic in system voltage may introduce error up to 100% in the measured value.

Resistive current consists of fundamental, third harmonic, fifth harmonic and seventh harmonic components. The harmonic content depends on the magnitude of the resistive current and on the degree of Non-linearity of the voltage-current (V-I) characteristics. The harmonic content also varies with the voltage and temperature of the surge arrestor.

The third harmonic is the largest harmonic component of the resistive current and is most commonly used for diagnostic measurements. No reference is needed for measurement of third harmonic resistive current (THRC) since it is assumed that all harmonics arise from the nonlinear resistive current. The conversion from harmonic to resistive current level, if required, relies on information supplied by surge arrester manufacturer or from measurements in the laboratory. Basic-principle of this technique lies in the measurement of third harmonic resistive current duly compensated for third harmonics present in system voltage. A trend analysis of the 3rd harmonic resistive current is necessary to observe periodical changes due to normal/abnormal ageing. Sudden rise in THRC or very high value of third harmonic resistive current indicates degradation of ZnO discs and inspections/corrective actions are required to be taken in advance to prevent catastrophic failures.

The total current (It) through the Surge Arrester having Capacitive component (Ic) and Resistive current (Ir) flows through the Leakage Current Monitor. The I_R component has 3rd, 5th harmonic and other harmonics present in it. However, when degradation of ZnO discs occur, the variation of 3rd Harmonic Resistive Current is more pronounced than other harmonics currents, total current (h) and total capacitive current (Ic).



The connection arrangement for the instrument is quite simple as shown in above Figure.
Connecting a clamp type CT probe to the ground wire allows the leakage current to be detected. Probe output passes through a shielded cable to the detector unit. A band pass filter is built into the initial stage to pass the third harmonic and to cut off the fifth and higher harmonics. After the third harmonic is selected, it is amplified and then displayed. Compensating antenna is also provided, output of which is fed to the test kit to compensate for the harmonics present in the system voltage.

The harmonics present in the EHV system are compensated and filter circuits are provided for bypassing undesired currents and only 3rd harmonic resistive current is measured.

Insulation Resistance Measurement: Insulation resistance measurement is to be first carried out on individual stacks and then carried out the complete arrester. As this is off line test, the arrester is to be taken out of service for such measurement.

IR test proves good to find out any moisture entry through sealing inside the arresters.
Keeping a stack with low LR value will stress the other stack also and failure is more prone on the other stacks also. Corrective action is to be taken immediately.

Thermo-vision Scanning: Thermo-vision scanning helps in identifying defects in EHV switchyard. As it requires no shut down of switchyard equipment, it can be widely used on condition monitoring. Any loose joint, improper isolator contacts and current transfer parts could be identified using thermo-vision scanning.

Thermo-vision scanning also helps in identifying defects in surge arresters. This may not be true always but if there is defect and more current is passing through the arrester, then the temperature inside arrester will increase and could be detected by thermo-vision scanning. It is advisable to carryout this test during maximum voltage condition of the switchyard unlike thermo-vision scanning of other current carrying components during maximum current flow condition. This test followed by IR measurement /Tan∂ and capacitance measurement shall indicate healthiness of surge arresters.

3.1.2.7 Earth Resistance Measurement

The resistance to earth of an earth' electrode may change under different soil moisture condition and over a period of time. Establishment of satisfactory earthing systems (low total resistance to earth) is essential to ensure safety to the equipment and operating personnel. Measurement of the resistance of earth electrodes is done to see that they meet and remain within the required resistance limits.

Earth tester manual or automatic, analogue or digital along with following accessories is required for measuring earth resistance.

Hammer 1.13kg – 1no, Galvanized steel spikes12 mm square section 450mm long - 4nos,
Spike extractors – 2nos, Cable complete with connector and clip – 30m (1 no.), 50m (1 no.)

Safety Precaution: It should be strongly impressed on all test personnel that a high potential (of the order of 1 kV to 10 kV) can exist between the station ground and a remote ground, if a power system fault involving the station ground (though the chances are remote) occurs while ground tests are being made and therefore insulating shoes, gloves and other protective devices may be used by the testing crew whenever measurements are carried out in an energized substation and handling the test leads.

Method of Testing using the earth Testing Megger: The earth testing megger consists of basically a moving coil meter with two coils at right angle. A control coil is arranged to be in series with the current probes. The movement of the pointer is then dependent on the ratio of currents in the two coils and is thus dependent on resistance. Terminals P1 and C1 should be connected to main station earth E by separate copper wires (E is the substation earth mat electrode). A current probe, usually a 12 mm square section, 450 mm long galvanized steel spike is connected to a cable which is run out a distance of 5 times, the length of the longest diagonal of substation (should this be physically impossible then the maximum obtainable distance should be used), the other end of the cable being attached to terminal C2. Another probe P (again 450 mm long, galvanized steel spike of 12 mm square section) is attached by another cable to terminal P2, completing the connections required for measurement. When running wires to the electrodes they should be laid at least 2m apart to minimize inductive coupling.

In carrying out earth resistance checks it should be remembered that overhead lines with their aerial earth wires can provide a path for the earth megger current, so giving a false reading. The electrode should therefore be run out in a direction to avoid any incoming line routes and if possible tests should be made in different direction.

At least 10 measurements are to be made at intervals from the C2 electrode inwards as far as practicable. The resistance/distance curve so obtained should show a "plateau" region. The resistance of this region is taken to be true earth resistance of the rod or plate. If a plateau region is not obtained, the test should be repeated with the C2 spike further away typically 500 m away from the substation.

However three measurements are recommended for simplicity with moving potential electrode P say by 6 m away from E and 6 m nearer to E and average can be taken.

Testing steps – Fall of potential Method: P1 and C1 terminal is sometimes named as terminal X which is connected to earth electrode E. Connect C2 terminal to remote current spike C, at least 100 m away from any part of the earthing system. In addition it should not be in line with any overhead transmission line, buried cable, metal water pipe or other earthed electrode. Connect P2 terminal to remote potential spike P, 61.8% of total distance d away from earth electrode E so that interference of electromagnetic field if any do not affect readings. Make the first measurement- R1.

Move the potential spike P nearer to electrode E by a fixed step (say 6 m). Make the second measurement- R2. Move the potential spike P further away from electrode E by 6 m (the other side of the centre position). Make the third measurement- R3. Resistance of the earth electrode is the average (RA) of these three results (provided they agree within the specification limits of the electrode system).

RA = (RI+R2+R3) / 3

Any error in earth testing measurement is due to mainly low value of testing current used and maximum sensitivity of any instrument. On large electrode systems the instrument is working at the extreme end of its designed range and should the earthing system exhibit a high reactance, then the true impedance is not measured.

An ideal grounding should provide a near zero resistance to remote earth. In practice, the ground potential rise at the station site increases proportionally to the fault current. The higher the current, the lower value of a total system resistance thus has to be obtained. For most transmission and other large grid substations, the ground resistance should be less than I ohm. In smaller distribution substations, the usually acceptable range is from I to 5 ohm depending on the local conditions (as per ANSI/IEEE 80/1986).The value measured should be within 20% of the previous value or if no previous history is available, it should be compared with the resistance of a similar rod or plate on the same site.

3.1.2.8 MAINTENANCE OF GAS INSULATED SWITCHGEAR (GIS)

Before taking up the maintenance of GIS, safety rules as recommended by the manufacturer shall be adhered to. Some of them are listed below

(a) The maintenance programme and periodicity specified/no. of operations whichever is earlier should form the basis of maintenance.

(b) The following shall be strictly followed:

- Maintenance shall be carried out by authorized persons only.
- Parts supplied by original manufacturers only should be used.

- Equipment to be maintained should be de-energized/de-gassed, isolated and earthed on all sides of the work zone.
- Necessary tools and tackle such as slings, platforms, electrical equipment and tools should be kept ready and should be in good condition

Condition Monitoring of GIS: GIS requires very little maintenance. Monitoring the SF6 gas pressure and quality is considered sufficient. Regular inspections, Routine scheduled maintenance and overhaul maintenance as specified by the manufacturers should be followed. The maintenance to be carried out and their periodicity is indicated in the "Maintenance Schedule". Manufacturer's instructions are to be followed for special tests, if any, for a particular make of GIS substation.

SF 6 Gas: As SF_6 gas is used in all chambers of GIS, monitoring of pressure and quality of gas is important. As per IEC 62271-203/2003 the leakage rate from any single compartment of GIS to atmosphere and between compartments shall not exceed 0.5% per year for the service life of the equipment. The pressure inside a GIS may vary from the rated filling pressure level due to different service conditions. Pressure increase due to temperature and leakage between compartments may impose additional mechanical stresses. Pressure decrease due, to leakage may reduce the insulation properties. Further the quality and dew point of SF_6 gas should also be monitored as the property of SF_6 is related to its insulation quality.

Partial Discharge Measurement: Electrical Ultra High Frequency (UHF) or Acoustic PD measurement techniques are being employed. Electrical UHF technique gives higher sensitivity and PD detection necessitates the installation of sensors inside the gas compartment during manufacture. Acoustic methods employ sensors which are fixed outside the enclosure. For both the methods the sensitivity depends on the distance between the defect and the sensor.

UHF Partial Discharge Measurement: The partial discharge signals in the range 1000 MHz to 2000MHz can be detected in the time domain or frequency domain by means of sensors usually installed inside the chambers. Due to the complexity of the resonance pattern, the magnitude of the detected PD signal depends strongly on the location.

Acoustic Partial Discharge Measurement: Acoustic signals are emitted from defects in a GIS mainly by the floating particles emitting a mechanical wave in the enclosure when they impinge on it. Discharges from the fixed defects create a pressure wave in the gas, which is then transferred to the enclosure. The resulting signal will depend on the source and the propagating path. As the enclosures are normally made of aluminum or steel, the damping of the signals is quite small.

Acoustic signals can be picked up by means of externally mounted sensors. The location of the defect can be found by searching for the acoustic signal with highest amplitude or time travel measurements with two sensors. Bouncing particles producing discharges in the 5pC range can be detected with a high signal to noise ratio. Sensitivity decreases with distance because the acoustic signals are absorbed and attenuated as they propagate in the GIS. Acoustic measurement is immune to electromagnetic noise in the substation. The acoustic sensitivity to bouncing particles is much higher than the sensitivity of any other method. **PD** measurement in a GIS installation is recommended once in 5 years.

In GIS substation some of the equipments like Bushings, Surge Arresters, and Transformers shall be provided outside the GIS area. Condition monitoring of these equipment is to be carried out as followed for conventional substation equipment.

3.2 TRANSMISSION LINES

3.2.1 Preventive Maintenance Procedures:

3.2.1.1 Periodical maintenance:

Normal ground patrolling of lines should be conducted by lines maintenance crew periodically. Periodicity will be decided on the basis of importance of the line, terrain condition, and proximity of the line to habitations, forests, gardens, water borne areas etc. and environmental impact on the line. During ground patrolling of the line, the patrolman should check for the following

- Location no; type of tower (tangent/angle, normal/extension), location address.
- Clearances of the line, both to ground and in air.
- Availability of all tower parts and their condition. Obstructions in the proximity of the line (within line corridor) like trees, branches, structures etc. location wise should be noted.
- Condition of foundations such as chimneys, copings and consolidation of foundation pits. Defects noticed should be recorded.
- Observing the condition of insulators, conductors, earth wire, jumpers, clamps, dampers, spacers etc., with binoculars, from ground level/nearest possible elevated level.

Observations made location wise by the patrolman should be noted in a diary and presented to the Engineer concerned within two days. Any specific observation warranting immediate action should be brought to the notice of the Engineer through mobile phone or immediately on return from patrolling.

Phase to ground faults on lines such as birds shorting the live point to ground, flash over of insulators, tree branches/levels coming into close proximity of the line (ionized zone) may cause momentary tripping of the lines.

3.2.1.2 Special patrolling of the line should be done after momentary tripping of the line on fault, for any defects. Defects noticed shall be rectified immediately if this can be attended while the line is live or at the earliest by availing shutdown, any way, before the defect develops into a major one causing breakdown. Proper planning of materials and manpower is required in order to carryout rectification under shutdown in minimum time to avoid/minimize interruption to loads.

3.2.1.3 Break down maintenance: When a permanent/semi permanent fault occurs on the line, the line may break down causing interruption of longer duration. The faults could be snapping of conductors, disconnection of jumpers, cross-arms/ towers twisting or tower collapse with or without damage to foundation. This may be due to various reasons like heavy wind due to storms, weakening of tower legs due to rusting and chemical pollution, accidents, thefts etc.

In olden days ground patrolling was arranged in the territories of concerned subdivisions to physically inspect the line to identify the fault. After identifying the faulty location and nature of fault through the nearest public telephone to the concerned, who would then arrange for mobilization of required materials, tools and tackle and necessary manpower and proceed to the location for rectification.

Introduction of Static/ Numerical relays replacing the old electro-mechanical relays, facilitated indication of distance to fault location in proportion to the impedance to fault on line. The accuracy of this measurement depended largely on the accuracy of the relays in measuring correct reach and the nature of fault.

Digital off-line fault locators are now in use in APTRANSCO for measurement of distance to the fault. After the line is declared faulty, the line is isolated. Off-line fault locator is connected on the faulty line and tested for measurement of distance to fault. This instrument indicates the distance to an accuracy of 100metres.

3.2.1.4 IT tools such as Transmission Network Asset Management System (TNAMS) developed in 2003 and Maintenance module in Enterprise Resource Programme (ERP) developed in 2007, provide and display relevant geographic and technical information of the assets of Transco as follows:

Substations: Single line diagram of the SS, Nameplate details of each electrical equipment connected in the SS. Date of commissioning of each equipment and various maintenance schedules for the equipment and the dates on which they are due and the dates when maintenance was done and the results of maintenance. Type of earthing and earth layout and earth resistance of each electrode and combined earth resistance and maintenance details as above.

Lines: Line route giving geographic details such as location no. significant land marks near the location viz; rail, road, power line/ P&T line crossings, river, streams, tanks, hill slopes, forests gardens, habitations, longitude and latitude of the location obtained through GPS and technical details such as type of tower (tangent/angle, normal/extension), type of foundation adopted, bill of materials for the tower, size and configuration of the conductors and earth wire, type and no. of insulators and their technical details, vibration dampers, spacers, prefabricated armored suspension grips etc. Maintenance schedules for the lines, dates due and dates done along with the results are also displayed.

The entire system can be monitored and reviewed by the concerned authorities at field and headquarters.

Immediately after finding the faulty location distance through fault locator and identifying the approach to the location with the help of TNAMS/ERP, the AE/ADE along with maintenance crew will proceed to the location along with essential materials like conductor bits, insulators, clamps bolts& nuts, ropes and slings, earth discharge rods, compression joints, hydraulic compressors etc. They shall carry with them torch lights to facilitate checking the locations and working in the nights. After identifying the fault, the AE/ADE with their crew should take up rectification with the available men and materials duly giving intimation to the DE and obtaining line clear. Line should be discharged and the work spot should be earthed on both sides to avoid induction from the adjacent lines, before working on the line. Assistance of local labor may be taken if required depending on the need. Where the fault is major one and cannot be rectified for want of major spares and more man power and machinery or where civil works like foundations are involved, description of such faults and the materials required for rectification shall be intimated to the ADE/DE concerned over mobile phones. DE will immediately assess the type of materials required based on the nature of fault reported and the technical details of the location available in the TNAMS/ERP, and plan for mobilization of men, materials and machinery for taking up rectification.

Use of off-line fault locator and IT tools save considerable time in identifying the faulty location and assessment of material and man power required.

3.2.2 Condition Monitoring Procedures

3.2.2.1 Condition monitoring is useful in identifying some of the defects on conductor and insulators, which is not possible through visual ground inspection. Assessment of nature of defect helps in taking preventive action. Possible breakdowns due to defective joints, punctured insulators etc. can be avoided.

Various condition monitoring methods are:

On Line Techniques -- Coronagraphy
-- Thermo vision scanning
-- On line puncture insulator detection test

Off Line Techniques -- Pollution measurement of insulators
-- IR measurement of insulators
-- Contact resistance measurement
-- Signature print outs by using off-line fault locator

3.2.2.2 Coronagrphy: Corona discharge is a luminous partial discharge from conductors, and insulators due to ionization of air where field intensity exceeds a critical value. Corona discharge is severe at sharp edges and generates corrosive material which reduces life of components. Corona radiations are in 280 nm – 405 nm of the spectral range and are not visible to naked eye. However they can be seen to certain extent in pitch dark during nights.

Coronagraphy is a technique used to observe corona on various transmission line components under live condition. Sophisticated camera enables to observe corona even during day time. With the help of this technique line components generating corona can be detected during normal patrolling and rectification / replacement of such components can be done during subsequent shutdown on the line.

3.2.2.3 Thermo-vision scanning: Current flow in the conductors generates heat in various electrical components. Intensity of current varies depending on the contact resistance and quantity of current flow. Most of the heat generated is in the infra-red range and hence not visible to naked eye. Amount of infra-red energy generated is proportional to the temperature. Detection and rectification of hot spots in early stages prevent breakdowns such as snapping of conductors etc.
Thermo-vision scanning/ thermal imaging/ thermography is a technique which produces an image of invisible infrared light emitted by objects due to their conditions. Sophisticated cameras can actually measure the temperatures of any objector surface in the image and produce false color images that make interpretation of thermal patterns easier.

Thermo-vision scanning systems can be used as hand held portable cameras, fixed monitoring systems as aircraft/vehicle mounted systems to cover a wide range of applications. The cameras provide accurate information about severity of the hotspots observed and time allowable for rectification.

With the latest version of Inframatics 760 system with Thermotroniks software, the condition of the line jumpers, insulators, metal parts, connectors of transformers and current transformers, where the change of temperature is there, can be identified well in advance and behavior of the metal part can be analyzed in the computer. The temperature rise of any connector after detection can be rectified in advance even before deformity or red hot occurs for the clamp or connector.

3.2.2.4 On Line Puncture Insulator Detection Test: The strength of an insulator can be measured by its IR value. The insulator string efficiency depends on the uniform distribution of electric field across the insulators. Any variation in the field strength across the string will indicate the healthiness of the insulator. It is practically not possible to measure IR values of each insulator in a string which is live. Degradation of insulating material may result in puncture of the insulator. When an insulator starts conducting due to puncture the field intensity across that insulator reduces. This change in electric field intensity across the insulators will be used to diagnose the healthiness of the insulator.

There are two test methods to detect insulator puncture on line:

(a) Voltage detection method - In this method a hot line stick mounted with a voltage recorder is moved across each insulator to record the voltage across it. The disc having voltage of above 11kV will be regarded as a healthy insulator.
(b) Electric field measurement method – The detector test kit consists of an electric field detector mounted on a plastic support. Test kit will be moved across the insulator string from top to bottom and vice versa. The field intensity across each disc will be recorded in the memory of the kit which can be down loaded into PC through a serial port. A graph is plotted with insulator no. on X- axis and log of electric field intensity on Y-axis. Comparison between the healthy insulator and the defective one is made.

3.2.2.5 Off Line Fault Locator: Digital off line fault locator works on the principle of wave reflection. High frequency high power signal is injected into the transmission line from one end of the line. This high frequency signal on its way to the other end encounters wave reflection or refraction depending on the nature of the fault. This echo of the wave is utilized to determine the fault location. Signature analyzer indicates the degree of faults from the minimum to the major fault in progressive numbers. A no fault line or uniform line is indicated as "-". All types of fault can be detected with an accuracy of +/- 100mtrs.

Inhomogeneities in the line could be due to improper joints in the conductor, hot spots due to loose jumpers, leakage points, Disc puncture where there is electrical path to ground and heating over 5 deg ambient, Crossing of another EHT line, Steep changes in terrain inclination or severe phase sag. If left undetected, these may turn into major problems resulting in outage of line. Fault locator can be used as a condition monitoring tool to provide signature analysis of the transmission lines to trace inhomogeneities existing in the line so as to help in taking suitable preventive measures to minimize the possible outages. Main components of a fault locator are Fault locator unit, Signature Analyzer, Line Simulator Unit and supply and grounding units.
Before conducting the signature analysis, the line should be de energized and isolators opened at both ends. Earth switch should be closed. After connecting the fault locator unit to system ground, connections to the overhead lines should be given. Before commencing the test, the line earth switch should be opened. All safety precautions such as wearing gloves, rubber shoes etc. should be taken.

