

# STANDARDS/MANUALS/ GUIDELINES FOR SMALL HYDRO DEVELOPMENT

---

---

## **3.5**

### **Electro-Mechanical–**

### **Design of Auxiliary Systems and Selection of Equipments**

---

---

Sponsor:

Ministry of New and Renewable Energy  
Govt. of India

Lead Organization:

Alternate Hydro Energy Centre  
Indian Institute of Technology Roorkee

November 2012

### **Contact:**

Dr Arun Kumar  
Alternate Hydro Energy Centre,  
Indian Institute of Technology, Roorkee,  
Roorkee - 247 667, Uttarakhand, India  
Phone: Off. (+91 1332) 285821, 285167  
Fax: (+91 1332) 273517, 273560  
E-mail: aheciitr.ak@gmail.com, akumafah@iitr.ernet.in

### **DISCLAIMER**

The data, information, drawings, charts used in this standard/manual/guideline has been drawn and also obtained from different sources. Every care has been taken to ensure that the data is correct, consistent and complete as far as possible.

The constraints of time and resources available to this nature of assignment, however do not preclude the possibility of errors, omissions etc. in the data and consequently in the report preparation.

Use of the contents of this standard/manual/guideline is voluntarily and can be used freely with the request that a reference may be made as follows:

*AHEC-IITR, “3.5 Electro-Mechanical – Design of auxiliary systems and selection of equipments”, standard/manual/guideline with support from Ministry of New and Renewable Energy, Roorkee, November 2012.*

## **PREAMBLE**

There are series of standards, guidelines and manuals on electrical, electromechanical aspects of moving machines and hydro power from Bureau of Indian Standards (BIS), Rural Electrification Corporation Ltd (REC), Central Electricity Authority (CEA), Central Board of Irrigation & Power (CBIP), International Electromechanical Commission (IEC), International Electrical and Electronics Engineers (IEEE), American Society of Mechanical Engineers (ASME) and others. Most of these have been developed keeping in view the large water resources/ hydropower projects. Use of the standards/guidelines/manuals is voluntary at the moment. Small scale hydropower projects are to be developed in a cost effective manner with quality and reliability. Therefore a need to develop and make available the standards and guidelines specifically developed for small scale projects was felt.

Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee initiated an exercise of developing series of standards/guidelines/manuals specifically for small scale hydropower projects with the sponsorship of Ministry of New and Renewable Energy, Government of India in 2006. The available relevant standards / guidelines / manuals were revisited to adapt suitably for small scale hydro projects. These have been prepared by the experts in respective fields. Wide consultations were held with all stake holders covering government agencies, government and private developers, equipment manufacturers, consultants, financial institutions, regulators and others through web, mail and meetings. After taking into consideration the comments received and discussions held with the lead experts, the series of standards/guidelines/manuals are prepared and presented in this publication.

The experts have drawn some text and figures from existing standards, manuals, publications and reports. Attempts have been made to give suitable reference and credit. However, the possibility of some omission due to oversight cannot be ruled out. These can be incorporated in our subsequent editions.

This series of standards / manuals / guidelines are the first edition. We request users to send their views / comments on the contents and utilization to enable us to review for further upgradation.

## Standards/ Manuals/Guidelines series for Small Hydropower Development

<b>General</b>	
1.1	Small hydropower definitions and glossary of terms, list and scope of different Indian and international standards/guidelines/manuals
1.2 Part I	Planning of the projects on existing dams, Barrages, Weirs
1.2 Part II	Planning of the Projects on Canal falls and Lock Structures.
1.2 Part III	Planning of the Run-of-River Projects
1.3	Project hydrology and installed capacity
1.4	Reports preparation: reconnaissance, pre-feasibility, feasibility, detailed project report, as built report
1.5	Project cost estimation
1.6	Economic & Financial Analysis and Tariff Determination
1.7	Model Contract for Execution and Supplies of Civil and E&M Works
1.8	Project Management of Small Hydroelectric Projects
1.9	Environment Impact Assessment
1.10	Performance evaluation of Small Hydro Power plants
1.11	Renovation, modernization and uprating
1.12	Site Investigations
<b>Civil works</b>	
2.1	Layouts of SHP projects
2.2	Hydraulic design
2.3	Structural design
2.4	Maintenance of civil works (including hydro-mechanical)
2.5	Technical specifications for Hydro Mechanical Works
<b>Electro Mechanical works</b>	
3.1	Selection of Turbine and Governing System
3.2	Selection of Generators and Excitation Systems
3.3	Design of Switchyard and Selection of Equipment, Main SLD and Layout
3.4	Monitoring, control, protection and automation
3.5	Design of Auxiliary Systems and Selection of Equipments
3.6	Technical Specifications for Procurement of Generating Equipment
3.7	Technical Specifications for Procurement of Auxiliaries
3.8	Technical Specifications for Procurement and Installation of Switchyard Equipment
3.9	Technical Specifications for monitoring, control and protection
3.10	Power Evacuation and Inter connection with Grid
3.11	operation and maintenance of power plant
3.12	Erection Testing and Commissioning

## **PERSON INVOLVED**

1. Dr Arun Kumar, CSO & Principal Investigator ,AHEC,IIT, Roorkee
2. Dr S K Singal, SSO & Investigator,AHEC,IIT, Roorkee

### *Drafting Group*

1. Prof. O.D.Thapar, Consultant, AHEC,IIT, Roorkee
2. Mr. S.K.Tyagi, Consultant, AHEC,IIT, Roorkee

### *Consultation Group*

1. Dr Arun Kumar,AHEC,IIT, Roorkee
2. Mr S.N.Singh, AHEC,IIT, Roorkee
3. Dr S K Singal,AHEC,IIT, Roorkee
4. Mr. S.C.Jain, Consultant, AHEC,IIT, Roorkee
5. Mr. Masum Ali, Consultant,AHEC,IIT, Roorkee
6. Mr. A.K.Chopra, Consultant, SHP, MNRE,GOI, New Delhi
7. Mr. R.P.Goel, Consultant, Hardwar
8. Mr. S.V.Dinkar, Consultant, Pune
9. Mr. Surendra Singh ,PGCL, PEDA,Chandigarh
10. Mr. Pankaj Kulshreshtha, UJVNL, Dehradun
11. Mr. Himanshu Tiwari, UJVNL, Dehradun
12. Mr. A.K.Singh, UJVNL, Dehradun
13. Mr. P.K.Singhal, UPJVNL, Lucknow
14. Mr. V.K.Sharma, THDC, Rishikesh
15. Mr. U Ukhal, HPPCL, Himachal Pradesh
16. Mr..S.S.Sidhu, HPP India Pvt. Ltd, Noida
17. Mr. K.C.Arora, Pentaflor Hydro power Ltd
18. Mr. P.K.malohtra, Pentaflor Hydro power Ltd
19. Mr. Sanjeev Handu, Andritz Hydro power Ltd.
20. Mr. Vishnupad Saha, Andritz Hydro power Ltd.
21. Mr. Dinesh Rajput, Andritz Hydro power Ltd.
22. Mr. Pradeep Dube, Tanushree Hydropower Consultants, Noida
23. Mr. H.M.Sharma, Jyoti Ltd.,Vadodra
24. Mr. Viral B Mahida, Jyoti Ltd.,Vadodra
25. Mr. Nishant Saha, Jyoti Ltd.,Vadodra