3.2.2.6 TRANSMISSION LINE MAINTENANCE BY HOT LINE TECHNIQUES

Hot line means energized electrical power line. Minor damages noticed on the line with the help of condition monitoring tools or other wise need to be attended in time to prevent breakdown. Timely attending of these minor problems may require shut down on the lines causing interruption of power supply and consequential revenue loss. Live line maintenance provides a solution to such problems. Live line maintenance or rectification of minor damages on live line is done using hot line techniques, by skilled and trained professionals.

Hot line Techniques: preventive hot line maintenance is carried out using Hot stick / bare hand techniques. Hot stick/Bare hand technique can be used from 11kV to 220 kV where as only bare hand method can be used for lines from 400kV and above.

Hot Stick Method: Hot stick is basically a wooden stick with exceptionally good insulating property, light in weight and having high mechanical strength. Laminated light wood like SITCA Spruce and Himalayan Spruce are used in the preparation of Tie sticks, Wire Tongs, Flexible wrenches etc.
Tie stick is used for tying or untying the insulator bindings where the pin bindings are taken up.
Wire tong holds the conductor or jumper and moves them for a safe clearance of the crew handling the works.

Flexible wrench – By fixing suitable sockets of required size, bolt and nuts of pad clamps, T clamps etc. can be tightened or loosened.

The above wood tools have an inherent property of absorbing moisture, which reduces the insulation level and hence need to be dried before attending to the hot line work. This requires heating chambers, air tight chambers and continuous insulation monitoring.

In spite of ensuring dryness before taking up the work, if the working time on the hot line is extended, the wood sticks absorb moisture from atmosphere, intensity depending on the humidity in air. This is dangerous to the crew working on the line and may cause breakdown of the line.

To overcome the above constraints Glass fibre is used in place of wood stick. The glass fibres are soaked with Epoxy resin and wound to produce a hollow stick. The hollow portion is filled with a unicellular foam to prevent external moisture from entering the inside stick and thus the insulation value of Epoxy glass stick is maintained. Because of this property, use of this stick is a safe option for the operating crew. Maintenance of glass fibre hollow stick is easy as just wiping the stick with moisture eater solution and a little drying in Sun is all that is required to make the stick fit for work.

Different suitable metal heads are fitted to the hot sticks for carrying out number of operations like changing of broken insulators, flashed over insulators and all the connected parts of tension and suspension points of the live lines without interruption to the power. Also tightening or loosening of cut point jumper bolt and nuts, replacing vibration dampers, replacing suspension shoe clamps etc., of the EHT lines and Lifting up of the conductors, changing of cross arms up to 11 KV and 33 KV can be carried out by Hot Stick method.

Bare Hand Technique:

Bare Hand Technique means carrying out work on a charged line with hands by person who stands charged to the required voltage level on an insulated platform. The person is either traversed by insulated ladder or by raising through an insulated boom. The chargeable person will wear a conductive suit comprising of cotton, asbestos and stainless steel threads, along with conductive shoes of copper threaded carbon sole with conductive socks and conductive hand gloves. Total continuity will be maintained from 'Head to Toe' covering the head with hood except the face.

The Bare Hand Technique is not a single man operation; it requires both Hot Stick Method as explained above and a person working with bare hands.

This method can be effectively utilized for connecting bus isolators of additional transformers and other equipment like capacitor banks in 220 kV and 132 kV Sub-stations to the live bus without interruption to any equipment or without Bus shut down.
By this Bare Hand Technique damaged Bus jumpers, T Clamps, Isolator Pad Clamps, Female Contacts can be replaced without the interruption to the bus bars, and conductor damages also can be attended when sufficient clearances are there for operation.

In addition to the above two techniques employed for carrying out hot line works, special works like removing and cleaning of the saline contamination of insulators, cement dust deposits and chemical deposits on insulators can also be carried out on live lines. Three methods are available for carrying out the cleaning.

a) Dry washing b) Hot Spraying c) Wet washing

Dry Washing: The Dry Washing and Spraying will be undertaken with huge hot air along with com husk or paddy husk or peanut husk with lime stone granules. The hot spray of air through nozzles will clean the cement contamination.

Hot Spraying: To avoid cement dust pollution and other chemical pollution, spraying of chemical on the insulators will be taken up. When once the cleaning of the insulators by dry washing is completed a thin film of silicon compound will be deposited on the insulators by Hot Spray.

Wet Washing: Previously the wet washing of the live insulators used to be carried out by a small cylinder with carbon dioxide along with water to a limited extent.

With latest equipment and trigger controls etc. available to day, ordinary water having the conductivity of less than 2 mhos is being sprayed directly on the live insulator to clear the salt contamination, dust and chemical contamination which is soluble in water.

The above works are essentially to be taken up periodically in high polluted industrial areas and coastal areas, where cement, chemical and saline deposits are a regular feature.

Persons working on hotlines are required to be trained and should posses a certificate issued by competent authority. Hot line Training Centre of National Power Training Institute in Bangalore is imparting training in hotline works and issuing a certificate.
Staff will be initially trained in hot stick method. After gaining some experience they can be further trained in Bare hand techniques. While working in Switchyards using bare hand technique, extra precaution shall be taken as the area is congested with equipment all around reducing clearance.

3.2.2.7 XLPE CABLES:

Once the cable is laid under ground following standard procedure and buried, no frequent inspection of the cable is necessary after charging during its life period.

Maintenance staff should be in possession of as built drawings for the cable laid showing land marks of the route.

Manuals and manufacturer's instructions for maintenance and jointing should be kept with the maintenance unit for any reference.

Coordination with other utilities whose under ground systems run in close proximity to the cable (such as water supply, sewerage pipes, communication cables, other power cables etc) is required to make sure that no interference or inconvenience is caused due to maintenance / service of their systems. As built drawings of cable route should be communicated to these utilities for identification of cable route while taking up of their works.

The following checks on the cables may be carried out periodically, to ensure that no damage to the insulation is caused by any other under ground system running in close proximity to the cable:

- Patrolling along the cable route to verify exposure of cable in any locations or interference with other under ground systems
- HVDC test should be done at every section to check the healthiness of sheath insulation
- Check the condition of link boxes at the jointing locations for tightness and sealing against seepage of moisture
- Check the IR values of the Surge Voltage Limiters (SVL) provided in the link boxes at the cross bonded joints.
- Also check for the proper working of SVL, by applying AC voltage in steps up to its rated voltage and check the leakage current. Keep a record of the test results for future reference.
- Also keep a record of nature of faults occurred in the cable system and the details of rectification carried out to provide an input for analysis and preventive measures for future. This would help in revising the maintenance practices based on experience.

3.3 MAINTENANCE SCHEDULES

SUBSTATIONS

Schedules for necessary preventive maintenance tests and condition monitoring tests for each switchyard equipment and transmission line and the adoptable frequency in which the tests are to be carried out are given here under. The schedule includes condition assessment tests and regular maintenance checks for each switchyard equipment and protection scheme. These maintenance schedules are to be adhered to by the Operation and Maintenance staff of the sub station and observations so made during such inspections have to be properly recorded giving complete details of the activity, observed parameters, remarks/views about the checks carried out. Such observations are to be duly signed by the maintenance engineer in-charge of the sub-station and deviations with reference to acceptable norms/limits are to be approved by the competent authority having requisite experience and expertise. Typical formats for inspection checks for various equipment covered below checks for various equipment covered below may be modified as required by site conditions.

Although it is difficult to prepare a single schedule for equipments from 33 kV class up to 400 kV class, the basic tests covered are same for all EHV equipments except for a few advanced Condition Monitoring checks which are more relevant for higher voltage levels.

The condition monitoring tests mentioned in the schedules require analysis of test results by expert engineers for evaluation of the condition of the equipments. The test results obtained during the maintenance activity have to be approved by the appropriate authority.

The tests should be carried out using reliable and calibrated testing instruments of proven credentials as well as accuracy of repeatability so that there may not be any doubt on the results obtained. The requirement of the testing instruments may also vary depending on the voltage range as only properly shielded equipment designed for immunity from Electromagnetic Induction will work in high induction areas.

Obsolete equipment like bulk oil circuit breakers have not been considered in the schedule.
Minimum frequency of maintenance has been given for the purpose of recording. Frequency of some of the activities, which require to be monitored more closely, should be increased. Any abnormality observed by shift/ Operation staff during daily visual inspections should be recorded for corrective action by the maintenance staff.

Typical formats indicating scheduled maintenance activities, periodicities and observations/remarks for each equipment are given below.

1. TRANSFORMERS AND REACTORS

(a) Monthly Maintenance - Activities not requiring shut down

Sl.No	**Activity**	**ICT**	**Bus Reactor**	**Line Reactor**	**Observations & Remarks**
1	**Date of commissioning**				
2	**Make**				
3	**Rating**				
4	**Sl.No.**				
5	**Bay location**				
6	**Bushing oil level**				
7	**Oil level in main &OLTC Conservators**				
8	**Manual staring of oil pumps and fans**				
9	**Check for oil leaks**				
10	**Oil level in breather oil seal**				
11	**Colour of silica gel**				
Signature of AE/ADE (O&M)			**Signature of ADE/DE (O&M)**		

Note: No. of columns may be adjusted to suit the no. of transformers/ reactors

(b)**Half yearly Maintenance**

(i) Measurement of IR values - Megger-(Make/Sl.No./Scale)

Date Temperature at the time of measurement Weather condition

Between	**IR value after 15 Seconds**		**IR value after 60 Seconds**		**IR value after 600 Seconds**		**IR60/IR15 (DA ratio)**	**IR600/IR60 (P1)**
	Pre-Comm /Temp	**Actual**	**Pre-Comm /Temp**	**Actual**	**Pre-Comm /Temp**	**Actual**		
HV-Tank								
LV-Tank								
HV-LV								

(ii) Check for trapped air: To ensure that oil comes out freely when air release valves are opened

(iii) Checking OTI and WTI for set temperature for coolers running, alarms and trips.

(c) Yearly Maintenance

Date of commissioning …… Make …. Rating ….. Sl.No. ….. Bay location ……

Due month ……. Done on ……….. Line Clear (Permit to Work) No. ………
(Wherever shutdown is availed)

(i)Auto starting of fans and pumps: Done / Not Done

(ii)Measurement of BDV of OLTC Oil Permissible limits: Min – 50kV

R phase	Y phase	B phase	Remarks

(iii) External Cleaning of (i) Radiators (ii) Bushings -------------

(iv) Maintenance of OLTC Drive Mechanism Date:

Sl. No.	**Description**	**Status**		**Remarks**
		OK	**Not OK**	
1	**Visual inspection of equipment**			
2	**Hand operation on all taps& handle inter lock switch**			
3	**Checking correct working of OLTC counter**			
4	**Over load device of Driving motor**			
5	**Local& Remote operation(Electrical) & L/R switch**			
6	**Stepping relay in remote operation**			
7	**Correct operation of tap position indicator**			

(v) Checking of Remote indications of WTI/Tap indication: OK/Not OK

(vi) Alarm/Trip Test Date ……

Alarm Test						Trip Test							
Main Bucholz	**OLTC Surge**	**WTI**	**OTI**	**PRD**	**MOG Low oil level**	**Diff. Trip**	**O/C trip**	**Main Bucholz**	**OLTC surge R/Y/B**	**WTI**	**OTI**	**PRD**	**MOG low oil level**

(vii) Marshalling Box- maintenance Date …….

Description	Tightening of termination Done / Not Done	Cleaning Done/Not Done	Checking of contactors, Space heater & Illumination
MB of OLTC			
MB of reactor			
MB of NGR			
TB of PRD			
TB of Bucholz relay			
TB of Oil Surge relay			
TB of SPR (if provided)			
TB of bushing CT			

(d) 2-Yearly Maintenance record

(i)Vibration Measurement (For Reactors only) Make/Sl.No. Bay location no.

Measurement of vibration to be done (Indicating the drawing with location of testing marked)

Due date Done on
Testing kit make/Sl.No System voltage
Ambient temperature System frequency
WTI / OTI reading

Zone No.	Location of measurement vibration (in micron)																
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**
1																	
2																	
3																	

(ii) WTI and OTI Settings Date ……… Temp. ……… ICT No. …………

WTI	SET FOR	TEST VALUE		OTI	SET FOR	TEST VALUE	
		Actual	Remarks			Actual	remarks
Alarm				**Alarm**			
Trip				**Trip**			
Fan start				**OTI NGR,**			
Pump start				**Alarm**			
				Trip			

(iii) Tan ∂ Measurement for bushings

Test kit Make & Sl.No: Ambient temperature:

Condenser Bushings		Capacitance				Tan ∂				Remarks
		Pre-commg * Values		Measured Value		Pre-commg * Values		Measured Value		Measurement to be taken after cleaning
Transformer Bushings		**C1**	**C2**	**C1**	**C2**	**Tan∂ 1**	**Tan ∂ 2**	**Tan∂ 1**	**Tan ∂ 2**	**Tanδ at 20degC = 0.007 Rate of rise of tan d per year = 0.001Max**
HV	**RØ/YØ/BØ**									
LV	**RØ/YØ/BØ**									
Ter.	**RØ/YØ/BØ**									**Rate of rise of Capacitance value per year = +/- 1%**
Line Reactors Bushings										
RØ/YØ/BØ										
145kV Neutral Bushing										
NGR145kV-Mains-Comm										

Where pre-commissioning values are not available, Comparison with previous year test results may be done

Note: For measurement of C1 values of the bushings, connection will be between HV and Test tap and measurements in UST mode at 10.0 kV.

For measurement of C2 value of bushings, connection will be between Test tap and Ground and HV will be connected to guard. Measurement will be carried out in GSTg mode and test voltage will be 1.0kV.

(e) 4 YEARLY MAINTENANCE RECORD

S/D-Activity LC.No. …………….. DATE …………….

(ii) Checking and Cleaning of Diverter Switch Contacts (After 50,000 operations or SOS)

(ii) Tans ∂ and Capacitance Measurement of Windings

Date of Measurement Ambient Temp Test kit Make/Sl.No.

Test Modes	**Pre-Commissioning Values**		**Actual Measurement**		**Remarks**
	Capacitance	**Tan ∂**	**Capacitance**	**Tan ∂**	**Note: Jumpers should be disconnected from all the Bushings before start of the Tests and all Bushings of particular windings are shorted.**
HV-LV in UST Mode					
HV-Ground in GSTg Mode					
LV-Tank in GSTg Mode					

(iii) Winding Resistance Measurement

Make of winding Resistance Measurement Kit

Auto Transformers

MEASUREMENT OF HV SIDE WDG RESISTANCE AT ALL TAPS (in milli ohms)									
TAP POSN.	**FACTORY TEST VALUES @ 75^0 C**			**MEASURED WDG. RESISTANCE (IN OHM)**			**WDG RESISTANCE AT 75 DEG C**		
	R	**Y**	**B**	**1R1 – 2R1**	**1Y1 – 2Y1**	**1B1 – 2B1**	**R**	**Y**	**B**
MIN									
NORMAL									
MAX									

Note: In a two winding / three winding transformer winding resistance measurement on HV side (star connected) shall be done on each phase of the winding i.e. 1R-N, 1Y-N, and 1B-N.

MEAUREMENT OF WDG RESISTANCE (IN Mohm) – IV SIDE				
BETWN. WDGS	**RESISTANCE SITE VALUE**	**RESISTANCE AT 75 DEG C**		**REMARKS & OBSERVATIONS**
2R 1 – N				
2Y 1 – N				
2B 1 – N				

MEAUREMENT OF WDG RESISTANCE (IN M OHM) – LV SIDE				
BETWN. WDGS	RESISTANCE SITE VALUE	RESISTANCE AT 75 DEG C		REMARKS & OBSERVATIONS
3R 1 – 3B1				
3Y 1 – 3R1				
3B 1 – 3Y1				

Signature of AE/ADE O&M………… Sig. of ADE/DE(TL&SS)……………

(e) Other Maintenance works

(i)	**Testing of oil for DGA and other oil parameters**	**HY**
(ii)	**Testing of main tank oil for BDV, moisture content, tanδ, resistivity, IFT etc.**	**HY**
(iii)	**Lubricating/greasing of moving parts of OLTC, pumps etc.**	**HY**
(iv)	**Electrical checking/testing of pressure relief device, bucholz relay, OLTC surge relay, and checking/replacement of the gaskets of terminal box**	**Y**
(v)	**Checking/testing of Bucholz rely by oil draining**	**Y**
(vi)	**Frequency response analysis**	**SOS**
(vii)	**Recovery voltage measurement**	**SOS**
(viii)	**Checking and cleaning of diverter contacts**	**2Y**
(ix)	**Filtration and degassing of main tank oil**	**SOS**
(x)	**Testing of bushing CTs**	**SOS**
(xi)	**Filtration/replacement of oil of OLTC**	**SOS**
(xii)	**Measurement of ratio of windings**	**SOS**
(xi)	**Checking of earth connection**	**Y**

M-monthly, QY-quarterly, Y-yearly, 2Y- once in two years, 3Y-once in three years, 4Y-once in four years, SOS-as and when required

Note: Insulation resistance measurement, tan δ of winding/bushings, winding resistance at all taps to be carried out once before expiry of warranty period and then to be continued as per schedule.
Vibration measurement on reactor should be carried out initially after 3 months and 6months after commissioning and then to be carried out as per schedule.

FRA at factory and as a pre-commissioning test before commissioning may be done to serve as base signature.

Visual observation of transformers and Reactors by going round, should be made daily to check for any variations in noise, vibrations and any abnormality/leakages from cooler fans, oil pumps, radiators, valves etc.

2. CIRCUIT BREAKERS

(a) Monthly Maintenance Record

Dt. of Commissioning …….. MAKE ………. RATING……..
Sl.No………. Bay Loc…………
Monthly Maintenance without Shutdown Date……….

ACTIVITY	OBSERVATION & REMARKS
Oil Leakage in Operating Mechanism **Oil Level (Top, up, if required)** **Air pressure/leakage in ABCB** **Oil level in MOCB** **Oil Leaks from Grading Capacitors**	

(b) Half Yearly Maintenance – W-S/D Activity

LC.NO…………… DATE ………………
SF6 CIRCUIT BREAKER (PNEUMATIC OPERATING MECHANISM) W-S/D
Maintenance of AIR DRYER – as per manufacturer's recommendations

(c) Yearly Maintenance – S/D Activity

(i) SF6 CIRCUIT BEAKER

Functional checking of Auto-Starting of Air Compressor
Pressure Drop during duty cycle operation – O-0.3 S-CO

	OIL PRESSURE		AIR PRESSURE	
	Pre-Commg / Previous Results	Actual	Pre-Commg / Previous Results	Actual
Before Operation				
After Operation				

Checking of Hydraulic pump operation

	START (Pressure)	Stop (Pressure)
Pre Commg.		
Actual		

ii) AIR BLAST CIRCUIT BREAKER – W-S/D

Humidity (DEW POINT) Measurement of operating air
VALUE Temp Ambient
Permissible Limit: -45^0 C at atmospheric Pressure

(iii) MINIMUM OIL CIRCUIT BREAKER (MOCB) – W S/D

BDV of Oil - ………………………… KV (Avg of Six Readings)

(iv) BREAKER OPERATION CHECKS – S/D ACTIVITY

(a) CB timing including PIR checks Make & Sl.No. of test kit

PHASE	Break	Close	Trip		Close Trip * USING		Remakrs & Observations
			Trip-I	Trip-II	Trip-I	Trip-II	
R – phase main contact R – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts R – phase auxiliary contact	**Break 1**						
R – phase main contact R – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts	**Break 2**						
Y – phase main contact Y – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts Y – phase auxiliary contact	**Break 1**						
Y – phase main contact Y – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts	**Break 2**						
B – phase main contact B – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts B – phase auxiliary contact	**Break 1**						
B – phase main contact B – phase pir Pir & main contacts overlap time/pir opening time prior to main contacts	**Break 2**						

*** - CO Time is to be measured with simultaneous Close – Trip commands**

(b) Checking Pressure setting of switches

CB Pole	SF6 Pressures Switch Setting		SF6 Pressures Switch Actual		Ambient Temp
	ALARM	LOCKOUT	ALARM	LOCKOUT	
R					
Y					
B					

Pressure Switch setting should be within +/- 0.1 Bar of set value

(c) Checking of Pole Discrepancy Relay

TRIP `R' ph	Measure Tripping Time of Y&B pole	
	Set Value in sec	Operating Value in sec
PRECOMMG		
ACTUAL		

Close any one pole and observe the tripping of same pole

CLOSE `R' pole	Measure Tripping Time of R pole	
	Set Value in sec	Operating Value in sec
PRECOMMG		
ACTUAL		

(d) Duty Cycle operating including rapid re-closing

O-0.3 S-CO	Timings in msec			
POLE	Break 1		Break 2	
	PRECOMG.	ACTUAL	PRECOMG.	ACTUAL
R				
Y				
B				

(e) Check of Interlocks- In case Pressure reduces in **ABCB**

(i) Local closing Interlock (ii)Closing of Line Isolator

(f) Check of Operational Lockouts

		Pressures Values					
Sl.No.	Test-Description	A/R Lockout		Closing L/O		Operational Lockout	
		Set value	Actual	Set value	Actual	Set value	Actual
1.	Driving mechanism (Hydraulic/ pneumatic)						

(g) Cleaning of Breaker Pole DONE / NOT DONE

(i) SUPPORT INSULATORS DONE / NOT DONE
(ii) PIR AND GRANDING CAPACITOR- DONE / NOT DONE
(iii) INTERRUPTER CHAMBETR DONE / NOT DONE

(h) Checking of close/trip coils

CB POLE	CURRENT DRAWN BY THE COIL IN AMPERES		
	Closing Coil	**Trip Coil – 1**	**Trip Coil – 2**
R ph			
Y ph			
B ph			

(i) Healthiness of Operation Counter

R phase ……… OK / Not OK REMEDIAL ACTION TAKEN
Y phase ……… OK / Not OK REMEDIAL ACTION TAKEN
B phase ……… OK / Not OK REMEDIAL ACTION TAKEN

(j) Control Cabinet Maintenance

- **Checking of tightness of all terminations in MB**
- **Checking of Door gaskets and replacement there of, if necessary**
- **General cleaning of MB and Repainting of Metallic Surfaces, if required**
- **Check functioning of space heater / illumination**

(D) 2 – YEARLY MAINTENANCE RECORD

Measurement of Static Contact Resistance:

Max Contact Resistance Acceptable For all breaks: 150 Micro Ohms

CB POLES	CONTACT RESISTANCE IN MICRO OHMS			
	Interrupter 1 (CT SIDE)	**Interrupter 2**	**Interrupter 3**	**Interrupter 4**
R phase				
Y phase				
B phase				

(E) 3 – YEARLY MAINTENANCE RECORD

(i) Dynamic Contact resistance and contact travel measurement

CB POLES	Break	Contact wipe	Arcing Contact Length	Observation & remarks
R phase	**Break 1**			
	Break 2			
Y phase	**Break 1**			
	Break 2			
B phase	**Break 1**			
	Break 2			

Dynamic contact resistance signature for CO operation for all the breakers of CB to be recorded and compared with the earlier signatures. Minimum CO time should be 300 ms.