## **CONTENTS**

ITEMS		PAGE NO
1.	Scope	1
1.0	References	1
1.1	Auxiliary System and Equipment	3
2.	General Consideration for Selection of Electrical and Mechanical Auxiliaries	4
2.1	General Design Considerations Electrical Auxiliaries	4
2.2	General Consideration for Mechanical Auxiliaries	9
3.	Electrical Auxiliaries	12
3.1	Auxiliary Power Supply System	12
3.2	D. C. Auxiliary Power System	15
3.3	Uninterruptible Power Supply System (UPS)	23
3.4	Power and Control Cables	24
3.5	Lighting System	30
3.6	Grounding System	36
3.7	Lightning Protection	36
3.8	Communication System	37
3.9	Transformer oil Purifier	38
4.	Mechanical Auxiliaries	38
4.1	Overhead Travelling Crane	38
4.2	Cooling Water System	39
4.3	Dewatering and Drainage System	41
4.4	Compressed Air System (where ever applicable)	44
4.5	Fire Protection System	46
4.6	Ventilation and Air Conditioning	57
4.7	Water Level Sensing	62
5.	Design and Installation of Grounding System for Generating Station and Step up Sub Stations including earth mats and Equipment Grounding	62
5.1	Introduction	62
5.2	Design Objectives	63
5.3	Parameters to be Considered for Designing Earthing System	63
5.4	Effect of Moisture, Alts and Temperature	63
5.5	Grounding System for Powerhouse & Switchyard	65
6.	Generating Station Grounding Design Powerhouse and Substation	72
6.1	Design Procedure	72
6.2	Generating Station Ground Grid Design	73
6.3	Design Values	74
6.4	Site Soil Resistivity	74
6.5	Ground Fault Current	74
6.6	Magnitude of fault Currents and Grid Current at SHP	75

ITEMS	PAGE NO
6.7 Design of Grounding Systems for SHP up to 100 kW Capacity Generating at 415 V	75
6.8 Grounding system design for SHP up to 5 MW and connected to grid at 33 kV and below and earth resistivity up to 100 ohm meter	77
6.9 Grounding System SHP Above 5 MW or Interconnected with grid above at 66 kV and above	90
6.10 Earthing Electronic Equipment	92
6.11 Installation	92

### **LIST OF FIGURES**

FIGURE NO.	TITLE	PAGE NO.
1	Typical System for Single Unit/Mini SHP	14
2	Typical Auxiliary Supply System for Multiple SHP	16
3	Typical Small Hydro Scheme (2 x 1000 kW)	17
4	Typical DC system for SHP up to 5000 kW	23
5	Typical Illustration of Pipe and Plate Earth Electrode	67
6	Resistance of Electrodes at Various Depths and Soil Resistivity	68
7	SLD for 2x8MW units, 11 kV and 0.85 p.f. connected to 33 kV through 11 MVA 11/33 Δ/Y transformer by 12 km long lines	76
8	Grounding System for SHP below 100 kW Capacity Generating at 415 V and Transmitting at 11 kV	76
9	Earthing Arrangement for Distribution Sub-Station (Pole Mounted)	78
10	SHP up to 100 kW Capacity – Earthing System	79
11	11 kV/433-250 V, Distribution Sub Station Location of Earth pits and Connections	80
12	Grounding Arrangement for 11 kV Sub Station	80
13	Earthing Arrangement in 33/11 kV Substation	81
14	Grounding arrangement for 33 kV S/S with feeders at right angle to bus bars	82
15	Grounding arrangement of 33/11 kV Sub-Station with Two Feeders (Parallel to bus bar) in opposite Direction	83
16	Grounding arrangement for 33/11 kV S/S with Earth Resistivity 250 ohm-meter	84
17(a)	Typical Power Plant Ground mat and Network	85
17(b)	Typical Power Plant Ground mat and Network	86
18 (a)	Typical Layout for Powerhouse Earth mat for 2 x 1.5 MW Project	87
18 (b)	Typical 33 kV Switchyard Earth mat for a 2x1.5 MW Project	88
19	Typical Earth mat of a Hydro Power Plant	89
20	Typical Power Plant interconnected with grid at 66kV	90
21	Earth mat for a 2 x 9 MW Power Plant interconnected with Large Grid (Grid Current 18kA)	91

FIGURE NO.	TITLE	PAGE NO.
22	Single Point Earthing System with Cabinets in Close Proximity for a 2 x 9 MW Power plant	92
23	Earthing of Computerized Electronic Equipment for proposed 2 x 9 MW Powerhouse	93

### **LIST OF TABLES**

TABLE NO.	TITLE	PAGE NO.
1	Type Commonly Used Battery Types in Hydropower Plants	21
2	Durations for computation of battery capacity	22
3	Normal range of size of UPS for SHP	24
4	Cables used in SHP	28
5	Max. Attenuation at various frequencies	29
6	Cable trays, support system and pipes	29
7	Requirements of Cable Laying	31
8	Recommended Illumination Values	32
9	Typical Lamps & Fittings in Some Identified Areas	34
10	Preferred Number of Air Changes	59
11	Recommended and maximum duct velocities for systems in power house buildings	60
12	Resistivity of various types of soil and other material	64
13	Resistance to ground of power plant, tailrace and substation ground mats for SHP and Step up Substations	69
14	Effective of cross sectional area after 75 years	71
15	Size of grounding conductors recommended for earthing system including equipment grounding	72
16	Ground Resistance for various values of earth resistivity	77
17	Design of earth mat for 33 kV Substation having capacity up to 10 MVA	81

### **LIST OF ANNEXURES**

ANNEXURE NO.	TITLE	PAGE NO.
1	Soil Resistivity Measurements	94
2	Installation of Grounding System	99



# DESIGN OF AUXILIARY SYSTEMS AND SELECTION OF EQUIPMENT

## 1. SCOPE

Electrical and mechanical unit and station auxiliaries integrity is important for successful operation of hydro station. Major considerations for selection and provision of auxiliaries in small hydropower (SHP) station are: (i) economic viability, (ii) lack of skilled operators (iii) unattended operation. Provision and selection of auxiliaries in SHP up to 25 MW capacity is detailed as follows:

- a) Selection of auxiliaries and system for SHP above 5 MW and up to 25 MW unit size
- b) Auxiliaries for SHP above 100 kW to 5 MW
- c) Micro hydro up to 100 kW

## 1.0 REFERENCES

R1	IEEE: 485 –2010	IEEE recommend practice for sizing lead acid batteries
R2	IEEE: 944-1986	Recommended practice for application and testing of uninterruptible power supplies for power generating stations
R3	IEEE: 142-2007	Recommended practice for grounding of industrial and commercial power systems
R4	IEEE: 1010-2006	Guide for control of hydroelectric power plants
R5	IEEE: 80-2000	Guide for safety in AC substation grounding
R6	IEEE: 665-1995	Guide for generating station grounding
R7	IEC: 60502-2005	Extruded solid dielectric insulated power cables for rated voltages from 1 kV up to 30 kV.
R8	IEC: 60331-2009	Fire resisting characteristics of electric cables
R9	IEC: 60332-2009- Par -3	Tests on electrical and optical fibre cables under fire conditions
R10	IEC: 60947 4-1-2002 and (Part 4-1)	Contactors and motor-starters – electromechanical contactors motor-starters
R11	IEC:IEC-60947-1-011	Degrees of Protection of Enclosures of LV Switchgears and Controllers
R12	IEC: 60076-11:2004	Dry type transformers
R13	IS: 11171-2001	Specification for dry type transformers
R14	IS-1239 (Part I)-1995	Mild steel Tubes
R15	IS-3589-2001	Steel pipe for water and sewage
R16	IS:10221-2008	Code of practice for coating and wrapping of underground MS pipe line
R17	IS:1730-2004	Steel plates, sheets, strips and flats for structural and general purposes-dimensions
R18	IS: 6304 -2002	Stationary batteries- lead acid type with pasted negative plates
R19	IS: 1652-2002	Plante Cells
R20	IS: 1651-2002	Tubular Cells