(ii) Measurement of dew point in SF6 Gas (For SF6 CB) DATE ………

CB POLE	DEW POINT MEASUREMENT			
	PRE-COMG		ACTUAL	
	DEG C	PRESSURE	DEG C	PRESSURE
R phase				
Y phase				
B phase				

(F) 4 YEARLY MAINTENANCE RECORD

(a) Capacitance & Tan ∂ Measurement of Grading capacitor

LC.No ………. Date ………….

Make & Sl.No. of kit Ambient Temp. Deg C

Description	INTERRUPTER 1			INTERRUPTER 2		
	R – PH	Y – PH	B – PH	R – PH	Y – PH	B – PH
Capacitance						
Pre-comm value						
Measured value						
Tan ∂						
Pre-comm value						
Measured value						

Note: Normally capacitance and Tan ∂ measurement is to be carried out in UST mode but if interference is more then, same may be done in GSTg mode with one side grading capacitor grounded and other side connected to guard.

AE/ADE (O&M) ADE/DE (O&M)

In addition to the above, the following checks also may be conducted periodically.

(a) SF6 circuit breakers

1	**Checking of oil leaks from grading capacitors**	**M**
2	**SF6 gas leakage test**	**SOS**
3	**Dew point measurement of SF6 gas**	**3Y**
4	**Checking tightness of foundation bolts**	**Y**

(b) Air blast circuit breakers

1	**Checking of oil leak from grading capacitors**	**M**
2	**Checking of air compressor for oil level, oil quality, air filter, V-belt tension**	**QY**
3	**Checking of air pressure drop during duty cycle operation**	**Y**
4	**Dew point measurement of operating air at the outlet of air dryer**	**Y**

5	**Checking of tightness of foundation bolts**	**Y**
6	**Air (pressure) leakage check**	**SOS**
7	**Overhauling of compressors**	**SOS**

(c) Minimum oil circuit breakers

1	**Checking of oil leak from grading capacitors**	**M**
2	**Checking for oil leakage/oil level and N2 pressure (if applicable)**	**M**
3	**Testing of oil for BDV**	**After 15 fault trips or yearly**
4	**Maintenance of breather and change of silica gel**	**SOS**

(d) Vacuum circuit breakers

1	**Cleaning of control cubicle and checking for loose connections**	**QY**
2	**Checking of ON/OFF indicator, spring charge indicator and checking manual and electrical operation**	**HY**
3	**Checking vacuum of interrupter by application of high voltage by disengaging with operating mechanism**	**Y**
4	**Checking erosion of contacts by erosion mark on operating rod or measurement of gap specified in closed position of contacts(wherever provided)**	**Y**
5	**Checking tightness of foundation bolts**	**Y**
6	**Replacement of vacuum interrupter**	**SOS**

(e) Hydraulic operating mechanism

1	**Checking of oil level oil leaks and replenishment/topping up, if necessary**	**M**
2	**Checking of oil pressure drop during duty cycle operation check**	**Y**
3	**Checking of auto starting/stopping of oil pump, pressure switch setting etc.**	**Y**
4	**Checking of healthiness of accumulator by checking the pre-charging pressure when building up pressure from zero**	**Y**
5	**Checking of operation of safety valve**	**Y**

(f) Pneumatic operating mechanism

1	**Checking of air compressor for oil level, oil quality, air filter, V-belt tension**	**QY**
2	**Maintenance of air dryer, where provided**	**HY**
3	**Functional checking of auto starting of air compressor and dryers**	**Y**
4	**Checking of air pressure drop during duty cycle operation**	**Y**
5	**Overhauling of compressors**	**SOS**

(g) Spring operated mechanism

1	**Oil leakages from close and open dashpots, replace if leaking**	**Y**
2	**Greasing/lubrication of gears and various latches in the operating mechanism**	**Y**
3	**Checking of play of gaps in catch gears**	**Y**
4	**Maintenance of spring charging motors, cleaning of carbon brushes and contactors**	**Y**
5	**Replacement of oil in dashpot**	**SOS**

3. CURRENT TRANSFORMERS

Date of Commissioning……… Make…….. Rating/Type……..
Sl.No…….. Bay Loc………
Date of test Phase: …………..

(a) Monthly Maintenance – without shutdown

Visual inspection of CT for oil leakage and cracks in insulators …………….
Checking of bellow for expansion …………….
Marshalling / Secondary Terminal Box
Check for any oil leakage from Secondary Terminal Box ………………
Checking of healthiness of gaskets ………………….

(b) YEARLY MAINTENANCE RECORD
Date of test
(i) MARSHALLING BOX

- Cleaning of MB
- Checking the tightness of all electrical connections including earthing of MB
- Cleaning and tightness of CT secondary terminals and checking healthiness of sec terminal bushing
- Checking of Space Heater & Illumination

(ii) Thermo vision scanning of CT & Top dome
Kit used: Load:

	Ambient Temp	**Scanned Temp. R Phase**	**Scanned Temp. Y Phase**	**Scanned Temp. B Phase**	**Remarks**
CT Tank					
Top Dome					

(iii) Capacitance & Tan ∂ Measurement Date …… Make of the kit ………

Sl.No.	**Phase**	**Capacitance**		**Tan ∂**		**Remarks**
		Pre-Commg Values	**Measured Value**	**Pre-Commg Values**	**Measured Value**	
	R Ø					**Measurement to be taken after cleaning the porcelain surface**
	Y Ø					
	B Ø					

Permissible Tan∂ at 20 Deg C = 0.007 Max Rate of rise of Tan ∂ per year = 0.001 Max
Rate of rise of Capacitance value per year = +/ - 1% Max.

(iv) Nitrogen Pressure Checking

AE/ADE (O&M) ADE/DE (O&M)

The following checks also should be conducted

i	**Checking of primary connection strips, if provided externally**	**Y**
ii	**IR measurement(Dielectric Absorption Ratio)**	**Y**
iii	**Measurement of secondary resistance**	**SOS**
iv	**Magnetization characteristics**	**SOS**
v	**CT ratio test**	**SOS**
vi	**DGA and testing other parameters of oil**	**SOS**
vii	**Checking of secondary winding burden**	**SOS**

4. POTENTIAL TRANSFORMERS/CAPACITANCE VOLTAGE TRANSFORMERS/COUPLING CAPACITORS

Date of Commissioning………
Make…….. Rating/Type…….. Sl.No…….. Bay Loc……… Date of test ….

A. Monthly Maintenance – without shutdown

(i) Checking of Oil Leaks

B. Quarterly Maintenance Date of test …..

Measurement of voltage at switchyard MB (in volts)

CORE No.	CONNECTION	VALUE IN VOLTS		
CORE-1	**PHASE-N**	**R PHASE**	**R PHASE**	**R PHASE**
CORE-2	**PHASE-N**			
CORE-3	**PHASE-N**			

Note: Maintenance Record is similar to Inductive Voltage Transformer (PTs) Items to the extent applicable may be recorded.

C. YEARLY MAINTENANCE

- **i) Visual checking of Earthing of HF Point – (IN CASE IT IS NOT USED FOR PLCC)**
- **ii) Checking of any breakage or cracks in HF bushing.**
- **iii) Cleaning of CVT Capacitor Stacks and tightness of terminal connections**
- **iv) Thermo vision scanning of Capacitor Stacks**

Camera used **Ambient Temperature**

	R-Phase	Y-Phase	B-Phase	Remarks
Top Stack				
Middle Stack				
Bottom Stack				
EMU Tank				

v) Checking of Neutral Earthing in CVT MB and Tightness of All connections

vi) Cleaning of Marshaling Box & Junction Box

vii) Checking of Space heater & illumination

viii) Checking healthiness of all gaskets

D. 3 Yearly Maintenance – S/D Activity

LC.No……………. Date …………..

Capacitance & Tan ∂ Measurement of CVT (All stacks Measured Together between HV and HF point) If discrepancy is found in the reading then measurement of each stack should be done, while measuring the capacitance of middle stack, short Top stack

Across Stack	Pre commissioning						Measured Values					
	Capacitance			Tan ∂			Capacitance			Tan ∂		
Top	R Ph	Y Ph	B Ph	R Ph	Y Ph	B Ph	R Ph	Y Ph	B Ph	R Ph	Y Ph	B Ph
Middle												
Bottom												
Total												

AE/ADE (O&M) **ADE/DE (O&M)**

The following checks also may be done

1	Testing of EMU tank oil for BDV(if oil found discoloured)	SOS
2	Checking for rust and painting	SOS

5. DISCONNECTORS AND EARTH SWITCHES

Date of Commissioning ………….. Make ………..
Rating/Type ……………… Sl.No. ………. Bay Loc ………….
(A) Yearly Maintenance – S/D Activity LC.No………… Date………..

CONDITION REMARKS

(i) OPERATING MECHANISM

- **Maintenance of Linkages including transmission gears –**
- **Maintenance of Stopper bolts –**
- **Cleaning of Aux. switch contacts & Greasing with Silicon Grease –**
- **Checking of Electrical/Mechanical Interlock with E/S & CB –**
- **Lubrication of operating Mechanism hinges, Lock Joints on Levers, Bearings. –**
- **Checking & Tightening of all the mounting bolts –**

(ii) MAIN CONTACTS

- **Cleaning and Lubrication of Main Contacts**

- **Alignment**
- **Tightening of Bolts & Nuts, Pins Etc.**
- **Cleaning of Support Insulators and Check for cracks in insulators, if any**
- **Checking of interlocks**

(iii) MARSHALLING BOXES OF ISOLATORS AND EARTH SWITCHES

- **Checking of space heater & illumination**
- **Checking of healthiness of Rubber Gaskets**
- **Visual Check of auxiliary contacts**
- **Cleaning and tightness of all terminations**

(iv) EARTH SWITCH

- **Checking and Alignment of Earthing Blades**
- **Cleaning of Contacts**
- **Operation of Earth Switch**
- **Checking of Aluminum/Copper flexible conductor**
- **Checking of earth connections of structure & MOM box**

(B) 4 Yearly Maintenance – S/D Activity

LC.No. …………. Date …………

	Measured Contact Resistance (in Micro ohms)			Pre Commissioning Values (in Micro ohms)		
	R Ø	Y Ø	B Ø	R Ø	Y Ø	B Ø
Disconnector						
Earth Switch						

Signature of AE/ADE (O&M) Signature of ADE/DE (O&M)

6. SURGE ARRESTERS

Date of Commissioning ………….. Make ………..

Rating/Type ……………… Sl.No. ………. Bay Loc ………….

(A) Yearly Maintenance

(a) Checking of Leakage by Current Analyzer (mA) after cleaning the porcelain surface

PHASE	TOTAL CURRENT	3^{RD} HARMONIC RESISTIVE CURRENT (13 R) in μ A	REMARKS
R			13R=500 μ A Max. for Gapless Type 13R=1000 μ A Max. for Gapped Type Arresters
Y			
B			

(b) Testing by surge Monitor kit – Counter and meter tests

(c) Cleaning of LA insulators

Signature of AE/ADE (O&M) Signature of ADE/DE (O&M)

Note: Measurement of capacitance and tan∂ and IR of each stack may be done depending on the requirement (SOS)

7. BUS-BAR JUMPERS, CONNECTORS, CLAMPS, SWITCHYARD ILLUMINATION, ETC.

Yearly Maintenance of Bus Bar & Bus Post Insulators

Sl. No.	Activity	Scheduled/ actual date	Measured value	Remarks
1.	Measurement of station earth resistance			
2.	Thermo Vision scanning of all Conductor Joints and Terminal Connectors/Clamps			* See table below
3.	Cleaning of Insulators and checking for cracks		Done/ not done	

THERMOVISION SCANNING OF SWITCHYARD – MAINTENANCE RECORD

Name of Substation: Name of Bay ……….
Date of measurement: Ambient Temperature ………………..

Sl. No.	Point of Measurement	R Phase	Y Phase	B Phase	Remarks
(I)	Main Bay EQUIPMENTS				
1	Connector/Clamp of Wave Trap				
	a) Towards line side				
	b) Towards bus side				
2	CVT				
	a) Top clamp				
	b) first joint				
	c) Second joint				
	d) Electro Magnetic Unit				
3	Connector/clamp of Shunt reactor bushings, disconnecting switches, disconnecting switch contacts				
4	Connector/Clamp of all disconnecting switches in the bay				
5	Connector/Clamps of CTs, Circuit breakers, in the bay				
(II)	TIE BAY EQUIPMENTS				
1	Connector/clamps of circuit Breaker, CTs, disconnecting switches				
(III)	All jumper/Dropper Joints related to Main bay, Tie bay, Strung bay, Rigid bus (IPS Tube)				

The above format is only indicative. To be modified depending on the equipment located as per the site layout. Points of connection of each equipment to the other equipment/ bus should be listed out and measurement phase wise done and recorded in the table.

Note: Permissible limits for thermo vision scanning:-

- Temp. up to 15 deg c (above ambient) – Normal
- Temp. above 15-50 deg C (above ambient) – Alert
- Temp. above 50 deg C (above ambient) – To be attended immediately

Signature of AE/ADE (O&M) **Signature of ADE/DE (O&M)**

The following checks may also be carried out

i)	**Removal of hot spots**	**SOS**
ii)	**Clearing the switch yard of all weeds, plants and shrubs**	**SOS**
iii)	**Repainting, rust removal of all structures, equipments etc.**	**SOS**
iv)	**Checking of switch yard lighting**	**SOS**

8. MAINTENANCE RECORD OF WAVE TRAP

Yearly Maintenance

Sl.No.	**Activity**	**Scheduled date**	**Actual date**	**Remarks**
1.	**Tightness and Cleanliness**			
2.	**General inspection/ Cleaning of Tuning Unit**			

Signature of AE/ADE (O&M) **Signature of ADE/DE (O&M)**

9. YEARLY MAINTENANCE FORMAT FOR SUB-STATION ILLUMINATION SYSTEM

Date of Maintenance: Date ……

LC No: 132kV/220kV/400kV/YARD

Sl. No.	Job Description	Remarks & Observation	Date	Signature
1.	**Check healthiness of light fittings in all circuits in the station bldg. PH, and DGS bldg. Repair, replace as required**			
2.	**Check if all switchyard fittings are in working condition (__________ nos. as per list). Repair, replace as required.**			
3.	**Check Lighting panel, receptacle panel tightening of terminals.**			
4.	**Check OUTPUT SUPLLY after fuse in receptacle panel**			

Signature of AE/ADE (O&M) **Signature of ADE/DE (O&M)**

10. PROTECTION SYSTEMS

1	**Testing of Disturbance recorder and event logger with time synchronization unit**	**M**
2	**Testing of all protective relays**	**Y**
3	**Checking of DC logic circuits for trip and annunciations including timers by simulation**	**Y**
4	**Calibration of boundary meters**	**Y**
5	**Calibration of all indicating instruments along with the transducers on all control panels**	**3Y**

Annual testing of relays should include the following:

(a) **Distance protection**: reach check for all 4 zones {Z1, Z2, Z3 and Z4 (reverse)} including time measurement. Checks on power swing block, switch on to fault, fuse failure, polarization and negative phase sequence detector.

The above checks are generic in nature. Manufacturer’s maintenance instructions for any particular make of relay shall be referred while testing. Whenever relays are tested on-line, proper isolation of the relay under test to be ensured. Stand by protection should be healthy and in service before taking any protective relay for on-line testing.

The following common checks for distance and unit protections should also be made.

Trip and annunciation check

Check for carrier send for remote trip, auxiliary relays healthiness, fault locator initiation
Check over voltage relays, LBB backup, and DR/EL initiation
Check for STUB protection
Check for auto reclose function

(b) **Bus-bar protection:** In addition to checking relay and DC logic circuits yearly, primary injection tests and protection stability and sensitivity checks should be done as and when required (whenever protection AC circuits are disturbed like addition of new bays).

(c) **Differential relays:** Pick up current, operation of highset element/instantaneous element at the adopted setting. Operation of the relay at the selected restraint bias setting. Operation of 2^{nd} harmonic current restraint feature, alarm and trip contacts. Checks for through current stability on the existing load.

(d) **Under voltage relay/ Over voltage relay:** Starting and pick up of the relay as per plug setting, Relay operating time as per relay characteristic, operation of alarm and trip contacts, and verification of input voltage on relay terminals.

(e) **Neutral displacement relay:** In addition to checks indicated in (d) above, verification of continuity of input circuit (for RVT/NCT secondary circuit in case of capacitor banks, under shutdown), Verification of open delta voltage input by by-passing PT secondary supply one phase at a time.

(f) **Over current and Earth fault relays:** In addition to checks indicated in (d) above, verification of input currents directional feature if applicable.

(g) **Under frequency relay:** Pick up value of the relay at its settings by slowly decreasing the frequency from 50Hz. Drop off value of the relay at its settings by slowly increasing the frequency from pick up value. Verification of df/dt feature of relay where applicable. Operation of alarm and trip contacts and verification of input voltage on relay terminals.

(h) **Over fluxing relay:** Operating of over flux alarm as per relay setting by varying the voltage and frequency one at a time. Operating of over flux trip features as applicable for IDMT characteristic, instantaneous element and fixed time setting. Operation of alarm and trip contacts and verification of input voltage on relay terminals.

(i) **Local breaker back up protection, Restricted earth fault(REF) and other instantaneous current operated relays:** Pick up value of the relay at the selected setting, operating time of the relay, operation of alarm and trip contacts, verification of input currents, checks for through current stability on the existing load in case of REF/ circulating current differential protection.

(j) **Fuse failure relay:** Main fuse of each phase voltage input to the distance protection scheme to be removed one by one in the relay panel and check for operation of the "VT Fuse Fail Alarm". Check that the distance protection does not operate.