R21	IS: 8320 -2000	General requirement and method of tests for lead acid storage batteries
R22	IS: 15549-2005	Stationary Valve Regulated Lead Acid Batteries (VRLA)
R23	IS: 10918-2007	Vented Type Ni-Cd battery
R24	IS: 1554 (Part-1)-2005	PVC insulated (heavy-duty) electric cables for working voltage up to and including 1100 V.
R25	IS: 1554 (Part-11)- 2005	PVC insulated (heavy-duty) electric cables for working voltage from 3.3kV up to and including 11 kV.
R26	IS: 7098(Part-11)-2005	Cross-linked polyethylene insulated PVC sheathed cables for working voltages from 3.3 KV up to and including 11 kV
R27	IS: 3961-2001 – Part	Recommended current ratings for cables.
R28	IS: 8130 -2001	Conductors for insulated electric cables and flexible cords.
R29	IS: 5831- 2001	PVC insulation and sheath of electric cables
R30	IS: 3646-2003-Part 1	Code of Practice for interior illumination (illumination glare index)
R31	IS:694-2005	PVC insulated cables for working voltages up to and including 1100 V
R32	IS: 732-2005	Wiring installation conditions
R33	IS: 9563-2006	Specification for carbon monoxide filter self – Rescuers
R34	IS: 2629-2006	Recommended practice for hot dip galvanising
R35	IS: 3177-2006	Code of practice for Electrical Overhead Traveling Cranes and Gantry Cranes
R36	IS: 807-2006	Structural design of crane
R37	IS: 1646-2002	Code of Practice for Fire Safety of Building (General)
R38	IS: 2189-2008	Code of Practice – Selection, Installation and Maintenance of Automatic Fire Detection and Alarm System
R39	IS: 3844-2005 0	Code of Practice for installation and Maintenance of Internal Fire Hydrants and hose reels on Premises
R40	IS:6382-2000	Code of Practice for Design and Installation of fixed Carbon Dioxide Fire Extinguishing System
R41	IS: 4720 – 2003	Code of practice for ventilation of surface hydro power stations
R42	IS:2309-2005	Code of Practice-Protection of building and allied structure against lightning
R43	IS;325-2007	Specification for three phase induction motor
R44	IS:3943-2002	Specification of voice pipe and voice pipe fitting
R45	IS:1038-2006	Specification for steel doors, windows for residential building
R46	IS: 136119782001	Specification for steel windows for industrial buildings
R47	IS: 655-1999	Specification for metal air ducts
R48	IS: 659-19642001	Safety code for air conditioning
R49	CBIP (T.R. -79)-1991	Specification of substation battery, charging equipment and DC switch boards
R50	CBIP Manual 1987	Manual on Transformer
R51	CBIP: 302-2007	Manual on earthing of AC Power Systems

R52	CBIP: 290-2006	Manual on substation lay outs
R53	CBIP:250-1996	Modern trends and practices in power sub-transmission and distribution lines
R54	CBIP:223-1992	Manual on substation: Chapter on design of earthing mat for high voltage sub stations
R55	REC Standards-1994	Specification and construction standards
R56	TNEBEA – 2002	Power Engineer’s Hand Book
R57	UPSEB-1978	Substation Construction Manual
R58	AHEC–IIT–Roorkee 2005	Micro Hydro Quality Standards

## **ABBREVIATIONS:**

AHEC IITR	: Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee
CBIP	: Central Board of Irrigation and Power
IEC	: International Electro-technical Commission
IEEE	: Institute of Electrical & Electronic Engineers
IS	: Indian Standard
NEMA	: National Electrical Manufacturer Association
REC	: Rural Electrification Corporation
TNEBEA	: Tamil Nadu Electricity Board Engineers Association
UPSEB	: Uttar Pradesh State Electricity Board
XLPE	: Cross linked poly ethylene

## **1.1 Auxiliary System and Equipment**

### **1.1.1 Electrical Auxiliaries**

- i. Auxiliary Power system – Electrical auxiliaries including aux. Power supply system equipment; Comprising of auxiliary transformer; AC LT Switchgear and control gear for unit and station auxiliaries
- ii. DC system – DC equipment and power supply system; Comprising DC batteries and DC switchgear and charging equipment for unit and station auxiliaries
- iii. Uninterruptible power supply (UPS)
- iv. Power and control cables and cabling
- v. Lighting System – including emergency lighting
- vi. Grounding System – covers ground mat below power house and switchyard ground and equipment earthing network
- vii. Communication system
- viii. Transformer oil purifier

### **1.1.2 Mechanical Auxiliaries**

- i. Powerhouse and auxiliary cranes
- ii. Cooling water system
- iii. Dewatering and drainage system
- iv. Compressed air system
- v. Fire protection system
- vi. Ventilation and air conditioning system
- vii. Water sensing (fore bay and tailrace)
- viii. Lubricating oil purifier

## **2. GENERAL CONSIDERATION FOR SELECTION OF ELECTRICAL AND MECHANICAL AUXILIARIES**

### **2.1 General Design Considerations for Electrical Auxiliaries**

All components of the electrical items of works of the auxiliary systems should be of reliable design.

Ratings of main electrical works should generally include a safety margin of 10%. Short circuit calculations, de-rating factors, etc. should be carried out and taken into consideration for design.

Short-circuit calculations should be evaluated and every electrical component should withstand the maximum stresses under fault conditions, for fault levels and durations obtained under the worst conditions, e.g., upon failure of the corresponding main protection device and time delayed fault clearing by the back-up protection device.

The equipment should be suitable for the prevailing climatic conditions and insensitive to any signals emitted by wireless communication equipment.

**Clearances :** The layout of the equipment in the power house should provide ready access for operation and maintenance whilst the remaining sections of equipment are alive. Working clearance provided between isolated equipment and nearest live metal work should be as per Indian Electricity rules & Standards.

#### **2.1.1 Electrical Supplies for Auxiliary Equipment**

The electricity supplies available for various auxiliary equipment are:

- (i) 415 V,  $\pm 10\%$ , 3-phase 50Hz, 4-wire for A.C. power supply,
- (ii) 230 V,  $\pm 10\%$ , single phase, 50 Hz for lighting, indication, and anti-condensation heaters,
- (iii) DC for essential indication, controls, protection, alarms and circuit breaker closing and tripping supplies, emergency power supply system
- (iv) UPS system for computerized controls and SCADA

#### **2.1.2 Alternating Current Supply**

All mains supplies should be through MCBs of appropriate rating. Double-pole switches should be used to break single-phase A.C. mains supplies. For multi-phase supplies, each phase should be switched simultaneously and the neutral should preferably not be switched.

#### **2.1.3 Direct Current Supply**

Power supply bus bars in cubicles should be carefully routed and each bus bar should be shrouded. It should not be possible to inadvertently short bus bars either between themselves or to earth. It should be possible to remove/replace cards from/to electronic equipment without damage and without interfering with the operation of the rest of the equipment or system.

## **2.1.4 Electric Motors**

### **2.1.4.1 General**

All motors should conform to IS: 325-1996 with suitable eyebolts. AC motors should have squirrel cage type rotors. The insulation of all the motors should be of class F but temperature rise during operation should be limited to class B insulation. It should be suitable for operation in damp locations and for occasional contact with corrosive gases/vapors.

### **2.1.4.2 Ventilation and Type of Enclosure**

All motors should be of the totally enclosed fan-cooled type, protection class IP 54 as per IEC: 60144-1963. Cable termination points should be of class IP55. Vertical motors should be provided with a top cover to prevent the ingress of dirt and droplets etc.

### **2.1.4.3 Terminal Boxes and Earthing**

The terminals, terminal boxes and associated equipment should be suitable for terminating the power cables. The terminal boxes should be of ample size to enable connections to be made in a satisfactory manner. For earthing purposes, each motor should have adequately sized bolts with washers at the lower part of the frame. In addition, each terminal box should contain one earthing screw.