11. AIR CONDITIONING PLANT

(i) Compressors

1	**Checking of belt tension, alignment safety guard**	**M**
2	**Leakage checks for refrigerants and oil**	**M**
3	**Check oil level, top up if required**	**M**
4	**Checking of tightness of flywheel, bolted joints, leakages of oil etc.**	**QY**
5	**Checking of oil pressure switch, LP/HP, cut-out switches, solenoid valve, thermostat, Humidistat etc.**	**Y**

(ii) Condenser Unit

1	**Checking for water leaks**	**M**
2	**Operations of inlet/outlet valve**	**M**
3	**Checking of water pressure – inlet/outlet and cleaning of side plates**	**HY**
4	**De-scaling of cooling water circuit**	**SOS**

(iii) Water treatment Plant

1	**Cleaning of Soft water tank and regeneration of chemicals**	**M**
2	**Checking operation of level switch**	**HY**
3	**Checking water quality**	**HY**

(iv) Cooling towers

1	**Cleaning of sediment**	**M**
2	**Cleaning of nozzles for clogging**	**QY**
3	**Flow switch performance checking**	**QY**

(v) Electrical motors

1	**Lubrication of moving parts**	**HY**
2	**Terminal connection checking**	**HY**
3	**Overhauling**	**SOS**

(vi) LT Panels

1	**Cleaning of bus bars, insulators etc.**	**Y**
2	**Tightness of the connections**	**Y**

(vii) Air handling units

1	**Cleaning of suction air filters**	**QY**
2	**Checking of all interlocks**	**Y**

12. BATTERY&DC DISTRIBUTION SYSTEM

1	**Measurement of specific gravity and voltage of cell**	**M**
2	**Checking electrolyte level and topping up with DM water, if required**	**M**
3	**Checking of Emergency DC lightings to control room**	**M**
4	**Checking of any earth fault (If E/F relay not provided)**	**M**
5	**Checking of electrical connections of charger panel and DCDB panels for tightness and cleanliness**	**Y**
6	**Checking of electrical connections for batteries and application of petroleum jelly on cell terminal, if required**	**Y**
7	**Checking control cards of charger and measurement of test point voltage values**	**Y**
8	**Battery impedance testing (Optional)**	**Y**
9	**Testing of DC E/F and under voltage relays**	**Y**
10	**IR measurement of charger transformer -------- MΩ**	**Y**
11	**Discharge test of battery set**	**3Y**

1.	**Maintenance**	**a) Keep the battery room well ventilated** **b) Keep the battery and its surrounding dry & clean** **c) Check and keep the electrical connections always tight** **d) Always keep the top surface of the battery clean and dry** **e) The joints and cell connections shall be kept clean and smeared with Vaseline and petroleum jelly** **f) Remove traces of corrosion promptly by cleaning with distilled water** **g) Metal vessels should not be used topping up** **h) Protective measures (wearing apron & rubber gloves) should be taken when handling concentrated acid electrolyte** **i) Care must be taken when using metal tools to prevent them from coming into accidental contact with connectors and causing short circuit** **j) Naked lights, smoking of cigarettes or anything which may create a spark should be avoided in battery room.**
2.	**Temperature correction**	**If cell temperature is different from 27°c correction to gravity to be applied is +/-0.0007 for every degree variation above or below 27°c respectively**
3.	**Topping up**	**a) Top up often as necessary with distilled water (as per IS: 1069) or de mineralised water to avoid adding a large quantity of water at one time which would cause Result in pronounced drop in the specific gravity** **b) Top up till the black mark of the float is just visible above the surface of the float guide and the level should never be allowed**

		to go so low that the red mar on the float-steer comes in line with the top surface of the plug. c) It is advisable, if necessary to top up cells during early part of charging or before charges so that the water would link (mix) with the electrolyte during charge
4.	Weak Cells	Cells which do not pick up specific gravity in spite of repeated charging are called "WEAK CELLS" The weak cells must be removed from the battery and charged separately at normal charging rate until gassing point is reached and the reduced to half the normal rate. When the cells appear to be in fully charged condition (i.e.) specific gravity of the acid seems to be stationary the charging should be stopped for an hour and then be resumed at half the normal rate until free gassing again takes place. Again after another one hour stop, charging should be resumed at half the normal rate. These stops of one hour duration alternated by charging should be repeated.
	Caution	While preparing the acid solution (electrolyte) it is very much important to note that always acid is added to the water and not water to the acid.

TROUBLE SHOOTING

Sl. No.	Battery Troubles	Symptoms/Cause	Remedies
1.	Over charging	a) Excessive gassing b) Falling active positive plates c) Buckling of plates d) Increased temperature	a) Reduce the Boost / Float voltage or charging rate reduced to lower value till the specific gravity attains 1.200. b) Add distilled water c) Check the accuracy of voltmeter in the charger if necessary
2.	Under charging	a) Low Specific gravity	a) Increase the float voltage 2.16 to 2.20 volts per cell or increase the charging rate till the specific gravity attains 1.200 b) Check for leakage of electrolyte of current conductors in the charge and battery circuit c) Reversal of cell voltage d) Buckling of plates
3.	Corrosion of plates	Electrolyte impure	a) Remove electrolyte b) Flush with distilled water c) Refill with pure electrolyte
4.	Shedding of active material	a) Over charging of plates b) Charging done at high rate c) Material improperly	Charging and discharging limits should be maintained at 2.40 volts and 1.85 volts respectively

		applied on plates	
5.	**a) Loss of voltage** **b) Battery voltage falling too rapidly on discharge**	**Excessive sulphation** **a) Loose connections** **b) Corroded terminals**	**Sulphation at initial stage can be cured by low rate of repeated charging and discharging. Contact manufacturer / supplier for special treatment** **a) Check up connections** **b) Corroded parts should be cleaned with warm distilled water and coated with Vaseline**
6.	**Continuous lowering level of electrolyte**	**a) Leakage of electrolyte** **b) Loss of water in the electrolyte due to evaporation by too high floating voltage or excessive charging**	**a) Replace container immediately in case of leakage** **b) Addition of distilled water to maintain the electrolyte level in the leaking cell will result in diminution of capacity and continuous lowering of specific gravity**
7.	**Overflowing in cells due to increase in electrolyte level even without the addition of distilled water**	**Due to damp atmosphere in the battery room causing condensation on the cell covers**	**Improve ventilation in the Battery Room**

Special Note: The following are guidelines for maintaining voltage and specific gravity of the cells at a uniform value:

a) When the battery is to be stored for long period, before putting into service, necessary care is to be taken for proper storage, other-wise there may be possibility of oxidation which may have adverse impact on the porosity of the plates. The Cells will develop uniform porosity only after repeated charge/discharge cycles and adjustment of specific gravity has to be made thereafter in all the Cells.

b) Variation in the quantity of Distilled water while topping up or failure to tope up some cells may also contribute to the variations in cell voltage and specific gravity

c) After installation of the battery, if voltages and specific gravities are not uniform and varying then equalizing charge shall be made by adjustment of electrolyte, ie., in addition or removal of electrolyte and/or addition of Distilled water is made until the specific gravities are uniform. This adjustment may be repeated after some cycles of operation ie., after 30 or 45 days.

Batteries should not be kept under continuous Boost Charge. Batteries shall be on float charge only. After sufficient discharge of the Battery (as indicated by the Voltage and specific gravity of the Cell, Battery shall be kept under Boost charge for the required number of hours only to get the normal voltage and specific gravity.

13. CAPACITORS

1	**Checking for leakage of oil**	**M**
2	**Check unbalance in capacitors by checking open delta voltage/ by measuring neutral unbalance current**	**M**
3	**Physical checks, cleaning of insulators/bushings and tightening of connections**	**Y**
4	**IR value, leakage current measurement, capacitance measurement of capacitor cells**	**Y**
5	**Checking of protection relays with approved settings**	**Y**
6	**Checking tightness of earth connection and foundation bolts**	**Y**

After initial charging the capacitors, the following checks shall be made:

a) Voltage : Within 110% of rated voltage especially during light load periods

b) KVAR : Operation KVAr are within 130% of the rated KVAr at the highest system voltage

c) Temperature rise: Container temperature should not exceed 75 Deg. C. This should be measured by having a thermometer fixed with the wall of the container, keeping the bulbs at one quarter of height of capacitor box down from the top edge.

d) Fuse: ensure correct type and rating of fuse

e) Light Load: At light load capacitors cause voltage rise in the system exceeding the permissible value some times. They may have harmful effects on capacitor or on other electrical equipment. Voltage at no time should go beyond the rated voltage by more than 10%.

While removing the faulty/defective capacitor units, the remaining healthy capacitors are connected in such a way that all the phases are balanced with equal number of units and phase capacitance. Operation with unbalance phases may cause over stressing of some of the capacitors causing further damage.

For capacitor banks operated with series reactors, operating the bank with less number of units than originally supplied may cause the capacitor with series reactor tuned to fifth harmonics.

Best way to check the healthiness of a capacitor is to check the capacitance with a capacitance meter, partial or complete failure of a capacitor can be established from this. Shorting of one internal series group on a capacitor results in a predictable increase in the capacitance level. This is the basis for the capacitances of partially failed capacitors.

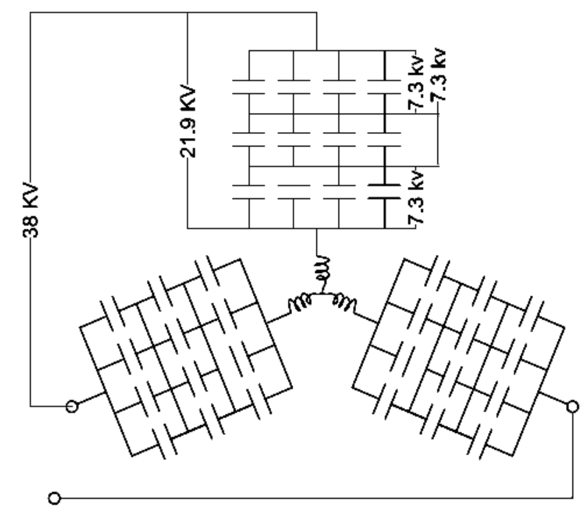
Defects in capacitors – causes and Remedy

Sl. No.	Symptom	Cause	Remedy
1.	Leakage of impregnant	Leak in welded seam Leak from terminal cap	After cleaning and abrading by emery cloth apply Araldite or solder the spot carefully
2.	Overheating of units	a) Poor ventilation b) Excessive ambient temperature c) Over voltage	Increase spacing for free circulation of air Arrange for forced ventilation. Reduce voltage or switch of capacitors (OR) adjust over voltage relay tripping to achieve below 10% of rated voltage of bank
3.	Current below normal value	a) Low voltage b) Loose connection	Usual Tighten carefully
4.	Noise inside the unit	Internal fault	Disconnect the unit properly balance remaining units. Refer to company. Measure insulation resistance between terminals and case. If the reading is zero the units is shorted and not fit. No repair is possible.
5.	Fuse blowing	a) Short circuit in unit b) Over current due to over voltage and harmonics c) Short external to the unit	Reduce voltage and reduce/eliminate harmonics by adding suitable series reactors after advice by the company.
6.	Abnormal bulging/ bursting	Gas formation due to internal arcing causing unit to bulge or burst	Replace the unit. Refer to the manufacturer
7.	Capacitor Bank tripping on unbalanced protection but expulsion fuse not blown	Co-ordination of expulsion fuse blowing with neutral protection not proper	Check and contact manufacturer's application Engineers.

HV / EHV Capacitor Banks - Maintenance and balancing of capacitors in the event of failure of one or more capacitor units - guideline:

In the 33 kV / 132kV Capacitor banks existing at various substations, the capacitor units are connected in no. of series groups (eg. two or three in a 33kV bank) to maintain uniform voltage distribution depending upon the rated voltage of the capacitor units. Capacitor units are supplied at rated voltage of 7.3 kV/10.97 kV/21.9kV. Required rating for Capacitor Bank is obtained by connecting capacitor units of smaller rating in parallel (numbering 2 to 9) in each series group.

Configuration of a typical 33kV capacitor bank is shown below.

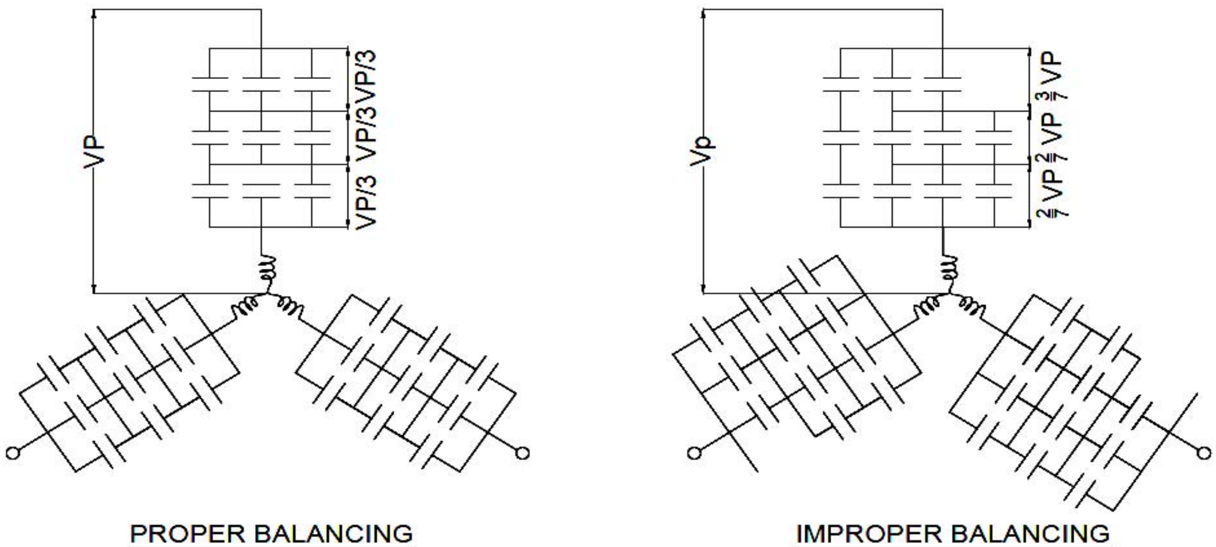


Whether it is single star or double star, the number of series groups per phase depends upon the rated voltage of the capacitor unit viz., 3 series groups if the rated voltage is 7.3 KV, 2 series groups if rated voltage is 10.3 KV and one group if rated voltage is 21.9kV, for 33kV bank.

In the event of failure of one capacitor unit (say in R-phase) it is observed that balancing is done by removing one capacitor each from Y and B-phases as shown in figure below. This arrangement is not correct, since it results in unequal voltage distribution between the capacitors in series groups.

It can be seen from the figure below that against a voltage distribution of Vp/3 across each series group, the series group containing less no. of capacitors in parallel gets 3Vp/7 (i.e.) gets overstressed. Whereas, the other series groups have 2Vp/7 (i.e.) are under stressed. This results in ultimate failure of the over-stressed capacitors.

Correct method of balancing is, to connect equal number of capacitors of identical rating in each series group in all the three phases on one star bank, to maintain equal voltage distribution across series groups.



The correct arrangement of capacitors in the given example is illustrated under "proper balancing" in the above figure.

14. FIRE PROTECTION SYSTEM

(i) Compressor

1	Cleaning/replacement of air filters	M
2	Checking of compressor oil and replace, if necessary	QY
3	Maintenance and cleaning of Compressor valves, gaskets, valve plates and replace, if necessary	QY
4	Operation check of low oil level switch	QY
5	Cleaning and checking for seating of the breather valve	QY
6	Cleaning of NR V/HP tank	Y
7	General overhaul	SOS

(ii) Fire alarm system

1	Sequence test for annunciation in control room panel	M
2	Smoke test	M
3	Cleaning	M
4	Battery electrolyte level checking	M

(iii) Diesel engine

1	Checking of auto staring of diesel engine	M
2	Check oil level, top up if required	M
3	Checking/replacement of fuel oil/lube oil/air filter	Y

(iv) Jockey pump

1	Check leakage and lubrication	M
2	Pump Overhauling	SOS

(v) V-Belt drive

1	Checking of belt tightness	QY

(vi) Strainers

1	Cleaning of oil strainer	QY

(vii) Motors

1	Checking of terminal connection	HY

(viii) Pumps

1	Checking of operation of Hydrant pumps sump pumps, jockey pumps	M
2	Adjustments of glands for leakages and tightening of nuts and bolts	HY
3	Checking of alignment of pump set	Y
4	Replenishment of grease	SOS
5	Overhauling	SOS

(ix) Hydrant system

1	Checking of pressure of the hydrant system at the remotest end, auto-starting of pumps, diesel engine, etc.	Y

(x) Deluge system

1	Operation of deluge system, check outlet pressure, check alarm, check starting of diesel/electrical pump.	Y

(xi) Electrical Panels

1	Cleaning and tightening of terminals	Y

(xii) General

1	Greasing of all Valves	HY
2	Painting of pipes, air lines, marshaling box	SOS

(xiii) Fire extinguishers

1	Re-filling of fire extinguishers	SOS
2	Check for sand availability in sand buckets	M

15. DIESEL GENERATOR SET

(i) Lubricating System

1	Check for oil leaks	M
2	Replacement of oil filter after recommended running hours	Y/SOS

(ii) Cooling system

1	**Check for radiator air blocking and coolant level**	**M**
2	**Check for fan hub, drive pulley and water pump**	**Y**

(iii) Air intake system

1	**Check for air leaks**	**M**
2	**Cleaning of air filters**	**HY**
3	**Replacement of Air cleaning element**	**Y**

(iv) Fuel system

1	**Check for Governor linkages, fuel transfer pump, fuel line connections**	**Y**
2	**Drain Sediments from fuel tank, change fuel filter and clean fuel tank breather**	**Y**

(v) Main generator

1	**Check for air inlet restrictions**	**M**
2	**Check for electrical connections for tightness**	**HY**
3	**Stator winding IR measurement**	**Y**
4	**Checking/cleaning of slip ring and its brushes**	**Y**
5	**Testing of protection/control relays and alarms**	**Y**

(vi) Exhaust

1	**Check for air leaks and exhaust restrictions**	**Y**
2	**Tight exhaust manifold and turbo charge cap screw**	**Y**

(vii) General

1	**Battery voltage and specific gravity measurement**	**M**
2	**Check for performance of DG set by running the set**	**Weekly**

16. LT SWITCHGEAR, LT TRANSFORMER, LT PANEL, ETC.

(i) LT panels

1	**Cleaning of panels, bus bar insulators, etc.**	**Y**
2	**Relays testing**	**Y**
3	**Tightness of all electrical connections**	**Y**
4	**Checking of Indicating meters**	**Y**
5	**Check for change-over facility, if provided**	**Y**
6	**Check operation/indications in Off-load condition of air CB**	**Y**
7	**Check spring charging of air CB**	**Y**

(ii) LT switchgears

1	**Functional checking (Trip, close, etc.) of 33/11 kV CBs**	**Y**
2	**Measurement of operating timings**	**3Y**
3	**Cleaning of insulators and tightness of terminal connections of CBs. CTs. PTs, Isolators, etc.**	**Y**
4	**Alignment checking of isolators**	**Y**

(iii) LT transformers

1	**Testing of oil BDV**	**Y**
2	**lR measurement**	**Y**
3	**Testing/checking of OTI, WTI and Buchholz (if provided)**	**Y**
4	**1 Checking of healthiness of pressure relief diaphragm**	**Y**
5	**Checking healthiness of Buchholz relay**	**Y**
6	**Checking tightness of earthing connections**	**Y**

17. GAS INSULATED SWITCHGEAR

Yearly visual inspection

Following visual inspection of the energized substation must be performed:

(i)	**Activity**
(ii)	**SF6 pressure with permanent manometer (if applicable)**
(iii)	**Oil level in tank (Operating mechanism)**
(iv)	**Hydraulic circuits tightness (Operating mechanism)**
(v)	**Oil level in damping device (CB with spring operating mechanism and earthing switch with making capacity (if applicable))**
(vi)	**Heating of cubicles**

Five Yearly Examination

Five yearly examination of the GIS is considered as minor examination and shall include but not limited to:

(i)	**Activity**
(ii)	**Checking of pressure with tool**
(iii)	**Dew point of SF6 gas in CB chamber**
(iv)	**Density switch operation**
(v)	**Gas leakages**
(vi)	**Operating time of main and auxiliary contacts of CB, mechanical operation of dis-connector and earth switch**
(vii)	**Cleaning of air bushings**
(viii)	**Checking optical indicators and signaling contacts**
(ix)	**Labeling of operating mechanisms and gas filling valves**
(x)	**Checking of alarm functions**
(xi)	**Checking of operating rods for torques in CB poles, disconnectors, earth switches**
(xii)	**Maintenance of gas handling device**
(xiii)	**Check hydraulic oil in drives (if applicable).**

*** If the compartment is not provided with an absorber**

Ten yearly maintenance

It is considered as major examination with small outage and shall include but not limited to:

	Activity
(i)	**Dew point of gas**
(ii)	**Replace filters in operating mechanism**
(iii)	**Replace oil in operating mechanism**
(iv)	**Lubricate the rams**
(v)	**Lubrication of dis-connector operating mechanism**
(vi)	**Lubrication of earth switch operating mechanism**
(vii)	**CB operating arm linkage torque adjustment**
(viii)	**Torque adjustments for disconnector operating rods.**
(ix)	**Cubicle tightness**
(x)	**Acoustic partial discharge measurement**

Twenty yearly or later

It is considered major examination with prolonged outage and shall include the following but not limited to:

	Activity
(i)	**Open CB pole and check**
(ii)	**Spring and pin replacement**
(iii)	**Maintenance of rams**
(iv)	**Open dis-connector pole**
(v)	**Open E/s pole**

Notes:

- Normally depending on specifications all GIS CBs comply with IEC 62271-100 and would have been tested for about 10,000 operating cycles of mechanical duty without significant wear and tear. A random inspection could be done at every 5000 close-open cycles for CBs, 3000 for dis-connector and 1000 nos. for earth switches.

- For electrical wear and tear depending on fault level the manufacturer recommendation should be adhered to.
- On account of high reliability of GIS, PD measurement it is not essentially warranted. In fact acoustic measurement offers better option for existing GIS for monitoring particle content and impurities, in place of PD measurement.

3.4.1 GUIDELINES FOR OPERATING PERSONNEL IN THE EHV SUBSTATIONS

1. Sub-station layout in detail including various equipment, particulars of Power Transformers, Breakers, CTs, PTs, Isolators, LAs, Batteries and Battery Charges, Station Transformers, Fire fighting equipment, Capacitor banks etc., shall be made available in the control room. Also substation operating instructions record shall be made available in the control room for ready reference.
2. Normal in-feed and alternate in feeds – Clear idea of the grid and location of the substation with reference to grid. A grid map showing the in-feeding sources and important load centers connected to the substation to be prepared and displayed.
3. Should be familiar with various equipment available in the substation. Should be thorough about normal operations and emergency operations to be carried out.
4. Battery charger operation - change from Float to Boost and Boost to Float rates changing in each mode.
5. Paralleling and de-paralleling operation of transformers
6. Operating instructions for all contingencies including issue and receipt of line clear should be made available. Shift staff should be conversant with such operations.
7. Lock-out values of gas pressures minimum air pressure where compressors shall start automatically and hydraulic fluid pressure where pump shall start automatically for different makes of Circuit breakers. A chart showing make, type, reference to P.O of power transformers, and breakers and the available and set parameters such as temperature alarms, trips Auto start and stop of cooler fans in respect of power transformers and gas pressures, air/hydraulic pressures, densities in respect of breakers shall be displayed for ready reference.
8. CT available and adopted ratios, relay settings meaning of relay indications on all circuit breakers shall be available.
9. Bucholz and differential relay indications. All annunciations and meaning and consequences of each.
10. Knowledge of all the relays and their functioning, purpose and shall be able to interpret correctly to decide whether the equipment can be charged again or to be kept isolated for further inspection/check-up by the concerned Maintenance/MRT personnel (especially when lockout relays, pressure relief relays, temperature relays, bucholtz relay sand differential relays operate)
11. Shift staff should follow the works being done by MRT/Maintenance staff in the sub-station.
12. While taking over the shift duty, he shall go through the entire log of operations from the time

last handed over to charge to know the important events happened, works done, condition of the equipment, line clears pending etc.

13. While taking over shift duty he has to check condition of communication equipment, lines, battery charger, batteries, feeders and transformers, breakers gas pressures, air pressures, healthy trip circuits, any relay indications not reset etc.

14. Whenever any feeder/equipment is loaded beyond normal load due to exigencies, such equipment shall be kept under close observation until normalcy is restored, temperature on transformers under such overloading conditions and cooler fans operation shall be constantly monitored.

15. In case of certain exigencies where operations started in particular shift are likely to be carried out during next shift, the personnel of both the shifts shall be available till the operations are completed and normalcy is restored. Shift duties should not be handed over to successor staff in the middle of an exigency.

16. ADEs/AEs posted to shift without earlier experience, shall be guided and assisted by senior personnel till such time they get acquainted with the equipment and operations in the substation (say for a fortnight).

17. Red hot joints at the substation shall not be continued even for brief periods. They shall be attended on priority. Each day during evening peak hours, the yard lighting should be switched off for a while and bad clamps joints should be identified and intimated to maintenance staff. This may be in addition to thermo vision scanning done periodically.

3.4.2 Checks & Observations to be made during shifts:

1. Voltages at all levels shall be observed and to be maintained nearest to the rated values by operation of tap changes of transformers. A little higher voltage is to be maintained (not exceeding 10%) so that tail end voltages are normal. Constant monitoring of capacitor banks shall be done.

2. Healthy trips of all breakers shall be checked every hour. If healthy trip fails, the breaker shall immediately be hand tripped; fault in the healthy trip circuit shall be immediately attended and rectified. Only after ensuring DC supply, the breaker shall be closed. Healthy trip indicating lamps shall be in working condition.
3. Battery voltages, DC leakage, Charger condition, switch off AC supply to charger (once in a shift) and observe any fall in DC battery voltage.
4. Communication equipment such as PLCC, P&T and wireless shall always be in working condition. They are to be treated on par with all other equipment at the Substations.
5. Check the loading on the transformers and capacitor banks. Load current in all the three phases and in neutral circuit (wherever available) to be checked. Any difference in phase currents shall be brought to the notice of maintenance staff and the concerned transformer or capacitor bank shall be cut off from service for detailed examination.
6. Note the oil and winding temperature and physically check-up by feeling the temperature of transformers by hand.

7. Note the tap position of various transformers. The tap position of the transformers in parallel shall be same i.e., the voltage corresponding to the tap shall be same.
8. Note the oil levels in conservator tanks
9. Check up for any oil leaks and red hot spots.
10. Check-up dehydrating breathers of transformers
11. Ensure that alarms and indications on annunciation panel are working
12. Check the diesel generator and trial run for 5 minutes daily once in the morning shift and note down the voltage.
13. Check the condition of Air compressors provided either common or separately for each breaker and drain the moisture accumulated once in a day during morning shift. During Rainy season this should be done once in each shift. Drain sufficient air to ensure auto start of compressors.
14. Running hours of each station compressors to be noted periodically and they shall be changed 'stand by' to 'running' to 'stand by'. Register of running hours of each station compressor shall be maintained.
15. Check the entire yard for any unusual sounds, sparks and red hots during evening shift.
16. Compressed air pipe lines to be checked for any air leakage. The oil levels in air compressors are to be checked
17. Check oil levels and condition of breather if available for the MOCBs
18. Check up gas pressures in SF 6 breakers.
19. Check up for any sparking and flash over marks in the earth pits especially whenever feeders trip on faults.
20. Watering of earth pits to be done daily.
21. Ensure proper working of Energy meters on all CBs. If the energy meters are slow or not working, check the potential supply to the meters, fuses etc.
22. Ensure the tripping of breakers on activation of relays whenever the LCs are issued on breakers.
23. When LC is issued on Power Transformers, Alarms and Trips are to be invariably checked up with the assistance of MRT/maintenance personnel
24. Check-up fire fighting equipment once in a week.
25. OLTC counter reading to be noted.
26. Ensure that lightning arrestor's leakage current (micro) ammeter reading is in safe zone (Green)
27. Whenever feeders trip, find out the position of breakers at other end and note down relay indications if any at other end.
28. Check-up the marshalling boxes of breakers, CT junction boxes, PT junction boxes etc. and ensure that they are vermin proof.
29. Check up the batteries, exhaust fans in the battery room for proper operation once in every shift, and report any abnormalities to the maintenance staff immediately.
30. Ensure that hind doors of al control and relay panels are properly closed and the panels are properly sealed from the bottom and made vermin proof.

3.5 TRANSMISSION LINES

3.5.1 Normal Patrolling

Name of the line

Name&Designation: Date ……..

Sl. No.	Activity	Loc.No.	Type of tower	Observation	Remarks
1	**Missing tower members**				
2	**Fixing bolts & nuts**				
3	**Foundation chimneys, copings and surroundings**				
4	**Insulators(Broken/ chipped)**				
5	**Clearances to ground& in air**				
6	**Obstacles (trees, dwellings, crossings, parallel lines etc.)**				
7	**Bird nests/ any foreign materials on the towers/conductors**				

Note: Conductor size, configuration of line may be noted and the condition of conductor, earth wire, clamps and fittings, vibration dampers, spacers, armor grips etc. along the span between two locations may also be noted.

Signature of the patrol man Signature of AE/ADE

3.5.2 Special Patrolling

Name of the line:

In addition to the activities indicated in normal patrolling, the following shall be carried out

Name and designation Date ………

Activity	Loc. No.	Type of tower	Observation	Remarks
Observing Condition of insulators, jumpers,vibrationdampers,spacers, clamps and fittings of ground wire and conductor and joints etc. closely with Binoculars				

3.5.3 Thermo vision scanning

Name of the line Date …….

Loc. no.	Item	Normal temp. range	Observed temp.	Remarks
	Insulators			
	Line jumpers			
	Clamps&fittin gs			

3.5.4 Pre-monsoon Inspection:

Pre-monsoon inspection of all transmission lines in the jurisdiction should be conducted once every year, before the on set of monsoon to ensure total healthiness of the line and to prevent any tripping or break down on the line during summer and rainy seasons. Inspection of each location should be thoroughly done and all the defects noticed should be rectified before the summer season starts. A report on the line inspected, defects observed location wise and action proposed for rectification shall be submitted every fortnight by the AE/ADE in charge of maintenance of lines to the DE and SE (TL&SS). DE and SE (TL&SS) should review the report and initiate action for rectification of defects.

A monthly report on the points raised during pre-monsoon inspection, action proposed and action taken should be submitted by the SE (TL&SS) to the zonal CE. The CE should follow up for rectification of all defects and ensure that all defects are rectified without fail and send a report to the CE (Transmission) at headquarters. Regular pursuance both in field and at headquarters is required to ensure proper working of the lines.

3.6 Safety Considerations for O&M of substations and lines:

In order to mitigate the inherent risks associated with Transmission of Power, it is necessary to use protective equipment and follow systematic procedure to protect the equipment and men working on them. Correct use of proper protective equipment ensures protection of equipment. Work procedures, practices, rules should be framed for carrying out works under shutdown/breakdown.

Safety rules should be framed taking into account statutory requirements, in a brief and clearly understandable manner.

3.6.1 Working Procedures: Responsibility of every working personnel should be defined. Primary method of achieving safety is isolation from the system and earthing EHV/HV equipment before commencing the work. All isolation points, vents and earths should be locked. Staff should be trained on safety devices and procedures and in the application of rules.

3.6.2 Safety considerations: Maintenance staff should familiarize them selves with relevant portion of safety document, before taking up the maintenance/ testing work. Team leader (maintenance Engineer) should ensure that maintenance team members adopt general safety. All the members of the working team must ensure that their activities do not affect other work areas. Language used during communication with the workers should be easily understood by them.

3.6.3 Application of Safety rules and procedures:

- Safe distance has to be maintained from live parts in accordance with appropriate safety standards
- After isolation of equipment/line, if any exposed conductors need to be approached, make sure that safe clearance is maintained using approved voltage measuring device or earthing device to avoid coming into close proximity of charged conductors
- Line clear (LC or Permit to work) shall be issued when work or testing on the HV equipments does not require removal of primary earths. When the work requires removal of primary earths, it shall be ensured that the equipment is earthed after isolating it and then only the LC to be issued.
- Persons working on equipment/line should ensure providing earths on both sides at the work area
- When restoration of power is required for work/testing, supplies required must be stated on the requisition form in accordance with the safety instructions
- Personal protective equipment (Safety belt, safety shoes, industrial safety helmets etc.) shall be used by the persons at work without fail to provide additional protection against inherent dangers. Use inspected and tested Protective equipment to ensure desired protection.
- Only skilled and experienced persons with necessary technical knowledge should be allowed to carryout the work.

3.6.4 General Precautions:

- Work on a line/ equipment should be supervised by AE/ ADE
- The circuit/ zone of work should be clearly identified
- Appropriate personal protective equipment shall invariably be used
- A caution board indicating “DO NOT OPERATE – MEN AT WORK” should be displayed on the control panel, which controls the feeder/ equipment, on which work is to be carried out; after isolating the equipment/line and issuing the line clear
- Safe electrical distances should be maintained until conductors are earthed
- Soundness and continuity of earthing device should be examined before use.
- The earthing device should be connected first to an effective earth. The other end of the device should then be connected to the conductors to be earthed.
- Only earthing devices/switches specially meant for the purpose should be used while earthing.
- All earthing and short circuit devices in the working zone should be closed and locked. All the three phases should be earthed. Earthing and short circuiting devices should remain connected for full duration of the work except for the purpose of testing.
- After completing the work, connection to the conductors should be removed first and the connection to earth next.

- If earth gets detached/faulty, another additional earth should be provided before removing faulty earth. Persons attaching the second earth shall maintain safe electrical clearance until it is attached

Electrical Safety Clearance (Live Metal clearance)

Rated Voltage	Safety Clearance (metres)
Up to 33kV	0.8
66kV	1.0
132kV	1.4
220kV	2.4
400kV	3.1
765kV	5.6

Clearances

Voltage level (kV)	Minimum Right of way (Mtrs.)	Minimum ground Minimum Ground clearance (Mtrs.)	Telephone line crossing clearance (Mtrs.)
132	27	6.1	2.745
220	35	7.015	3.05
400	52	8.84	4.88
765	85	15.0	7.5

Electrical clearances for Transmission lines crossing each other

Voltage level in kV	**132kV (in mm)**	**220kV (in mm)**	**400kV (in mm)**	**765kV (in mm)**
132	3050	4580	5490	7940
220	4580	4580	5490	7940
400	5490	5490	5490	7940
765	7940	7940	7940	7940

Electrical clearance from Railway Tracks electrified on 25kV AC

Voltage level In kV	Inside station limit (mm)	Outside station limit (mm)
132	14000	12000
220	15300	13300
400	16300	14300
765	24700	24700

3.6.5 A Safety manual for O&M of Substations and Lines shall be prepared with the following contents.

i) Procedure for obtaining permission to work for carrying out O&M of equipment.

ii) Safety in O&M of various electro-mechanical equipment as per recommendations of manufacturers

iii) Safety of structures/buildings
iv) Safety in work shops and garages
v) Safe handling, collection and disposal of hazardous waste
vi) Safety in Substations/Switchyard/switch boards
  - Safe working clearance
  - Guarding of live apparatus
  - Operation on live apparatus
  - General provisions relating to maintenance
  - Working in areas containing exposed live HV/EHV conductors
  - Demarcation of work areas
  - Working on remotely controlled and automatically controlled equipment
  - Working on equipment containing or operated by compressed air
  - Working on CBs, Transformers, Isolators, Surge arresters, Instrument transformers,
  - Handling failed SF6 circuit breaker
  - Working on or near to Low, Medium, High and extra high voltage equipment
  - Procedure for adding/removing equipment to/from the HV/EHV system.
vii) safety measures in overhead lines
viii) Inspections and maintenance of steel towers and structures
ix) Norms for patrolling of lines
x) Classification of terrain of lines viz. Normal terrain/ vulnerable terrain
xi) Tower top patrolling
xii) Thermo vision scanning
xiii) Punctured insulator detection
xiv) Off-line fault location, signature analysis,
xv) Maintenance schedule of electric line
xvi) Safety in washing of live insulators and testing of insulators on live lines
xvii) Hot line maintenance
xviii) Safety in working in under ground systems

3.7 INSPECTION OF SUBSTATIONS AND LINES:

3.7.1 Checks and cross checks on the maintenance activities scheduled and carried out and action taken based on the results of maintenance within a given time frame, are essential for proper upkeep of equipment and lines. Officers at various levels shall be entrusted with the role and responsibility in the maintenance management.

AE/ADE in charge of maintenance of substation/ lines shall be responsible for carrying out maintenance activities and updating the maintenance records. They shall also be responsible for general upkeep of substations/lines they maintain. Maintenance schedules shall be strictly adhered to, as per the periodicity and carried out on the due dates duly planning for shutdowns. Necessary t&p, consumables and spares shall be kept ready and they shall be in working condition. Reasons for deviations or delays if any shall be reported to next higher officers. The ADE and DE should take steps to provide all required tools, plant, and all other facilities to attend to maintenance as scheduled. Reasons for deviations in schedules and delays should be analyzed and steps taken to avoid delays in future.

Annual target for inspection of substations and lines to be conducted by senior officers (DE&SE) will be fixed by the zonal CE as recommended by the Management. Periodical inspection of substations and lines should be conducted by senior officers to ensure that all scheduled maintenance activities are carried out and the equipment and lines are in fit condition. They should also ensure the general upkeep of the installations including auxiliaries and civil structures. Norms in vogue for patrolling of lines and inspection of lines/substations by senior officers are indicated below.

3.7.2 Patrolling of lines: AE in charge of lines shall arrange for 100% normal patrolling of lines (all voltage classes) in his jurisdiction once in a year i.e. at 10% of the lines every month. Special patrolling of lines should be done immediately after tripping of line and send a report to the ADE and DE. Defects noticed should be rectified at the earliest. Pre-monsoon inspection covering all the lines in his area should be done in two/three months time between December to March and defects got rectified well before onset of monsoon.

3.7.3 Inspection of lines and substations:

Cadre	132/220/400kV lines to be inspected	Substations to be inspected
AE/Lines	10% every month	---
ADE/Lines	5% every month	---
DE /TL&SS	30 Km (to cover 6 different lines)	All the SSs in the jurisdiction every Six months (20% monthly)
SE / TL&SS	15 Km (to cover 3 different lines)	All the SSs in the jurisdiction in A year (10% monthly)

Various checks to be made and points to be covered during inspection are indicated in the format given below.

Name of the substation: Date of inspection: …….. Due on ……

Sl. No	Item of inspection	Observation	Action required	
(i)	Check up of maintenance registers for maintenance works due and done			
(ii)	Check the combined earth resistance of station and earth resistance of individual electrodes			
(iii)	Physical condition of earth pits and watering arrangement			
(iv)	Working of battery-check voltage, discharge current after switching off charger. Check for DC earth leakage.			

(v)	**Check battery charger and Dc distribution for proper function**			
(vi)	**Check control & relay panels for tightness of terminal connections, vermin proof arrangements**			
(vii)	**Working of Boundary meters and sealing arrangements**			
(viii)	**Working of feeder energy meters and analysis of energy audit**			
(ix)	**Check up of equipment in switchyard- surroundings, proper working etc.**			
(x)	**Oil leakage and oil spilling from equipment**			
(xi)	**Check up cable ducts, cables and cable duct covers**			
(xii)	**Check up clearances of bus, condition pf terminations and connections between equipment – Hot spots**			
(xiii)	**Growth of weeds, water stagnation in ducts and drain arrangements**			
(xiv)	**Adequacy of yard lighting, check for proper working of yard lights, DC emergency lights**			
(xv)	**Check for cleanliness and condition of control room, battery room, roads and drains, security fencing and main gates, other civil structures**			
(xvi)	**Check for correct working of Compressors, Diesel generators, Fire protection system and other auxiliary devices**			

Name of the Line:

Locations inspected Date ……. Due on ……

Sl. No.	Item inspected	Loc. No.	Observation	Action required	
1	**Activities covered in normal patrolling**				
2	**Cross check of specific items(viz. tree growth, clearances, condition of insulators, foundations etc.) reported by patrol men during normal patrolling at the location and action taken on these items**				
3	**Tower footing resistance at the locations where disc flashover is reported** **132 &220kV lines – DE/SE (TL&SS)** **400 kV lines – SE / CE (TL&SS)**				

Report on the inspections done during the month by the DE(TL&SS) and the SE(TL&SS) shall be sent to the zonal CE and the CE (Transmission) at headquarters who will prepare a consolidated report and put up for review by the Management. The reports should cover the status of the SS and Line inspected, observations made and action taken for rectification including the action taken on the points raised during the maintenance of the SSs and Lines by the maintenance staff.