### **2.1.4.4 Motor Voltages and Power Ratings**

The service voltages and corresponding power ratings for electric motors to be used should be as follows:

Motors up to 1 kW

- Service voltage : Single-phase AC 240 V, 50 HZ
- Mode of starting : Condenser

Motors above 1 kW and up to 75 kW

- Service voltage : 3-phase AC 415/240 V, 50 HZ
- Mode of starting : Direct-on-line (DOL)

Motors intended to work on the D.C. System

- Service voltage : As per battery voltage
- Mode of starting : Resistor

### **2.1.4.5 Rating**

The rating of the motors should be adequate to meet the requirements of its associated driven equipment. The service factor, being the ratio of the installed motor output to the required power at the shaft of the driven machine at its expected maximum power demand, should be applied as follows:

<u>Power Demand of Driven Machine</u>	<u>Service Factor</u>
Up to 5 kW	1.2
More than 5 kW	1.1

A.C. motors should be capable of operating continuously under rated output conditions at any frequency between 95% and 105% of the rated frequency and/or with any voltage variation between 90% and 110% of the nominal voltage. A transient over voltage of 130% of the nominal voltage should be sustained.

The motors should be capable of maintaining stable operation when running at 70% nominal voltage for a period of 10 seconds. The pullout torque for continuously loaded motors should be at least 160% of the rated torque and for intermittently loaded motors 200% of the rated torque.

D.C. motors should be capable of operating continuously under rated output conditions at any voltage between 90% and 110% of the nominal voltage with a fixed brush setting for all loads. The speed drop between no-load and full-load should not exceed 10% of no-load speed.

#### **2.1.4.6 Starting**

A.C. motors should be designed for direct on-line starting. They should be capable of being switched on without damage to an infinite busbar at 110% of the nominal voltage with an inherent residual voltage of 100% even in phase opposition. For starting the motors from the individual main and auxiliary bus bars, a momentary voltage drop of 20% referred to nominal voltage should be taken into consideration. With 85% of the nominal voltage applied to the motor terminals, each motor should be capable of accelerating its associated load to full speed with a minimum accelerating torque of 5% of full load torque.

The maximum starting currents (without any tolerance) should not exceed the following values:

- 5 times of rated current for L.V. motors rated 100 kW or above
- 2 times of rated current for D.C. motors (by means of starting resistors)

Generally, all motors should be able to withstand five cold starts per hour, equally spaced. Each motor should be capable of withstanding three successive starts under the same conditions or once every fifteen minutes without detrimental heating. Motors for frequent automatic starting should have an adequate rating.

#### **2.1.4.7 Bearings**

As far as possible, the motors should have sealed ball or roller bearings lubricated for life. All other motors with ratings of about 1 kW and above should be equipped with lubricators permitting greasing while the motor is running and preventing over-lubrication. Additionally, the bearings should be fitted with grease nipples permitting the use of a universal grease gun. Vertical motors should have approved thrust bearings.

#### **2.1.4.8 Terminal Boxes and Earthing**

The terminal leads, terminals, terminal boxes and associated equipment should be suitable for terminating the respective type of cables as specified in these General Technical Specifications and in the Particular Technical Specifications.

#### **2.1.4.9 Noise-Level and Vibrations**

Under all operating conditions, the noise level of motors should not exceed 75 dB (A) at any place 1.0 m away from operating equipment. All motors should be statically and dynamically balanced. The vibration amplitude should not exceed values specified in IS 4729.

#### **2.1.4.10 Tests**

Each motor should be factory tested and should undergo a test at site. The following tests should be performed under full responsibility of the Contractor.

Workshop Tests:

- Measurement of winding resistances
- No-load and short-circuit measurements
- Measurement of starting current and torque
- Efficiency measurement (type test)
- Heat test run
- Dielectric test
- Measurement of insulation resistance

#### **2.1.5 Starters and Contactors**

A.C. motors should be designed for direct on-line starting. They should be capable of being switched on without damage to an infinite bus bar at 110% of the nominal voltage with an inherent residual voltage of 100% even in phase opposition. For starting the motors from the individual main and auxiliary bus bars, a momentary voltage drop of 20% referred to nominal voltage should be taken into consideration.

With 85% of the nominal voltage applied to the motor terminals, each motor should be capable of accelerating its associated load to full speed with a minimum accelerating torque of 5% of full load torque.

The maximum starting currents (without any tolerance) should not exceed the following values:

- 5 times of rated current for L.V. motors rated 100 kW or above
- 2 times of rated current for D.C. motors (by means of starting resistors)

Motor starters and contactors should be equipped with short circuit protection and local disconnecting devices. The control circuit voltage should be obtained from a 415/240 V isolating transformer with primary circuit breaker and secondary fuse. The secondary winding of this transformer should be grounded. The operating coils of the contactor should be connected between the grounded side of the transformer and the control contacts.

Starters and contactors should comply with IEC 60947 and be suitable for direct on-line starting, uninterrupted electrical duty, and capable of 30 operations per hour. They should be installed in ventilated enclosures for indoor installation and weather proof enclosures for outdoor installation. The enclosures should be complete with locks, cable sealing boxes, conduit entries, cable gland plates, bus bars, internal wiring, terminal boards, etc. as required by the duty of the starter.

Thermal type overload and phase failure relays should be supplied with starters for motors of 7.5 kW or greater. For motors of less than 7.5 kW, suitable rated 3-phase thermal overloads may be provided. Ammeters to read current in one phase should be provided for motors above 7.5 kW.

#### **2.1.6 Moulded Case Circuit Breakers**

All moulded case circuit breakers should be of 2 or 3-pole type as required, with requisite short time rating having thermal time delay and instantaneous trips with "On-Trip-



Off", indicating/operating mechanism. Circuit breakers used in combination type motor starters or contactors should have the operating mechanisms interlocked with the starter or contactor cover so that the cover cannot be opened unless the circuit breaker is open.

### **2.1.7 Cubicles and Control Panels**

Cubicles and control panel enclosures should be of sheet steel with minimum thickness of 1.5 mm, vermin proof, rigid self-supporting construction and supplied with channel bases. Cubicles should be fitted with close fitting gasketed and hinged doors capable of being opened through 180 deg. The doors of all cabinets/panels should be provided with similar integral lock.

### **2.1.8 Instrumentation and Control Equipment**

#### **Design Criteria**

Shielded cables should be provided for the control and supervisory equipment where required.

#### **Measuring Systems**

Electric measuring signals of 4-20 mA should be transmitted to the control room for essential or regulating circuits. Measuring signals for indicating purposes will be 4-20 mA. Measuring ranges of indicators, transducers, etc. should be selected in such a way that the rated value of the measured magnitude covers approx. 75% of the range.

All local instruments should, as far as practicable, be mounted vibration free to allow good reading. Wherever required, damping elements should be used. Corresponding systems should be grouped together in local panels.

### **2.1.9 Pressure Measurements**

Pressure gauges should be shock and vibration-proof (preferably by filling with glycerin) and the movement should completely be made of stainless steel. The casings should be dust and watertight and be made of stainless steel. The adjustment of the pointer should be possible by means of an adjustment device without removing the pointer from its axle.

Each gauge, pressure switch and transmitter for absolute or differential pressure should be equipped with a pressure gauge isolating valve including a test connection of the screwed type M20 x 1.5 mm so that such device can be removed without any disturbance of the plant operation. If the pressure is pulsating, the devices concerned should be connected via flexible tubes or other pulse-absorbing means.

The error for pressure transmitters should be limited to  $\pm 0.5\%$ .

### **2.1.10 Level Measurements**

The liquid level measurements in reservoirs and tanks with atmospheric pressure should be made by means of capacitance measurement type or any other appropriate type. The errors should not exceed  $\pm 1.0\%$  of the total measuring range.



### **2.1.11 Electrical Measurements**

All Electrical instruments should be of flush mounted design, dust and moisture-proof. A.C. ammeters and voltmeters should have digital type system of not less than 1.5 accuracy classes. D.C. measuring instruments should also be digital type of the same accuracy. Watt meters should be suitable for unbalanced systems and accuracy of energy meters should be of 0.2 % accuracy class.

All indicating instruments should generally withstand without damage a continuous overload of 20% referred to the rated output value of the corresponding instrument transformers. Ammeters should not be damaged by fault-currents within the rating and fault duration time of the associated switchgear via the primaries of their corresponding instrument transformers. All instruments and apparatus should be capable of carrying their full load currents without undue heating. Means should be provided for zero adjustment of instruments without dismantling.