3.8 System Availability:

3.8.1 Environment in which the substations and lines operate, system operating conditions (Frequency, voltage, active, reactive loads, temperature) and proper equipment maintenance, have an influence on the system reliability. Prevention/minimizing faults and reducing downtime due to outage of equipment/lines, by timely identification of defects and rectification of the same, help in increasing system availability. Strict adherence to condition monitoring and other maintenance schedules enable achieving this objective.

In the regulated regime of power sector, demand for reliable and quality power assumes significance. As per the provisions in the Electricity act-2003, the State Regulatory Commission set up performance standards for Transmission Utility. Transco should maintain a high standard for supply of reliable and quality power. Power system availability shall be not less than 99%. Transmission losses should be reduced every year by a percentage to be decided by the Regulatory Commission. Also the Commission reviews interruptions on EHV industrial feeders and breakdowns on EHV system components (Power transformers and transmission lines). Fire and accidents, causing damage to equipment/lines and loss of life or otherwise should be reported to Regulator.

3.8.2 In the wake of the norms for standards stipulated by regulations, time based maintenance and modern methods of condition based maintenance of system elements play a vital role in meeting the norms and sustaining the same. The following performance parameters approved by APTRANSCO shall be monitored monthly at field level by the zonal CEs and to be reviewed by the Management periodically.

- **Interruptions to EHT Industrial Feeders and Railway Traction Feeders:** Feeder wise interruption to EHV industrial and traction feeders during the month should be recorded. Interruptions due to incoming supply failures, tripping of feeder due to momentary faults, faults at the substation, breakdowns, load relief, and due to faults at consumers premises shall be indicated with duration interruption. Reasons for the interruptions should be analyzed and measures to minimize the duration and prevent recurrence of similar faults should be taken. These details should be furnished in the format given below.
- **Line clears availed on EHT Feeders (Industrial & Traction):** All planned maintenance works in a substation or on a line affecting power supply to the industrial and traction consumers should be taken up after informing those consumers in advance and with their consent. Wherever possible alternate supply shall be arranged. The works shall be well planned. All required tools, spares, consumables and manpower should be kept ready to ensure that works are carried out well within the scheduled time to minimize interruption. Where consumer requests for line clear, planning of maintenance works on the connected feeder/ bay may be done to minimize interruption. All the details should be furnished in the formats given below.
- **Breakdowns on EHT Feeders:** Breakdowns on any equipment in the substation/ Transmission line shall be recorded in the substation and a monthly report on the breakdowns circle wise (SETL&SS) shall be sent to zonal CE and CE (Transmission) in the format given below. The report should contain time of occurrence of breakdown, identification of fault by fault locator/ patrolling, time required for rectification of fault and restoration of supply. Alternate supply should be arranged wherever possible and the time taken for extending alternate supply should be indicated. Duration of interruption and the extent of loads interrupted should be recorded.

Reasons for the breakdown should be analyzed and steps taken to prevent such occurrences in future.

- **Monthly progress on testing of Capacitance and Tan ∂ of EHV CTs:** Variation in the trend of capacitance and tan d of a CT in service reflects the condition of the CT. Higher tan∂ value indicates deterioration of dielectric which may result in partial discharge and subsequent failure/explosion of conventional porcelain clad oil filled CT. Monitoring of CTs for capacitance and tan∂ once in a year is to be done and values recorded. A programme for monthly testing of CTs in the circle shall be prepared so as to cover entire range of CTs within the jurisdiction of the circle in a year. Wherever the CTs show values above acceptable limits, frequency of testing should be increased i.e. those CTs should be tested for tan∂ every fortnight/ month depending on the severity and trend in the variation should be monitored. Needless to mention that the testing should be done duly observing all the precautions and in permissible weather conditions. A report on the trend tests conducted and the values measured shall be sent circle wise by SE (TL&SS). This shall be reviewed by the zonal CE and CE (Transmission) and the course of action recommended based on the trend and put up to Management for taking a decision on continuance/ removal of the CT. The relevant formats are given seperately.

- **Monthly Power transformer failure and repair/overhaul status:** Power transformer is a major and costly equipment in a substation. Proper operation and maintenance is necessary to extend a reliable service. Power transformers should be monitored regularly, problems noticed should be attended on priority and rectified to the extant possible at site to minimize down time. Where the problems can be attended only in repair shops, action shall be taken to transport and arrange repairs either by the manufacturer or identified repairer registered with Transco. A report on failure of power transformers capacity wise and substation wise every month by the SE (TL&SS) in the format given below for review by Management to take prompt action. Reasons for failure should be analyzed and corrective steps taken to prevent failure.

- **Monthly review of feeders with exceptional losses:** An over loaded transmission line causes increase in line losses. Proper planning and augmentation of transmission network help in meeting the demand without overloading the transmission system. A line is said to be healthy when it is free from loose joints, defective insulators, obstacles such as trees, dwellings in the proximity and having adequate clearance. When power flow on such line is uniform (without many peaks) line losses will be minimum. Targets for reduction in transmission losses are set by Regulator every year. In order to achieve the target, it is necessary to monitor losses in individual elements of transmission network i.e. transmission lines/ transformers. Loading is the main factor that affects the losses considerably. Condition of the line/transformer influences the losses. With a view to check the losses on each line and the transformer a limit on losses allowable on each line, voltage wise has to be set and monitored for variation every month. The limits of losses set in APTRANSCO are for 132kV – 3.5%, 220kV – 2.5% and 400kV – 2%. Digital energy meters of 0.2 class accuracy should be provided on all lines at both ends and on all power transformers. These meters must be suitable for remote communication of the data to the main control centre/ down loading the data with a MRI. The meters shall be time synchronized and should be able to store hourly data for at least 60 days so that data for a specified date and time is down loaded (Ex. 00hrs. on the first day and 24hrs. in the last day of a month) for accurate computation of line losses. A monthly report on the feeders on which losses observed for a month are beyond internal set target, shall be sent by SE(TL&SS) to the zonal CE and CE (Transmission) in the format given below for review by Management. Reasons for high losses should be analyzed and corrective action taken on such exceptional feeders to keep the losses at minimum.

- **Transmission System availability for the month:** A high transmission system availability is an indicator of the reliability of the system. Main elements of network that govern the system are transformers, reactors, capacitors and transmission lines. Availability of individual elements in a month and the period of outage of the element during the month is noted down from the substation records. Availability of transmission system for the month is computed using the following formula:

(I) % system available for the month = $\dfrac{o.Avo + p.avp + q.Avq + r.Avr}{o+p+q+r}$

Where o = Total no. of Ac lines
p = Total no. of transformers
q = Total no. of capacitors
r = Total no. of reactors
Avo = Availability factor of AC lines
Avp = Availability factor of Transformers
Avq = Availability factor of capacitors
Avr = Availability factor of Reactors

$$\text{Availability factor (Avo or Avp or Avq or Avr)} = \frac{\text{Weightage Factor} \times \dfrac{\text{(Availability in Hrs – Non availability in Hrs)}}{\text{Availability in Hrs}}}{\text{Weightage Factor}}$$

Weightage Factor = Length x Surge impedance loading (for AC lines)
Weightage Factor = Capacity of the equipment (for Transformers, Capacitors, Reactors)
System availability for the previous month and cumulative availability up to the previous month shall be computed. Analysis in the system availability should be made and action taken to minimize the outage time of system elements to improve system availability.

(II) %TAFM for a calendar month = (100 – 100 x NAFM), where TAFM is the total availability factor for the month and NAFM is the non-availability factor in per unit for the month of the transmission system.

$$NAFM = \left[\sum_{l=1}^{L} (OHl \times Ckt\ kml \times NSC1) + \sum_{t=1}^{T} (OHt \times MVAt \times 2.5) + \sum_{r=1}^{R} (OHr \times MVAR \times 4)\right]$$

$$\div\ THM \times \left[\sum_{l=1}^{L} (Ckt\ kml \times NSCl) + \sum_{t=1}^{T}(MVAt \times 2.5) + \sum_{r=1}^{R} (MVARr \times 4)\right.$$

Where

l identifies a transmission line circuit
t identifies a transformer / ICT
r identifies a bus reactor, switchable line reactor or SVC
L = Total number of line circuits
T = total number of transformers and ICTs
R = total number of bus reactors, switchable line reactors and SVCs
OH = Outage hours or hours of non-availability in the month
Ckt km = Length of a transmission line circuit in km
NSC = Number of sub conductors per phase
MVA = MVA rating of transformer / ICT
MVAR = MVAR rating of a bus reactor, switchable line reactor or a SVC
(in case of SVC it would be the sum of inductive and capacitive capabilities)
THM = Total hours in the month

NAFM for each HVDC system shall be calculated separately, as follows :

$$NAFM = [\ \Sigma\ (TCR \times hours)] \div [THM \times RC]$$

Where TCR = Transmission capability reduction of the system in MW
RC = Rated capacity of the system in MW

Note: For the above purpose, HVDC terminals and directly associated EHV/HVDC lines of a HVDC system shall be taken as one integrated system.

3.8.3 Interruptions on EHT Industrial feeders and Railway Traction feeders

Name of the circle Month ……

Sl.No	**Substation**	**Feeder**	**Date of interruption**	**Hours of interruption From - To**	**Duration Hrs/Mts.**	**Reasons**
Incoming supply failure						
Momentary Tripping						
Breakdown						
Fault at Substation end						
Fault at consumer end						
Others (Load Relief etc.)						

3.8.4 Line clears on EHT feeders (Industrial & Traction)

Name of the circle Month ……

Sl.No.	Substation	Feeder	Date of interruption	Hours of interruption From - To	Duration Hrs/Mts.	Reasons
Line Clear availed by APTRANSCO						
Line Clear availed by Consumer						

3.8.5 Status of Outages
Name of the circle Month …..

Sl no.	Name of the feeder and length	Date and time of tripping	Alternate supply arranged Date & time	Extent of interruption to loads	Patrolling commenced at	Identification of fault by fault locator/ time.	Type of fault	Distance to fault	Men & material moved at

Line clear – Requisition time Returned time Duration
Line Charged at – ………………..
Reasons for delay in rectification

3.8.6 Current Transformers Tan Delta test results Trend Month ……

Sl. No.	Name of the circle	Name of substation	CT location	No. of CTs	Monthly test values of Tan delta Phase Make YOM/YOC 1st 2nd 3rd 4th							Remarks
					Phase	Make	YOM/ YOC	1st	2nd	3rd	4th	
CTs having tan delta values more than 3 and less than 5												
CTs having tan delta values more than 5 and less than 10												
CTS having tan delta values more than 10												

3.8.7 Status of failure of Power transformers Month ……

Sl. No.	Transformer Rating	Failed during the month	Issued for repair/overhaul during the month	Repaired/Overhauled and allotted during the month

Details of failed power transformers during the month

Sl. No.	Details of failed transformer	Name of the substation	Remarks

Details of power transformers allotted for overhaul/repairs

Sl. No.	Details of power transformer	Name of repair agency	Remarks

Repaired/ Overhauled and allotted during the month

Sl. No.	Details of repaired/overhauled transformer	Allotted to	Status of the transformer allotted

3.8.8 Statement of Exceptional feeders voltage wise Month …..

Sl. No.	Name of feeder	Length in CKM	Average load in MW	% loss in the month	Remarks

3.9 OVERHAUL OF MAJOR EQUIPMENT- PROCEDURES

Reliability of power supply depends on the proper performance of equipment in the network. The life of the equipment generally depends on:

- The working conditions in which the equipment operate, Stresses sustained depending on the severity of the faults faced , types of loads fed;
- The quality of the materials used in the manufacture, and manufacturer's workmanship;
- Care exercised in the pre-commissioning stage while commissioning the equipment;
- Periodic maintenance.
  Failure of equipment some times may cause damage to other nearby equipment in the network.

The manufacturer also prescribes the overhauling of the equipment in the lifetime of the equipment. The overhauling process considerably enhances the life of the equipment.

Overhauling major equipment VIZ. Power transformers, Circuit breakers, Current / potential transformers are covered below.

3.9.1 POWER TRANSFORMER:

The life of the transformer is mainly dependant on the life of both solid and liquid insulation. Hence, it is very important that the insulation is properly maintained.

Condition monitoring indicates any deterioration inside the transformer including the primary insulation. The following condition monitoring test results are to be examined and interpreted carefully, before deciding to open any transformer:

- Dissolved gas analysis history and trend
- Oil quality analysis and trend
- Winding resistance and ratio tests
- Tan delta of winding and bushings
- Frequency response analysis
- Recovery voltage measurement
- Furfural content measurement

If none of the test results indicates any deviation trend, there is no need to open any transformer for internal inspection.

Whenever a transformer is opened moisture may enter the winding from atmosphere in spite of taking all the precautions. Complete removal of moisture at site is a difficult process and incomplete removal may result in faster deterioration of the transformer. A very careful judgment need to be exercised before opening of transformer at site.

Close monitoring of auxiliaries like bushings, tap changers, cooling system, protective devices etc. and timely rectification of any defects may extend life of the transformer. As transformer is a static device, its internal inspection may not yield any useful result if no abnormality is detected.
Close monitoring of transformer oil prevents sludge formation inside the transformer. Any violation on the oil parameters such as resistivity, tan delta, inter facial tension, acidity can not be improved by oil filtration. Replacement of oil at the initial time of violation could increase the life of the transformer.

Normally, the manufacturers prescribe overhauling of the transformer at least after 10 years of service. During the overhauling process it is expected that the transformer is completely drained, and the core and coils are lifted for thorough inspection. But this need not be taken as mandatory if no abnormality is noticed during condition monitoring.

Internal inspection/overhauling can be taken up whenever the following abnormal conditions are noticed:

- Continuous and profuse oil leakage through gaskets and not able to arrest by all external means, requiring changing of all gaskets.
- Increase in fault gases indicating fault inside the transformer
- Problem in OLTC requiring opening of transformer
- Changing of oil due to oil degradation

The overhauling work is normally carried out in the repair shop. Wherever the repair shop is not available, the overhauling may be done at the substation itself by creating required facilities.

The following activities are normally associated with overhauling:

- Internal inspection.
- Flushing the core and windings with hot oil jet and cleaning the tank to remove any sludge, foreign particles, etc.
- Replacement of gaskets of all dismantled parts.
- Flushing the radiators; cleaning the conservator tank, headers, and all connecting pipe-lines.
- Tightening of all core and yoke clamps, spacers, winding jumpers to tap selectors and bushings, bottom guides and supports
- Overhauling all cooling fans, and oil pumps. Overhauling all valves.
- Attending to minor leakages in the radiators (which could be sealed by cold welding).
- Washing the OLTC with hot oil jet, overhauling the diverter switch, (This includes checking and cleaning all contacts, interchanging the worn out contacts) checking, cleaning the auxiliary contacts, cleaning and greasing of all mechanical parts, and also the gear box mechanism.
- Removal of moisture from windings and solid insulation by alternate vacuum and heat cycles and filtering the oil.
- Finally testing the transformer for tan ∂, capacitance of bushing and winding, FRA, DGA of oil, etc. in addition to other routine tests.

Life Assessment: While carrying out diagnostic tests on equipments it is vital that the parameters are benchmarked/ permissible values noted, and the deviations are noted in order to study the trend in the behavior of the equipment, as these predictions are based on the deviations from the base values.

Restoration: In a transformer, restoration after major overhaul/internal inspection is very important. When oil is removed, the winding paper insulation absorbs moisture from the atmosphere. It is always required to use dry air inside transformer when oil is being removed. This helps in keeping the transformer paper insulation dry. Portable dry air generators are commercially available for this purpose. Dry air is also available in cylinders which could be used if dry air generator is not available.

After completion of work, the transformer is to be kept under vacuum to remove complete moisture with dry nitrogen purging and hot oil circulation. It needs to be ensured that the transformer is dry.

3.9.2 CIRCUIT BREAKER

SF_6 circuit breaker over the period develops problems like gas leakage, air pressure building up, etc. There are different operating mechanisms in SF_6 circuit breakers, such as pneumatic, hydraulic, and mechanical (spring). Manufacturers recommend overhauling of the circuit breakers after a service period of 10 years.

Unlike transformers, circuit breakers have moving components and they require more maintenance and periodic overhaul. The parts which require overhaul in circuit breakers are:

- Operating drive
- Interrupting chambers

Operating drive require maintenance depending on the number of operation or specific time period like greasing and changing of gaskets etc., as per manufacturers instructions and experience of the utility.
In EHV circuit breakers, operating mechanism requires more frequent maintenance than the main interrupting chambers provided the breaker is not subjected to fault trippings more often. Regular maintenance and condition monitoring checks are to be carried out to keep the circuit breakers in healthy condition. It is desirable to get confirmation from condition monitoring checks before opening interrupter assembly.

The overhauling schedule of circuit breakers is as follows:

(i) Checking the arcing chamber, and overhauling all internal parts of the interrupter.
(ii) Replacement of '0' rings and gaskets.
(iii) Checking the male, female contacts of the interrupter for erosion; checking the travel of the contacts, etc .
(iv) Checking the working of all internal parts;
(v) Checking PIR and grading capacitor;
(vi) Checking the working of operating mechanism;
(vii) Checking the tripping and closing timings of all interrupters;
(viii) Measurement IR values of the breaker, both in open and close position;
(ix) Checking the dynamic and static contact resistance.

The last three measurements are indicative of the working condition of the circuit breaker. Overhauling of interrupting chamber depends on number of operation and the amount of current interruption by the contacts. The decision for opening interrupting chambers is to be taken based on condition monitoring checks especially dynamic contact resistance -measurement (DCRM). Leakage of gas/air, discrepancies in timing, abnormal static contact resistance etc. All the defective components and all gaskets are to be replaced.

Need to take up overhauling, depends on the findings of the tests as above, irrespective of the manufacturer's recommendations. We may keep the operating part in trim condition in case the diagnostic/ indicative testing doesn't ring caution bell. It is, however, felt preferable that one or two interrupters may be opened on sample basis to assess the internal condition and based on the outcome opening of the remaining breakers could be decided.

3.9.3 CURRENT TRANSFORMER AND POTENTIAL TRANSFORMER/CVT:

For monitoring the performance of the CTs it is essential to watch the parameters like

- IR values; Tan δ & Capacitance values;
- Oil level;
- Inspection with thermo-vision camera for hot clamps, if any.
- Physical checking of terminal joints.

There are no specific set guidelines for overhauling / replacement of CTs. The CT/PT being static equipment does not have any mechanical wear and tear. If the parameters as above are regularly monitored the CTs, PTs can give long service.

If the CT shows a higher trend of Tanδ and capacitance values, deterioration of oil quality and oil DGA indicates violation it shall be taken out from service and overhauled/ minor damages if any are attended, before the CT fails. Failure of oil filled/porcelain housed CT normally associates with explosion causing damage to the adjacent equipment.

Overhauling of CT includes opening the CT, checking the windings, core, primary leads and the condenser portion, flushing the same with hot oil jet to remove sludge and foreign impurities. Core and windings and the condenser portion should be placed in a hot air chamber and subjected to alternate vacuum and heat cycles to eliminate moisture from the solid insulation. After ensuring drying out of moisture the components should be reassembled and oil filled and nitrogen sealed. Overhauling activity can be taken up at manufacturer’s works or in a transformer repair shop where required facilities are available.

As CTs and PTs/CVTs are sealed units, it is not recommended to open these units at site.

3.9.4 RECOMMENDATIONS:

(i) The overhauling process being a major activity as regards the life of the equipment in the network, it is very important to codify the process in very clear terms as regards the interval, the process and the expertise required.

(ii) R&D activities in-house may be set up with the available expertise who can guide the field in interpretation of results of condition monitoring tests and advise on the condition of equipment and need and time for overhaul as overhauling requires considerable time resulting in interruption of supply/ reduced supply affecting the reliability. R&D activity should be well developed to define and adopt suitable maintenance and overhauling practices according to the needs and the environments. It is necessary to create a comprehensive database of the plant and equipment, failure reasons and frequency, remedial actions taken, manufacturing defect observed, etc.

3.10 LIMITS OF TEST VALUES AS PER STANDARDS:

To enhance the life and reliability of substation equipment, maintenance schedule and procedures, as discussed earlier, need to be followed meticulously. Any deviation from the earlier noted results may be looked into thoroughly in subsequent maintenance of sub-station equipment as per recommended maintenance schedule. The limits up to which deviations in the various parameters are not likely to hamper functioning of the main equipment are considered acceptable. Acceptable norms / permissible limits specified in various Standards, which are considered safe for keeping the equipment in service without sacrificing the reliability are furnished in the table.

Sl. No.	Property	New uninhibited	IS/IEC	At the time of first charging	During O&M	IS/IEC
i	Appearance	Clear& transparent, free from suspended matter/ sediments	IS335/ 1993	Clear, free from sediment and suspended matter	Clear without visible contamination	IS1866/ 2000
ii	Density@29° C (max)	0.89gm/cm³	-do-	0.89 gm/cm³	Not essential	-do-
iii	Kinematic viscosity at 27° C (Max)	27 cSt	-do-	27 cSt	Not essential	-do-
iv	Inter Facial Tension (IFT) at 27°C (Min)	0.04N/m	-do-	0.035N/m	0.015N/m	-do-
v	Flash point (Min)	140° C	-do-	140ºC	Max decrease of 15ºCfrom initial value	-do-
vi	Pour point (Max)	- 6°C	-do-	- 6ºC	Not essential	-do-
vii	Neutralization value (acidity) (Max)	0.03mg KOH/gm	-do-	0.03mgKOH/gm	0.3mgKOH/g m	-do-
viii	Corrosive sulphur	Non-corrosive	-do-			
ix	Di-electric strength (BDV) New unfiltered After filtration	30kV rms min 60kVrms min	-do-	40kV for <72.5kV 50kV for 72.5 to 170kV 60kV for >170kV	30kV for <72.5kV 40kV for 72.5 to 170kV 50kV for >170kV	-do-
x	Dielectric Dissipation Factor (tan∂) at 90°C (Max)	0.03	-do-	0.015 for <170kV 0.01for 170kV and above	1.0for<170kV 0.2 for above 170kV	-do-
xi	Specific resistance	35x10 12 Ω cm	-do-	6x 1012 Ω cm	0.1x1012 Ω cm	-do-

	(Resistivity) at 90° C 27° C	min 1500x1012 Ω cm min			1.0x1012 Ω cm	
xii	Oxidation stability Acidity after oxidation (Max) Total sludge after oxidation (Max)	0.4mgKOH/gm 0.1% by Wt.	-do-	0.4mgKOH gm 0.1% by Wt.	Not essential Not essential	-do-
xiii	Aging characteristic after accelerated aging Sp.resistance @27ºC DDF@900C Total acidity Total sludge Total Sulphur	2.5x1012 o cm Min 1.02 Max 0.05mgKOH/gm Max 0.05% by Wt. Max 0.15% Max	-do-			
xiv	Water content (New unfiltered) (Max)	50ppm	-do-	20ppm for,72.5kV 15ppm for72.5 to 170kV 10ppm for >170kV	No free moisture for<72.5kV 40ppm for 72.5 to 170kV 20ppm for >170kV	-do-
xv	SK value	4 to 8% by mass Max	-do-			
xvi	PCA content (Poly Cyclic Aromatics)	3% by mass Max	-do-			
xvii	PCB content (poly Chlorinated Biphenyl)	Not detectable 0.1mg/Kg max	IEC 60296: 2003			
xviii	2 Furfural (Furan analysis-list method IEC-61198: 1993)	0.1mg/Kg Max	IEC 60296: 2003			
xix	Furfural (aging criteria) for oil immersed Trs.	Warning trouble	CIGRE Doc.No227- Life management Technique for Pr.Trs. Page-107			

xx	**Total Furfural content**	**250 parts per Billion parts (ppb)**	**Tr.diagnosticUSBR June2003-page 15**			

Note: Oil shall not contain anti-oxidant additives. Value of 0.05% by mass (max) shall be treated as absence of Ditertiary Butyl Paracresol (DBPC)–phenolic type inhibitor

DISSOLVED GAS ANALYSIS

Typical rates of gas increase for Power transformers	Value in milliliters per day	Standard
Hydrogen (H_2)	<5	IEC:60599-1999
Methane (CH_4)	<2	
Ethane (C_2H_6)	<2	
Ethylene (C_2H_4)	<2	
Acetylene (C_2H_2)	<0.1	
Carbon Monoxide (CO)	<50	
Carbon Dioxide (CO_2)	<200	

Note: Equation to calculate the rate of gas increase as per IEC 60599-1999
Rate = $(Y_2 – Y_1)\ m / \{> (d_2 – d_1)\}$ ml/day
Where Y_1 = reference analysis, Y_2 = last analysis, m is the mass of oil, in Kilograms
P = mass density in Kg/m3, d_2= last date for Y_1 and d_1= date for Y_2
$(Y_2 – Y_1)$ is the increase in micro- litres per litre

TRANSFORMER/REACTORS

Tan Delta for Bushing 20°C	**0.007 at20ºC**	**IEC-60137**
Capacitance for Bushing	**- 5 % to + 10 % Variation**	
Contact Resistance of Bushing	**10 Micro-Ohm /Connector**	**NGC,UK, Recommendation**
Tan Delta for Windings at 20°C	**0.007**	**IEEE/C57. 12.90.1999 9**
Tan Delta for Windings at 20ºC(Power Factor)	**0.005**	**Transformer Diagnostic USBR, June 2003**
Rate of Rise of Tan Delta(Bushing & Winding)	**0.001 Per year (Max.)**	
Magnetizing current Test (Excitation Current Test)	**If the excitation current is less than 50 milli-amperes (mA) the difference between the two higher currents should be less than10%.If the excitation current is more than 50mA, the difference should be less than 5%. In general, if there is an internal problem, these differences will be greater.**	**Transformer Diagnostic USBR., June 2003,**

<table>
<tr><td>Magnetic Balance Test
(Three Phase)
-</td><td>Value of supply voltage (230 V AC) in one phase is equal to sum voltage induced in other two phases.
When supply voltage is in middle limb, voltage induced in outer limbs should equal and roughly half of the supply voltage.</td><td></td></tr>
<tr><td>Winding resistance Transformer and Reactor((resistance converted to 75ºC)</td><td>± 5% difference between phases or from Factory tests</td><td></td></tr>
<tr><td>Voltage Ratio of Transformer (All Taps)</td><td>± 0.5% difference from Factory test results</td><td></td></tr>
<tr><td>Transformer Neutral Resistance Value</td><td>Below 1 ohm</td><td></td></tr>
<tr><td>IR value of windings (Min)</td><td><table>
<tr><th>Rated voltage class of winding</th><th>Min desired IR value at 1 minute at 30^0C (Mega ohm)</th></tr>
<tr><td>11 kV</td><td>300</td></tr>
<tr><td>33 kV</td><td>400</td></tr>
<tr><td>66 kV & above</td><td>500</td></tr>
</table></td><td></td></tr>
<tr><td>Polarization Index
(Ratio of IR values at 600 seconds to 60 seconds)</td><td><table>
<tr><th>Polarization Index</th><th>Insulation condition</th></tr>
<tr><td>Less than 1</td><td>Dangerous</td></tr>
<tr><td>1.0 – 1.1</td><td>Poor</td></tr>
<tr><td>1.1 – 1.25</td><td>Questionable</td></tr>
<tr><td>1.25 – 2.0</td><td>Fair</td></tr>
<tr><td>2.0 – 4.0</td><td>Good</td></tr>
<tr><td>Above 4.0</td><td>Excellent</td></tr>
</table></td><td></td></tr>
<tr><td>Core Insulation Test (Minimum) (between CL and CC + G with tank ungrounded)</td><td>1000 kilo ohms at 2.5/3.5kV DC for 1minute</td><td></td></tr>
<tr><td>Turret/ Neutral CT ratio errors</td><td>+ 3%</td><td>IS- 2705</td></tr>
<tr><td>Vibration level for Reactors</td><td>200 Microns (peak to peak)
60 Microns (Average)</td><td></td></tr>
<tr><td>Sweep frequency response Analysis Tests
(20Hz to 2 MHz)</td><td>In general, changes of +/- 3 dB (or more) in following frequency range may indicate following results

5Hz to 2KHz – Shorted turns, open circuit, residual magnetism or core movement

50Hz to 20KHz – Bulk movement</td><td>Euro-Doble Client Committee/ Transformer Diagnostic

USBR, June 2003</td></tr>
</table>

	of windings relative to each other 500 Hz to 2 MHz – Deformation within a winding 25 Hz to 10 MHz – Problems with winding leads and/ or test lead placement		
Moisture measurement of winding (RVM measurement)			**IEEE Std. 62 – 1995**
Insulation condition	**% Moisture by dry weight in paper (Wp)**	**% Water saturation of oil ( )**	**CIGRE DOC.NO.227 Life Management Technique for Power Transformer – Page 119**
Dry (at commissioning)	**0.5 to 1.0%**	**< 5%**	
Normal in operation	**< 2%**		
Wet	**2 to 4 %**	**6-20%**	
Extremely wet	**> 4.5 %**	**> 30%**	
Degree of Polymerization (DP)	**New Insulation**	**1000 DP to 1400 DP**	**EPRI's guidelines for the life extension of substations, 2002 Update, chapter 3. Table 7** **DP values for Estimating Remaining Paper Life**
	60% to 66% life remaining	**500 DP**	
	30% life remaining	**300 DP**	
	0 life remaining	**200 DP**	

CIRCUIT BREAKERS

Dew point of SF6 Gas	**Dew Point values as per Annexure-II**			
Dew point of operating air	**-450 at atmospheric Pressure**			
(A) CB Operating Timings **(a) Closing time (Max)** **(b) Trip time (Max)** **(c) Close/Trip time pole discrepancy at rated operating pressure** **- Phase to Phase (Max) close open** **- Break to Break (Max) of same phase.**	**400 KV** **150 ms** **25 ms** **5.0 ms** **3.33 ms** **2.5 ms** **35 ms** **300 ms** **± 5 ms** **± 3 ms**	**400 KV** **150 ms** **35 ms** **5.0 ms** **3.33 ms** **2.5 ms** **35 ms** **300 ms** **± 5 ms** **± 3 ms**	**400 KV** **150 ms** **45 ms** **5.0 ms** **3.33 ms** **2.5 ms** **35 ms** **300 ms** **± 5 ms** **± 3 ms**	**IEC-62271-100 (2001)** **IEC-62271-100 (2001)** **IEC-62271-100 (2001)** **With simultaneous close & trip command.**

(d) Trip delay time for DCRM test (CO operation) – **(f) Deviation from standard Timings as per GTP of manufactures – close open**				

	(B) PIR time **BHEL make** **CGL make** **ABB make** **NGEF make** **M&G make** **TELK make** **Alstom make (HVDC)** **ABB make (HVDC)**	**400 KV** **12 – 16 ms** **8 – 12 ms** **8 – 10 ms** **8 – 12 ms** **8 – 12 ms** **8 – 12 ms** **8 – 12 ms** **8 – 12 ms**	**Manufacturer's Recommendations**
	(C) PIR operating time prior to opening of main contacts (ABB, CGL, NGEF make CBs)	**5 ms (Min) at rated pressure**	
	(D) PIR and main contacts overlap time (BHEL, M&G, ABB (imported make CBs)	**5 ms (Min) at rated pressure**	
	(E) Tan delta of grading capacitors	**0.007**	**Since temperature correction factor for Tan-Delta depends on make, type and also aging conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.**
	(F) Rate of rise in Tan Delta	**0.001 per year (max)**	
	(G) Capacitance of grading capacitors	**Within ±5% of the rated value**	
	(H) Contact Resistance of CB (in Micro-Ohm)	**400kV 220kV 132kV** **150 100 100**	
	(I) Contact Resistance of CB terminal connector	**10 Micro-Ohm per connector**	**NGC, UK Recommendations**
	(J) Evacuation level before SF6 gas filling	**5mbar (min)**	
	(K) N2 leakage rate from N2 accumulator	**3 bar per year (max)**	
	(L) IR VALUE		
	Phase – Earth	**1000 M-Ohm (Min) by 5.0/10.0 kV megger**	

	Across open contacts Control Cables	1000 M-Ohm (Min) by 5.0/10.0 kV megger 50 M-Ohm(Min) by 0.5 kV Megger	
	(M) PRESSURE SWITCH SETTINGS SF_6 gas pressure switches Operating air pressure switches Operating oil pressure switches	 Within ±0.1 Bar of set value Within ±0.1 Bar of set value Within ±1.0 Bar of set value	
	(N) BDV of oil used for MOCB - At the time of filling - During O&M	 40kV at 2.5 MM GAP (Min) 20kV at 2.5 MM GAP (Min)	Manufacturers' Recommendations

CURRENT TRANSFORMERS

	(A) IR Value - Primary – Earth - Secondary – Earth -Control Cables	 1000 M-OHM (Min) 50 M-OHM (Min) 50 M-OHM (Min)	 by 5.0/10.0 kV Megger. by 0.5 kV Megger by 0.5kV Megger
	Tan delta value	0.007	Since temperature correction factor for Tan-Delta depends on make, type and also aging conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.
	Rate of rise in Tan Delta	0.001 per year (max)	
	(B) Monitoring of Tan delta Upto 0.007(rise @ 0.001) 0.007 to 0.011 0.011	 Yearly monitoring Half yearly monitoring Replace the CT	
	Terminal connector contact resistance	10 Micro-Ohm per connector	NGC, UK Recommendations
	CT Ratio errors	± 3% protection cores ± 1% metering cores	IS-2705 -do-

CAPACITIVE VOLTAGE TRANSFORMERS

	(A) Tan delta value	**0.007**	**Since temperature correction factor for Tan-Delta depends on make, type and also aging conditions, the correction factors for different types/ makes are different. Hence, no standard temperature error factors can be applied.**
	(B) Rate of rise in Tan Delta	**0.001 per year (max)**	
	(C) Change in Tan ∂ from pre commissioning value	**Measured value Frequency** **Up to + 0.002 - Three Yearly** **+0.002 to +0.003 - Yearly** **Above +0.003 - alarming**	
	(D) Capacitance	**Within ±5% of pre commissioning value**	
	(E) Contact resistance of terminal connector.	**10 Micro-OHM per connector**	**NGC, UK recommendations**
	(F) Change in Capacitance from pre commissioning value	**Measured Value Frequency** **Up to ±2% of - Three yearly** **±2% to ±3% - Yearly** **Above ±6% - alarming (needs replacement)**	
	(G) IR value **- Primary to earth (Min)** **- Secondary to earth (Min)** **- Control cables (Min)**	 **1000 MΩ by 5.0/10.0 kV Megger** **50 MΩ by 0.5kV Megger** **50 MΩ by 0.5kv Megger**	
	(H) Drift in secondary Voltage (to be measured with a 0.2/0.5 class multimeter **Upto ± 0.5 volts** **±0.5 to ±0.8 volts** **±0.8 to ±1.2 volts** **±1.2 to 2.0 volts** **Above +2.0 volts** **-0.8 to -4.0 volts** **Less than -4.0 volts**	**Condition Measurement Frequency** **Healthy – Six monthly** **To be monitored – 03 monthly** **Close monitoring – monthly** **Close monitoring – 15 days** **Alarming – replacement** **Close monitoring – 15 days** **Alarming – replacement**	

	(I) EMU tank oil parameters **BDV (Min)** **Moisture content (Max)** **Resistivity at 90^0C** **Acidity** **IFT at 27^0C** **Tan delta at 90^0C** **Flash Point**	 **30kV (2.5 mm gap)** **35 PPM** **$0.1 * 10^{12}$ Ohm-Cm** **0.5 mg KOH gm (Max.)** **0.018 NM (Min)** **1.0 Max** **125^0C (Min)**	**IS-1866**
	(J) CVT Voltage ratio errors	**±5% protection cores** **±0.5% metering cores**	**IEEE/C93.1.1190** **IEC 186**

DISCONNECTING SWITCHES

	(A) Contact resistance **(B) Contact resistance of terminal connector.** **(C) IR Value** **- Phase – Earth (Min)** **- Across Open Contacts (Min)** **- Control cables (Min)**	**300 Micro-Ohm (Max)** **10 Micro-Ohm per connector** **1000 MΩ by 0.5/10.0 kV megger** **1000 MΩ by 0.5/10.0 kV megger** **50 MΩ by 0.5kV megger**	 **NGC, UK recommendations**

SURGE ARESTER

	(A) Third Harmonic Resistive Current (THRC) – for all makes Elpro / Alstom / Oblum / CGL **- For new Las** **- For Las in service**	• **Upto 30 Micro-Ohm** • **(upto 150 Micro-Ohm)- Normal** • **(150 to 350 Micro-Ohm)- to be tested for insulation test & if value found low - to be removed from service** • **Beyond 350 Micro-Ohm (Gapless type) - to be removed from service** • **Beyond 500 Micro-Ohm (Gapless type) - to be removed from service**	
	(B) IR Value	**1000 Mega-Ohm (Min.)**	

MISCELLANEOUS

	(A) Station Earth Resistance **(B) Thermo vision Scanning** **- Temp up to 15^{0}C (above ambient)** **- Temp above 15-50^{0}C (above ambient)** **- Temp above 50^{0}C (above ambient)**	**1.0 Ohm (Max.)** **Normal** **Alert** **To be immediately attended**	**IEEE/C 37.010.1979**
	(C) Terminal connector resistance	**10 Micro-Ohm per connector**	**NGC, UK recommendations**
	(D) IR values **- All Electrical Motors** **- Control Cables** **- LT Transformers** **- LT Switchgears**	 **50 MΩ (Min) by 0.5 kV megger** **50 MΩ (Min) by 0.5 kV megger** **100 MΩ (Min) by 0.5 kV megger** **100 MΩ (Min) by 0.5 kV megger**	**IS 900**

BATTERIES

	(A) Terminal connector resistance **(B) Specific Gravity**	**10 Micro-Ohm ±20%** **1200 ± 5gm/litre at 27^{0}C**	**ANSI/IEEE – 450-1987**

DG SET

	(A) Winding IR Value **(B) Stator winding resistance**	**50 MΩ** **Within ±10% of the STD value**	

3.11 Quality Control Checks on O&M of substations and Lines.

3.11.1 Quality is the total composite product and service characteristic of manufacturing and maintenance through which the product and service in use will meet the expectations of the organization.

Quality has four facets, viz. the quality that results from the best possible product design, quality due to conformance to product design, quality that results from the best construction practices and the quality that results from the best O&M practices.

Responsibility for carrying out operation and maintenance of substations and lines primarily rests with the maintenance units (TL&SS). AE/ADE in charge of substations/lines plan for executing the maintenance works as per the schedule and arrange to keep the materials ready for the works before commencement. They should also plan for required manpower ahead of works so that the works are executed in time. The DE& SE (TL&SS) will inspect periodically and extend support in arranging all the men and material requirements and ensure compliance with the maintenance schedules and proper upkeep of the installations.

Performance of equipment/lines depends not only on best maintenance carried on them, but on proper operation of these equipment, environment and surroundings in which they work. It is necessary that proper upkeep of the premises such as cleaning and conditioning civil structures, roads, drainage system, security fencing, water supply, electrical distribution systems etc. is carried out in addition to maintenance of equipment, auxiliaries/ lines.

By proper operation it is meant that the equipment /lines are operated with in the specified parameters viz. voltage, current, load and temperatures and all statutory clearances are adhered to. Also all auxiliaries like cooling fans, oil pumps, are in working condition and the controls and protective devices are in trim condition. Standard operating instructions for carrying out day to day operations and the guide lines are made available with the shift staff to follow.

While the regular maintenance works are executed by the maintenance staff and periodically inspected by higher officers in maintenance organization, there is a need to cross check the works done with emphasis on the quality of work carried out and check on the compliance to the instructions by the operating staff and on the general upkeep and amenities provided. This task can be entrusted to an independent quality control team.