When more than one measured value is indicated on the same instrument, a measuring point selector switch should be provided next to the instrument and should be engraved with a legend specifying each selected measuring point.

All instruments mounted on the same panel should be of same style and appearance.

### **2.1.12 Position Measurements**

Position transmitters for continuous position indication and measuring transducers should have an output current of 4-20 mA and aux. supply voltage (if required) 24 V D.C.

### **2.1.13 Limit Switches**

Limit switches should be mounted suitable for easy adjustment and for rigidly locking in position after being adjusted. They should be of heavy-duty rating and have two changeover contacts suitable for station DC voltage operation proximity switches may be preferably used for this purpose.

## **2.2 General Consideration for Mechanical Auxiliaries**

### **2.2.1 General**

The mechanical items of Works of the auxiliary systems electrical including installations should generally fulfill the requirements as given below. All components should be of reliable design.

#### **2.2.1.1 Bolts, Screws, Nuts etc.**

All bolts, studs, screws, nuts, and washers should be as per ISO metric system. Mild steel bolts and nuts should be of the precision cold forged or hot forged type with machined faces parallel to one another. All bolts and studs which will be subject to high stress and/or temperature should be of high tensile material with nuts of appropriate material.

Fitted bolts should be a driving fit in the reamed holes and should have the screwed portion of a diameter such that it will not be damaged during driving. They should be properly marked in a conspicuous position to ensure correct assembly at site.

All parts (other than structural steel work) bolted together, should be spot faced on the back to ensure that nuts and bolt heads bed down satisfactorily. Mild steel nuts and bolts

should be Zinc or Cadmium plated. Stainless steel bolts, nuts, washers and screws should be used for holding renewable parts in water or when exposed to high humidity.

#### **2.2.1.2 Seals**

Rubber seals should be made of synthetic rubber suitable for particular application and should be designed in such a manner that they are adjustable, water tight and readily replaceable. Seals should be manufactured by moulding process and not extruded. All adjusting screws and bolts for securing the seals and seal assembly should be of non-corrosive stainless steel.

#### **2.2.1.3 Oils and Lubricants**

Different types of oils, lubricants, etc. should be subject to the written approval of the Engineer. Unless otherwise stated in the Particular Technical Specifications, the oil or grease for bearings, pressure oil systems, transformers, etc., including the necessary quantity for flushing and quantity for first oil change with 20% extra should be obtained.

### **2.2.2 Piping, Fittings, Valves and Gates**

#### **2.2.2.1 General**

All required piping should be furnished complete with flanges, joints, expansion joints, gaskets, packing, valves, drains, vents, pipe suspensions, supports, etc. Flanged joints or connections should be provided only as required for transport, installation or for dismantling and reassembly. Standard metric flanges and connections should be used for all pipe works. Adequate clearance should be given to parallel pipes to allow for easy maintenance without disturbing other lines. All overhead piping should have a minimum clearance of 2.1 m from operating floors and platforms.

All pipes should be supported/restrained/anchored in order to prevent any undue localised stress and deflection/sagging anywhere along the piping length due to the applied forces/moments. For the above purpose standard support attachments such as clamps, saddle plates, braces, angles/cleats, guides etc. and support components such as hangers, rods, turn buckles, spring boxes etc. should be used.

#### **2.2.2.2 Materials of Pipes & Fittings**

Water, air and drain piping less than 25 mm nominal bore should be of galvanised heavy grade to IS 1239, Part-I or equivalent standards steel pipe. Pipes equal to or greater than 25 mm nominal bore should be galvanized heavy grade to IS-1239, Part I/IS-3589 or equivalent.

Oil piping greater than 25 mm nominal bore should be of seamless high quality steel pipe conforming to IS-1239 or API-5L GR.B or equivalent grade as per process requirement, whereas pipes less than 25mm bore should be of stainless steel.

Steel pipes of diameter 100 mm and above for a pressure upto PN 10, may be used in welded type. The minimum wall thickness of pipes should be the "normal" or "standard" wall thickness as per applicable standards.

#### **2.2.2.3 Pipe Work Fabrication**

Steel pipe work smaller than 25 NB and for operating pressure more than PN 10 should be joined by screwed fittings and pipe work for 25 NB and over should be joined by welded

flanges. Pipe work for operating pressure up to PN 10 may be joined by screwed fittings up to 50 NB size. TIG welding must be used for fabricating pipe work.

#### **2.2.2.4 Pipe Work Cleaning**

Oil pipe work internal bores should be chemically cleaned and passivated prior to use. Water, air and drain piping should be blown through with high pressure air and flushed with water prior to use.

#### **2.2.2.5 Pressure Testing**

All pressure piping should be pressure tested at a pressure 50% greater than maximum operating pressure after erection and cleaning but before painting at site. The test pressure should be maintained without loss for half an hour.

#### **2.2.2.6 Painting**

All steel piping should be painted on the exterior to prevent rusting. The paint treatment should be of the same system as used for the turbine exterior. Colour coding of pipe work should be adopted as per applicable Indian Standard. Paint damaged during erection and commissioning should be repaired prior to handing over the plant.

#### **2.2.2.7 Protection for Transport and Storage**

Oil piping should have a protective coating applied to prevent corrosion occurring during transport and storage. The ends of the pipe lengths should be plugged to prevent ingress of water.

#### **2.2.2.8 Valves & Gates**

Generally, valves should be leak-proof in either flow direction (except for non-return valves) when the nominal pressure is applied. All valves with design pressures higher than PN10 and diameters larger than DN100 should be workshop-tested for tightness and soundness of materials. Valves should close clockwise and be provided with position indicators/marks on hand wheel. The drive units of motor-driven valves should also be provided with hand wheels for manual operation. To facilitate operation, large valves and gates should be provided with by-pass lines for pressure balancing, if required. Valves spindles and pins should be of stainless steel, spindle nuts and bushes of bronze, the body of cast steel. No valve in cast iron body will be accepted.

All pressure reduction valves; safety valves and similar components should be workshop-tested.

### **2.2.3 Mechanical Instruments**

All mechanical parts of instruments should be suitably protected against shocks and vibrations, heat, humidity and splash water, etc. Pressures gauges should be provided with a damping liquid, e.g., glycerin, to compensate vibrations. Pressure gauges without damping means should not be normally permitted.

### **2.2.3.1 Pumps: Materials of the main parts of pumps should be:**

- Casing            Cast steel
- Impeller        stainless steel
- Shaft            stainless steel
- Sleeves         stainless steel
- Wear rings     bronze
- Keys            stainless steel
- 

The capacity of the driving electric motor should be 15 % higher than the maximum power required by the pump at any operation point. The overall pump-motor efficiency for the specified rated head and discharge should not be less than 60%. The pumps should withstand corrosion and wear by abrasive matters within reasonable limits. Shafts sealed by packing glands should be fitted with sleeves. Pump seals should be replaceable without extensive dismantling of the pump. Leakage water should be directed to suitable drainage facilities.

### **2.2.3.2 Miscellaneous Metal work**

Except where otherwise indicated elsewhere in the Particular Technical Specifications, the Supplier should supply the following:

- i. All platforms, ladders, guards, handrails of tubular construction and hatch covers necessary for easy and safe access to works.
- ii. Safety guards at each point where normal access provision would permit personnel to come within reach of any moving equipment.
- iii. All covers for pipe work, cable trenches and access hatches, required for completing the floors around and over the equipment will be supplied and installed. Unless otherwise approved, floor chequered plates should be of an angular pattern.

## **3. ELECTRICAL AUXILIARIES**

### **3.1 Auxiliary Power Supply System**

#### **3.1.1 General**

Station service power supply system capacity includes supply of power to following

- a. Unit and station auxiliaries i.e. governor oil pumps, cooling water pumps, transformer cooling fan, sump pumps, air compressors, battery chargers, ventilation and air conditioning equipment
- b. Dam/weir bye pass etc. auxiliaries
- c. Lighting of the project and adjacent area
- d. Colony lighting (if required)
- e. Uninterrupted power supply

#### **3.1.2 Design Criteria**

- a) Station service power supply system should have a minimum of two full capacity redundant power sources
- b) Service should not be interrupted by system disturbances.
- c) Service continuity be maintained under all conditions.

- d) There should be provision for starting the station from cold.
- e) First cost, maintenance cost and operating cost should be low.
- f) Safety of personnel, simplicity of operation and ease of maintenance be ensured.
- g) Provision of black start in emergency
- h) Source of Power
  - i. Transformer connected to generator leads
  - ii. Main station buses through house transformers
  - iii. Direct supply from another station
  - iv. House station service generator – Diesel generator for black start in emergency

### **3.1.3 Auxiliary Power Supply System for SHP Interconnected with the Grid**

The design of the auxiliary power supply system of small hydroelectric power plants may vary significantly depending on consideration of a combination of factors including, but not limited to:

- a) The degree of importance of the generator or generators
- b) The number of main transformer to be installed
- c) The number and availability of power sources to the plant
- d) The availability of necessary electrical and mechanical auxiliary systems

### **3.1.4 Auxiliary Power Supply System for SHP**

#### **3.1.4.1 A Single Power Supply System**

This is recommended for a single unit plant non-critical plant whose loss of generation can be tolerated, and which would suffer no harm due to loss of auxiliary systems. A typical single line diagram is shown in Fig 1. When the unit is feeding power into the power system, it also feeds plant AC station service. If the generator in Fig 1 is out of service, station service can be fed from the transmission line. If the main transformer is out of service, station service may be fed from the generator, with the isolating switch open, provided the generator is synchronous type and hydraulic conditions permit stable operation at low loads.

The flexibility for restoring auxiliary AC supply can be of prime importance if there are critical loads that must be energized quickly. Examples of such loads are sump pump, spillway gates, and head gate motors. The need for rapid restoration of station service power may justify a stand-by source such as a small diesel engine generator or a separate feed from the utility.

#### **3.1.4.2 Multiple Auxiliary Supply System**

In the case of plants with multiple auxiliary supplies, the single line diagram would typically be as in Fig 2. Emergency power supply is obtained from grid substation. Fig. 3 shows Auxiliary power supply for SHP in Bihar, where two units are shown feeding station service. The second supply could alternatively be obtained from a separate utility connection rather than a second generator. Another possibility for station service supply is by provision of an emergency generator connected to the plants distribution system. The station service supply configuration will depend on the degree of reliability of station.

For Micro hydro auxiliary power refer AHEC Micro hydro quality standards.

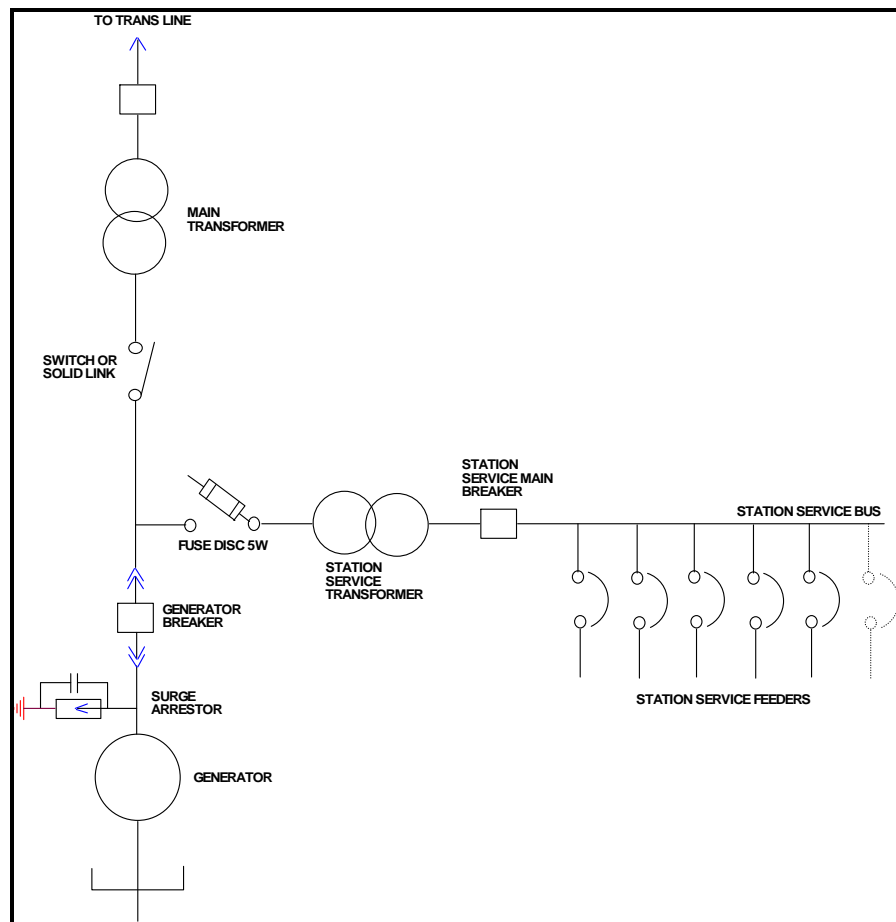
### 3.1.5 Selection of Auxiliary power AC Switchgear and Control Gear

#### 3.1.5.1 General Design Consideration

The electrical items of Works of the auxiliary systems including mechanical installations should generally fulfill the requirements as given in Para 3.1.2. All components should be of reliable design.

The power supply and control cables should be laid up to the common terminal blocks. Various control/protection devices and instruments should be uniform, interchangeable and connected as per system requirement.

Ratings of main electrical works as selected or proposed, whether originally specified or not, should generally include a safety margin of 10%. Short circuit calculations, de-rating factors, etc. should be carried out and taken into consideration for design.



**Fig 1: Typical System for Single Unit/Mini SHP**

Short-circuit calculations should be evaluated and every electrical component should withstand the maximum stresses under fault conditions, for fault levels and durations obtained under the worst conditions, e.g., upon failure of the corresponding main protection device and time delayed fault clearing by the back-up protection device.

All Works should be suitable for the prevailing climatic conditions and insensitive to any signals emitted by wireless communication equipment.

### **3.1.5.2 Switchgear**

The high voltage switchgear in power station for 3.3, 6.6 and 11 kV is almost universally specified as air-break switchgear. High degree of safety of air-break switchgear, suitable performance characteristics and high degree of availability combine to make it so acceptable for the job. The fire fighting equipment can, therefore, be dispensed with. Further absence of current chopping reduces the over voltages in the system and minimizes outages due to insulation failures. Withdraw able type, cubicle mounted, solenoid operated from the battery is usually specified to be provided. A total opening of approx. 5-8 cycles is usually satisfactory for protection of equipment and for maintenance of system stability under fault conditions.

### **3.1.6 Auxiliary Transformers**

Epoxy cast/resin encapsulated air cooled transformers conforming to IS: 11171-1985 and IEC: 60076-11:2004 are recommended. These can be located inside the powerhouse. Oil filled auxiliary transformer will be required to be placed in outside switchyard along with main transformers requiring long cables; fire protection arrangements etc. for fire hazards transformers.