Various checks and cross checks to be made by the independent quality control team are as follows:

3.11.2 Maintenance of equipment in substations:

- Check for passage in the switch yard and the condition of the area surrounding the equipment.
- Observe the earthing arrangements made and adequacy of the same as per the standards. Check the condition of earth electrodes/ pits, earth mat and earth resistance values .Check for water supply arrangements to the earth pits. Also check whether earthing of the bodies of the equipment and all metal structures is made from two points to two different earth grid points nearby and tightness of connections. Also check whether connections between neutrals of transformers and LAs ground points are connected to independent earth electrodes.
- Verify the maintenance records for incorporation of all the standard maintenance schedules equipment wise and maintenance plan. Check for the availability of manufacturers' guide lines/ instructions on the equipment.
- Check the maintenance works carried out in the last one year or between the previous and present inspection dates. Attention should be paid to action pending on long pending observations/remarks.
- Check whether tests were done in a conducive weather and all the precautions for accurate testing were followed. Accuracy of test results obtained should be checked and any correction factors for temperature/pressure applied. Check for any deviation from the standard permissible limits and the trend in the variations from the previous results and interpretation of the results from the trend.
- Battery, charger and DC distribution system performance: Connections between cells, condition of terminals, cell voltage, specific gravity and connections to charger should be checked. Charge and discharge currents, earth leakages etc. to be checked. Working of DC emergency lighting should be checked. Connected maintenance records may be examined to see the tests done and maintenance carried out as per schedules.
- Adequacy of yard lighting and its proper working should be observed.
- Working of all auxiliaries such as cooler fans, oil pumps, OLTC, oil & winding temperature indicators for transformers, air compressors etc. should be checked. Working of all pressure switches, monitors should be ensured.
- Availability of fire protective devices and their condition should be checked.
- Check for condition of cables, cable ducts, trenches in the yard and in the control room.

3.11.3 Operation of substation

- Ensure availability of document containing operating instructions for switching in/out of various equipment and lines, issuing of line clears, breakdown operations, communication with load dispatch etc. and that operation staff are conversant with operating instructions.
- Check that the load on feeders, transformers, voltages at different buses and temperatures on transformers are within permissible limits.

3.11.4 Miscellaneous checks

- Observe the condition of flooring, roof, walls, doors and windows, Ac system, C&R and other panels in the control room; ventilation and exhaust arrangements in the battery room and other buildings within the substation.
- Observe the condition of roads, drainage, culverts, security fence etc.
- Check the availability of required tools, spares and consumables for work at site or at any central place and their condition.
- Check for availability of personal protective equipment such as rubber gloves, shoes, safety belts etc. and earthing devices and their condition.
- Test equipment available may be inspected to ascertain their condition and their suitability.

3.11.5 Maintenance on Lines

- Check for approach to the location, area surrounding the tower base
- Check for condition of foundations, copings, chimneys, area around foundations for back fill etc.
- Check for missing members and the physical condition of the members, cohesiveness between adjacent members.
- Check for the correct earthing of tower at the location
- Check for the condition of conductors and earth wire/wires and clearances to ground and between phases and circuits
- Check for the availability and position of arcing horns, vibration dampers, spacers, clamps and connectors, armored grips etc. and their condition and dislocation of these if any.
- Check for the position and condition of the insulators and need to replace or rectify the same.
- Check for any obstacles viz. tree branches, dwellings etc. in the corridor causing unwarranted tripping of the line.

Checks listed above are indicative. Any additional checks to suit the site condition may be done and recorded.

3.12 Quality Control Checks on Meters and Metering System:

3.12.1 Electronic Energy meters are available at all EHV substations for recording energy transmitted and received at the substation feeder wise.

Electronic energy meters of 0.2 class accuracy shall be provided at all interface points between Generation – Transmission and Transmission – Distribution at the boundaries of generators and transmission substations and EHT consumers.

Since bulk energy is handled by TRANSCO, exact amount of total energy received from all generators including central generating stations, and neighbouring utilities, energy delivered to distribution companies, EHT consumers, Open Access consumers and energy transmitted on various transmission elements is to be accurately measured for computing the total energy input to Transco, energy delivered to discoms (output from Transco) and losses in transmission network. For this purpose very accurate electronic meters of 0.2 class accuracy with facility for storing all load survey data and compatible to both two part as well as ABT tariff are installed in Transco. Associated metering equipment viz. CTs and VTs of 0.2class accuracy are installed.

The entire metering system needs to be regularly monitored to prevent any loss of revenue and to analyze transmission losses. Analysis of transmission losses helps in taking corrective steps in reduction of losses and improving the efficiency.

MRT unit under SE (TL&SS) will be normally testing the meters and the metering system periodically (once a year). Since the metering system at boundary points located at generating stations and at transmission substations have commercial implication, there should be proper sealing arrangement for meters and metering system to prevent any meddling by unauthorized persons. Authorized TL&SS staff should have access to downloading the data from meters. Meters should also be equipped with facility for remote communication of data to the controlling station for online analysis. Tamper proof arrangements should be available in the meters. All accessible points for data transfer (serial ports, modems remote communication ports etc) should have provision for sealing by authorized persons.

While regular testing and periodical checks and additional checks on specific complaints are made by MRT staff and readings are downloaded by authorized maintenance staff, random check on the entire metering system and the condition may be necessary to ensure regular attention to the metering system to prevent any leakages. This counter check may be carried out by a neutral agency such as quality control unit. In APTRANSCO this activity is undertaken by MRT unit under the control of Joint Managing Director (Vigilance and Security).

3.12.2 Various checks and cross checks to be made by the independent team are as follows.

- Check for accuracy class of meters, metering CTs and VTs installed at the interconnecting points with reference to PPA/ metering code
- Check for foolproof arrangement of the metering cubicle.
- Check for proper earthing of system and safety earthing of meter body and metal bodies and structures of metering equipment. Also check that the star point of CT secondary winding is connected to ground at only one point preferably inside the metering cubicle.
- Check that no wires are seen from outside the test terminal block (TTB)
- Check for the due date of test of the meters as per periodicity and the date on which it was done and conformity of test results to standards.
- Cross check the working of meters and errors with actual generation / load with a ESS meter at site
- Check contracted maximum demand of EHT consumer
- The multiplication factors of the boundary meters will be verified with the data from field and data from EBC.
- During the general inspections of generators/ EHT consumers and also in the vendor registration inspections, the multiplication factors adopted will be checked and verified by calculating MF based on the ratio of CTs & PTs and ratio adopted in the energy meters.
- Analyze the energy losses on the feeders connected to the generating station/ EHV station under inspection, by comparing the meter readings of these feeders at the other ends

In addition to the above the following points may also be verified while inspecting the generator premises:

- Capacities of the generators, turbines and boilers etc.
- Auxiliary loads of the plant.
- Inter connected equipment.
- Type of fuel used for generation with reference to the sanction/agreement conditions.
- Inter connections with neighbouring premises/any processing plants.
- Fuel metering point, if any.
- Metering arrangement for measurement of energy for In-house consumption in case of Captive Power Plants.

After physical inspection, reports will be generated with reference to agreement conditions, energy transactions and other commercial aspects and the remarks will be communicated to the concerned after approval by JMD(V&S).

3.12.3 <u>Random check of energy transactions of open access users:</u>

- Collecting the details of Open Access Users and actual/Implemented schedules from Load Dispatch.
- Collecting MRI data of Open Access Users from EBC.
- Collecting JMRs from field.
- Estimation of UI Energies and comparing with EBC calculations.

3.12.4 <u>Joint Inspection of Generator for processing Vendor Registration:</u>

Vendor registration is made mandatory for all the Intra-state Generators who want to sell power to APPCC for short time. During the vendor registration process a joint inspection will be carried out with MRT Vigilance, IPC and concerned TL&SS unit. The following points will be observed during joint inspection.

- Availability of ABT compatible energy meters for metering.
- Exclusive metering system (CTs &PTs) for metering.
- Accuracy class of meter and CT&PTs shall be 0.2.
- Metering point is located at the Transco/Discom SS.
- Whether the generator is using the right fuel as per sanction.
- Capacities of generators, turbines, boilers and transformers which are connected to grid will be taken as indicated on the name plate.
- Total generation capacity, auxiliary consumption and ex-bus capacity will be verified.
- Fuel supply agreements will be verified.
- Test reports of the energy meters tested at the standard NABL accredited laboratory
- Test reports of CTs & PTs should be be verified.

3.12.5 Booking of cases for tampering meters with assistance of Anti Power Theft Squad (APTS):

MRT vigilance may be authorized to book cases on the generators/EHT consumers with the assistance of APTS in case any fraud like tampering the meters, deviation of agreement conditions etc is detected.

3.12.6 <u>Witnessing Synchronization & COD of intrastate generators:</u>

- Witness of the synchronization of the new intrastate generators will be carried out by the MRT vigilance and the aspects like capacity of the generators, turbines & boilers will be verified.
- The protection scheme settings will be verified as per the settings communicated by APTRANSCO.
- For declaration of the commercial operation date for the new generators who are entering into long term agreements with APPCC, Performance Acceptance Test will be conducted as per the standard practices. In the PAT, the generator has to prove the full capacity as per the agreement conditions. This test will be witnessed by the MRT vigilance. This unit will ensure application of correction curves if any as per the EPC contract, for calculating full capacity of the generator.
- Reliability tests regarding capacity of the IPPs if any also will be witnessed as and when required as per the agreement conditions.

The MRT vigilance wing will obtain from EBC, MRI data for actual energy recorded in meters, schedules from Grid Operation, agreements from IPC / commercial wings and bills raised / claimed from Dy.CCA(PPS) etc.apart from the field information and review the proper working of all boundary meters, feeder energy meters, grid connectivity and regulations related to CPPs,IPPs, Inter/Intra state OA transactions and UI transactions.

Observations made in respect of various checks and reviews by the quality control team should be recorded and referred to the concerned functional heads and compared with the maintenance reports maintained by the maintenance staff. If the observations are already reported by the maintenance staff, action taken in attending and rectifying the defects should be recorded.

Observations requiring attention should be divided into three categories:

i) Most critical – warranting immediate action and rectification without time delay
ii) Less critical – Action required within a specified time
iii) Increase frequency of maintenance and monitor the trend

Item (i) should be reported immediately to the DE&SE (TL&SS), Zonal CE and the CE (Transmission). All efforts shall be made to attend to the defect promptly and compliance reported by the zonal CE and CE (Transmission) to the Board.

Item (ii) - plan of action should be prepared by the maintenance staff in consultation with the DE/SE (TL&SS) and rectification of defects done within the prescribed time

In respect of item (iii) since the defect observed is minor, the condition should be monitored more frequently and the trend observed and analyzed. When in dispute, analysis of the interpretation of results may be referred to a committee comprising of persons with expertise and experience on the subject.

A review on all the observations made by the quality control staff may be conducted at higher level (By the CMD) on a regular basis (once in three months), wherein actions proposed and action taken in a given time frame may be reviewed so as to ensure efficient working of the system.

Timely action on the defects identified, help in improving the performance of the equipment and in extending the life of the equipment.

3.13 Renovation and Modernization of Transmission System

Every equipment/Line has a useful life period. Depending on the environment in which they operate and the operating conditions and proper maintenance carried out they perform well during their life period and even beyond life period.

Insulation deterioration in electrical equipment takes place due to aging despite regular operation and maintenance. Degree of deterioration varies depending on the operation and maintenance levels. Operational efficiency and reliability get affected with deterioration.

To limit the interruptions, to improve the availability and to improve efficiency, it is necessary that the equipment / lines which have served their life period and which are nearing completion of their life period are identified and listed in the order of seniority and replaced.
Advancement in technology brought a revolution in the design and development of equipment giving more reliable, fast acting, more efficient, fail proof and compact equipment.

It is imperative that replacement of old and obsolete and outlived equipment is done with equipment with present day technology.

Also modernization of important and more significant stations, which are sufficiently old and which have old equipment, results in improvement in efficiency and reliability of the system. Such stations and lines also should be identified and replaced with modern equipment.

A list of equipment and lines substation wise where old, obsolete and outlived equipment and equipment whose life period is approaching should be prepared. Replacements/ modernization or renovation of such equipment shall be made seniority or priority wise and necessary estimates under the head “Renovation and Modernization” (R&M) prepared.

As it may not be possible to revamp all the old and obsolete system in one stroke, due to high costs involved and budget constraints, a plan for R&M shall be prepared on a five year basis and equipment/line proposed for replacement prioritized.

Budget allocation under R&M should be made every year and lists of outlived and obsolete equipment/lines updated after deleting the equipment/lines replaced. This way transmission system’s reliability can be improved. This task can be taken up by CE (Transmission) and reviewed from time to time by the Board.

3.14 Scrap Management & Disposal Procedure

3.14.1 Electrical equipment, working under normal operating conditions and with proper maintenance carried out periodically, perform satisfactorily through the entire life period. However they are susceptible to damages due to prolonged/continuous operation under stressed system conditions (such as sustained over loads, over fluxing due to over voltage and/ or under frequency) sustained faults, fires, bad maintenance etc. Damages could be minor or medium in nature depending on the intensity of faults, which can be repaired at site / at repair shop and the equipment, can be put back into service. Major damage can leave the equipment beyond economical repairs and render the equipment unserviceable and reduces it to scrap. Economics of repairs should be worked out taking into consideration the type and number of components that have failed, remaining life of the failed equipment, cost of repairs considering the present market value of the equipment and expected life period after repairs.

Also such of those obsolete and outlived equipment not meeting the desired level of operation and not able to match with the present day power system requirements (viz. increased fault levels, reduced impedances, insulation levels etc.) which have been removed from service consequent to replacement under renovation and modernization schemes, become unserviceable and hence can be treated as scrap.

Scrap materials, if left to be accumulated in a substation, will be a potential fire hazard. Further they occupy considerable space hindering free movement for day to day works apart from presenting an untidy appearance. In addition, the condition of retrievable material in the scrapped equipment deteriorates with time and reduces its value. Therefore every effort shall be made by all concerned in the field for disposing of scrap materials at the earliest.

3.14.2 Immediately on failure of any equipment, the AE/ADE (maintenance) should take steps in getting it repaired. Where the damage is beyond economical repair, the equipment should be treated as scrap. Steps should be initiated for disposal of scrap. Survey report on proposed scrap equipment should be prepared giving full details about the equipment as given below.

- Date of first commissioning the equipment and date of commissioning at the present station where it failed and no. of years in service
- Details of equipment
- History of the performance of the equipment from first date of commissioning viz. results of maintenance, no. of failures previously and details of repairs done earlier,
- Total no. of years in service (can be checked from the name plate details)
- Reasons for present failure leading to damage beyond repairs along with log of events prior to, during and immediately after the failure
- Analysis of failure by the reporting officer
- Book value of the equipment or present market value
- Present condition of the damaged equipment and remnant (scrap) value of the materials like steel, copper, aluminium, brass, oil, at the present market rates.

Divisional Engineer concerned shall examine the survey report and send the same with his remarks to the Superintending Engineer concerned and the Chief Engineer of the zone. Proposals for survey report of failed equipment beyond repairs shall be sent by the DE (TL&SS) within one month.

All equipment other than power transformers and circuit breakers of 132kV and above (where the present market value of the damaged equipment is Rupees 5lakhs and below), shall be inspected by a committee consisting of SE, Senior Accounts officer of the zone and CEzone. Proposals for writing off of the scrap equipment will be put up by the concerned DE (TL&SS)to CE zone. The CE zone will examine the proposals received along with the remarks of SE (TL&SS) and approve for write off of damaged equipment. If the damage in the opinion of the committee is due to negligence /error in judgment on the part of station staff or due to lapse in maintenance, the committee should bring out in detail all such issues in their report and submit a report to the CE / Transmission. CE/Transmission will examine all such proposals and circulate to Board for further action.

In case of power transformers/breakers of 132kV class and above, where the present market value is above Rupees 5 lakhs, survey report proposals should be sent by zonal Chief Engineer to the Chief Engineer (Transmission) after inspecting the damaged equipment, as mentioned above together with his assessment of circumstances leading to failure and consequential damage of the equipment and action proposed on the staff if any for any lapse. CE (Transmission) shall examine the survey report proposals and arrange for inspection of the damaged equipment by a committee to be proposed by him and approved by the Director concerned. The committee may be constituted with DE (TL&SS) concerned, one member of the rank of SE/DE, from CE (Transmission's office) and one member from Quality assurance wing as per the instructions issued in T.O.O. CE (Transmission) Ms.No. 159 dt.30-07-2010. The committee shall inspect the failed equipment and assess the condition and submit report to the zonal CE and CE (Transmission). CE (Transmission) will examine the proposals and put up for write off of such equipment for approval by the Board. Board's approval shall be communicated to the CE zone for initiating action for disposal of scrap.

3.14.3 Disposal Procedure:

After approval for write off of equipment is issued by CE zone/ APTRANSCO, depending on the value of the equipment as explained above, DE (TL&SS) concerned shall initiate for disposal of scrap. All the scrap items except power transformers shall be devoluted to stores as scrap. The CE zone shall arrange to invite bids for auctioning the scrap either through e-procurement or conventional process depending on the assessed value of scrap materials. Auction may be conducted once in six months or once a year depending on the volume of scrap materials accumulated in stores.

In respect of power transformers, after receipt of assessment of condition of transformer and its scrap value from the team and approval of the same, CE (Transmission) shall arrange auction of the transformer on e-procurement platform.

Auction shall be conducted for lifting of the scrap on as is where is basis. Further with a view to prevent deterioration of condition of scrap material and reduction in scrap value due to long storage, theft or fire; time period for disposal and responsibility for safe custody are fixed in the above T.O.O. as given below:

- Since scrap transformers are disposed off on as is where is basis, the concerned AE and/or ADE (Maintenance) and DE (TL&SS) shall be made responsible for physical custody of the same till disposed.
- DE (TL&SS) and CE (Transmission) shall be responsible for disposal of transformer scrap as early as possible i.e. with in nine months from the date of approval of write off. Bids for auction shall be called within six months and finalized within next three months.
- The team constituted as per T.O.O. shall be responsible for assessment/ reassessment of scrap value with in one month from the date of approval of write off and submit a report to CE/Transmission. The assessment report should be followed by video/photos of components/items of power transformers considered for assessment.

3.15 Delegation of Powers to Officers

Field officers are delegated with certain powers for sanction of estimates, purchase of materials works and O&M. Latest delegation of powers communicated by APTRANSCO vide T.O.O. CE (Transmission) Ms.No.229 dt.18-09-2010 are given in the table below.

(All figures in rupees)

Sl. No	Type	CE	SE	DE
1. Purchase Powers (Clause No.10.2 of purchase Manual and description)				
i)	Open competitive bidding	7,00,000	5,00,000	25,000
ii)	Limited competitive bidding	1,00,000	50,000	10,000
iii)	Short notice bidding	50,000	25,000	Nil
iv)	Rate contract	Full powers	2,00,000	Nil
v)	Emergency purchase in open market for non-centralized items	Nil	20,000	10,000
vi)	Purchase on Nomination basis	Nil	Nil	Nil
vii)	Purchase of proprietary spares through single bid	5,00,000	10,000	Nil
2. Powers for award of work contract(Capital& O&M of Electrical and Civil works) (Item No.2: Clause No.10.2 of Purchase Manual)				
i)	Open competitive bidding	20,00,000	8,00,000	1,00,000
ii)	Nomination basis	Nil	Nil	Nil
3.Deposit contribution Works (Item No.4 of Delegation of powers)				
i)	Shifting of line structures, shifting of services etc.	Full powers	5,00,000	50,000
4. Technical Sanctions (Capital expenditure – Electrical&Civil works) (Item No. 16 of delegation of powers)				
i)	Technical sanctions under capital expenditure	Full powers	15,00,000	5,00,000
5. O&M/R&M expenditure (Electrical&Civil works) (item No.20 0f Delegation of powers)				
i)	Technical sanctions under O&M expenditure	Full powers	5,00,000	50,000
6. Electrical works: Non-Residential Buildings: (Item No.18(i) of Delegation of powers				
i)	Non-residential buildings	Full powers	2,00,000	50,000
7. Repairs to the vehicles (Item No.20(ii) of delegation of powers)				
i)	Lorry	30,000	20,000	8,000 2,000(ADE)
ii)	Jeep	20,000	15,000	6,000 1,000(ADE)

8. Tools and Plant (T&P) (Item No.21(c) of delegation of powers)				
i)	**Tools and Plant (T&P) chargeable to capital**	**2,00,000**	**25,000**	**10,000**
9. Office furniture (per annum) (Item No.46 of delegation of powers)				
i)	**Office furniture (per annum)**	**1,00,000**	**Nil**	**Nil**
10. Computer Spares, Repairs (T.O.O.No. 146 dt. 22-10-2007)				
i)	**Computer spares, repairs (per annum)**	**1,00,000**	**50,000**	**Nil**
11. Printing (T.O.O.No. 146 dt. 22-10-2007)				
i)	**Printing (per annum)**	**5,00,000**	**Nil**	**Nil**

APTRANSCO

REFERENCE MANUALS ON CONSTRUCTION AND OPERATIONAL PRACTICES OF EHV SUBSTATIONS & LINES AND COMMERCIAL AND LOAD DESPATCH OPERATIONS

- BY M. GOPAL RAO