## **3.2 D. C. Auxiliary Power System**

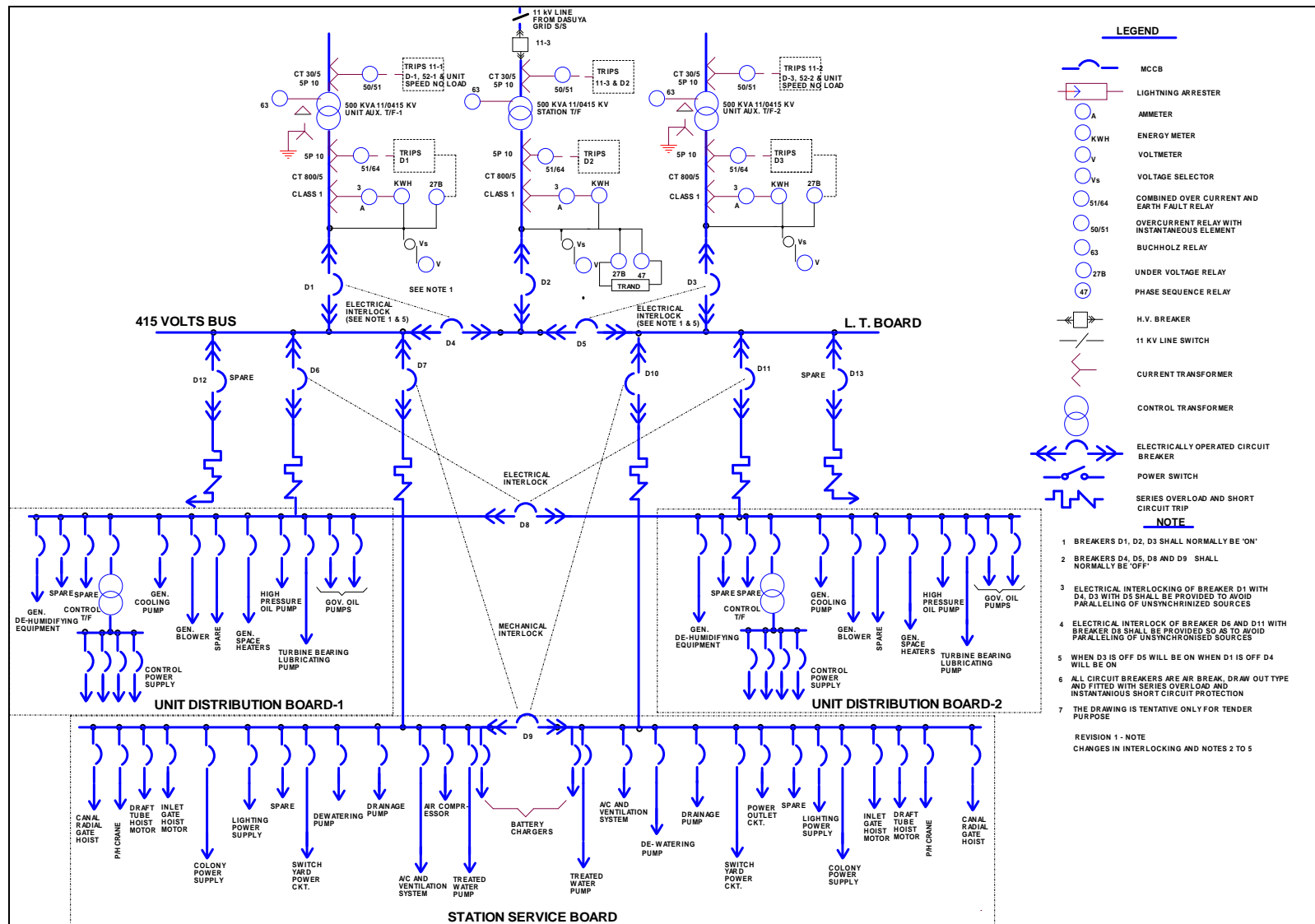
### **3.2.1 General**

Direct current system in hydro generating stations and step up sub station is one of the most crucial electrical systems in a hydro plant because it provides power to critical controls, protective relays and uninterrupted power system (UPS) associated with computers that control plant operation and is provided for following functions.

- a) Supply to trip coils and closing coils of switchgear for switching operations.
- b) Indication: Indicating lamps, facias, semaphores, alarm and annunciation etc. For energizing the holding and operating coils in control and interlock schemes, and in protection schemes.
- c) Supervisory control and data acquisition system (SCADA)
- d) For power supply to communication equipments
- e) Emergency lighting
- f) Generator exciter field flashing – may use rectified station service AC supply system

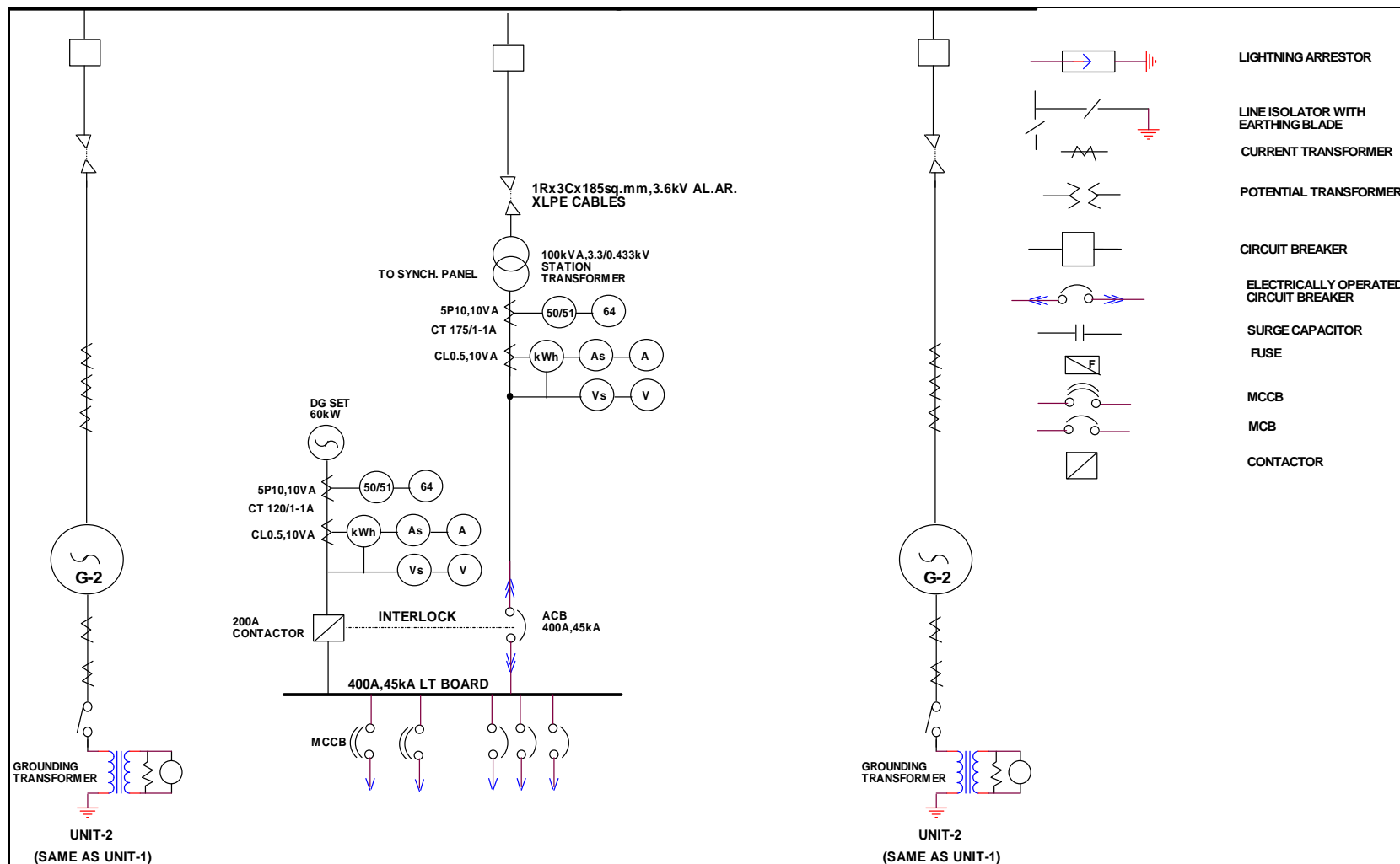
The system consists of a storage battery with its associated eliminator type chargers, providing the stored energy system required to ensure adequate and uninterruptible power for critical power plant equipment. The battery and battery circuits should be properly designed, safeguard maintained and the requirements should be carefully estimated to ensure adequate battery performance during emergencies.

AC supply from station service or generator leads can be used for this purpose if the cost of DC system cannot be justified.



**Fig 2 : Typical Auxiliary Supply System for Multiple SHP**





**Fig 3 : Typical Small Hydro Scheme (2 x 1000 kW)  
(Auxiliary Power System)**

### **3.2.2 Batteries and Battery Chargers**

#### **3.2.2.1 Type**

Table-1 list commonly used battery types and their normal expected life, approximate number of full discharges, ampere-hour range, approximate cost range, frequency of use, advantages and disadvantages. Latest applicable Indian standard specification mentioned in the table-1 and be referred for confirmation.

Type of battery or batteries generally used in hydro generating stations are of the lead-acid type in vented cells or a sealed cell.

Following types of lead acid batteries are commonly used in power plants.

- i. Tubular positive plate with pasted negative plate: and
- ii. Plante positive plate with pasted negative plate.
- iii. Valve regulated lead acid Sealed batteries (VRLA)

Plant positive plate batteries are costly and preferred for large hydro station above 5 MW as they have longer life and these cells are suited for applications requiring supply of large currents for short durations as required in unattended stations whereas the cells with tubular positive plates are suitable for the supply of smaller currents for medium to long durations. Use of glass containers is preferable over the other types as these facilitate checking up of sedimentation, electrolyte level, condition of plates, separators etc.

#### **3.2.4 Construction Features**

Each battery should have a static battery charger, rated to fully recharge the battery from a completely discharged condition in not more than ten (10) hours in boost charging mode. Each battery charger should be capable of float charging the batteries while supplying at normal voltage. Voltage regulators shall have following facilities.

- (a) Manual selection facility for battery charging mode i.e. whether trickle or boost.
- (b) Automatic and manual control of output voltage and current. Selector switch should be provided for auto/manual selection. Auto to manual change over should not result in any harmful surges.
- (c) Effective current limiting feature and filters on both input and output to minimise harmonics, RFT (Radio frequency transients), EMT (Electro magnet transients) etc.
- (d) When on automatic control mode during trickle charging, the charger voltage should remain within 1% of set value for maximum permissible voltage, frequency and combined voltage and frequency variation on feeding system and DC load variation from zero to full load.
- (e) Degree of protection should be IP: 42. For chargers located in air conditioned areas, same may be IP: 31.
- (f) The rectifier shall utilise diode/ thyristors and heat sinks rated to carry 200% of the load current continuously. Temperature of heat sink shall not be permitted to exceed 85 deg. C duly considering the maximum charger panel inside temperature.

- (g) Rectifier fuse and RC surge suppressor should be provided
- (h) Ripple content to be limited to 1% peak to peak.
- (i) All inter cell connectors and terminals should be fully insulated/shrouded.

### **3.2.5 Battery Room**

#### **3.2.5.1 SHP Plant above 5 MW**

A separate room with lockable doors provides adequate protection against accidental contact or malicious tampering. The room or area should be ventilated in such a manner that exhaust air from the room does not enter any other room in the plant. If necessary, heaters should be provided to obtain full rated performance out of the cells. The cells should be mounted in rows on racks permitting viewing the edges of plates and the bottom of the cells from one side of the battery. The tops of all cells should preferably be of the same height above the floor. The height should be convenient for adding water to the cells. Tiered arrangements of cells should be avoided. Space should be provided permitting removal of a cell from its row onto a truck without reaching over any other cells. The lighting fixtures in the room should be of the vapor-proof type, with the local control switch mounted outside by the entrance to the room. Battery charging equipment and controls should not be located in the battery room.

#### **3.2.5.2 SHP Plant Up to 5 MW**

At plants smaller than 5 MW, a ventilated battery room is not always required except for a flooded liquid electrolyte (lead acid) battery, because the small ampere-hour size means that the battery produces a minimal amount of hydrogen gas during charging. Furthermore, typically only qualified personnel (usually the operators) have access to the powerhouse. Therefore, a separate battery rooms is not required.

For plants smaller than 5 MW “hydrogen produced” calculations are performed to verify whether a ventilated battery room is necessary. Elements of these calculations are:

- i) Air volume in the powerhouse
- ii) Number of air changes per hour based upon the heating, ventilating, and air conditioning (HVAC) system design; and
- iii) Amount of hydrogen gas released during charging. (This amount is based upon the ampere hour size of the battery, the float charging voltage selected, and the type of battery to be charged)

The calculations should confirm that, in the worse case scenario, the hydrogen production of the batteries will be less than 1 percent of the total air volume in the powerhouse. Normally, a minimum of 3 percent hydrogen by volume is required before any explosive mixture is possible.

For very small SHP and micro hydro station AC may be used.

### **3.2.6 Battery Voltage and Number of cells**

Rated voltage of the DC control supply for electrical installations can be selected out of the fairly standardized values of 110, 48 and 24 volts. Higher voltage leads to more

economical configurations as the total load of the DC system, lengths of circuits and number of DC cables increases. Usually 110 V turn out to be the optimum choice for SHP above 5 MW capacity. For smaller plant 24 V may be provided. For micro hydro interconnected with grid –12V UPS system may be sufficient for emergency lighting and PC.

The voltage of a lead acid cell being 2 volts per cell, the number of cells in the battery would be half of the rated DC voltage adopted.

A separate battery for communication equipment is normally provided. The choice of communication battery, voltage has to be made according to voltage rating of the communication equipment already existing or that to be installed. In the absence of any precedent 24 volts is normally found to be optimum for most installations.

### **3.2.7 One or Two Battery System**

Selection of a one-or two – battery system will depend not only on comparative costs of different battery sizes and combinations, including circuits and charging facilities, but consideration of maximum dependability, performance, and flexibility during periods of plant expansion.

### **3.2.8 D.C. Loads Classification**

Recommended procedure for determining battery rating is outlined in “CBIP Technical Report No. 79 and IEEE 485.

These standards classify the system load into following categories.

- a. Momentary loads
- b. Continuous load
- c. Emergency light load: Duration of light load may be required for duration of 1 – 12 hours. Modern computerized control system require uninterruptible power supply (UPS) system and emergency power is supplied from these UPS system.

Commonly battery types shown in table 1 are used in hydro power stations.

### **3.2.9 Battery Accessories are generally as follows**

- i) Cell testing voltmeter
- ii) Hydrometer
- iii) Thermometer
- iv) Acid jugs for topping up of the cell
- v) Rubber gloves
- vi) Rubber apron
- vii) Tool box
- viii) Battery log books
- ix) Bridging clamps for cutting out individual cell in the event of defect
- x) Protective goggles

**Table 1: Type Commonly Used Battery Types in Hydropower Plants**

S. No.	Type	Normal Expected Life <sup>1</sup> Years	Approximate Number of full discharge	Ampere Hour capacity range in SHP	Relative Cost of battery	Advantages	Disadvantages	Remarks
<b>Flooded Liquid Electrolytic</b>								
1.	Lead Acid Flat pasted cells IS: 6304	<b>See note -1</b>	1000 – 1200	6 -4000	Base	Capable of providing a significant number of full discharges over 20-year life	Frequent water addition, high hydrogen emission, needs monthly equalizing charge	Only recommended for SHP below 5 MW in separate ventilated rooms
2.	Lead Acid Tubular IS: 1651		500 – 1000	6 - 4000	1.2 x base	Low water consumption, low hydrogen emission, no monthly equalizing charge		Recommended for SHP upto 5 MW and grid substation
3.	Lead Acid Plante IS: 1652		1000 – 1200	6 - 4000	2.0 x base	Can function at room temperature higher than the standard 25 <sup>0</sup> C, longer life		Recommended for SHP above 5 MW
4.	Nickel Cadmium (Ni-Cd) IS: 10918		1200	2.5 – 1000 IS: 10918	3 x base	Low maintenance; longer life, performs well in low temperatures, not damaged by freezing, low self-discharge rate, will not deteriorate in discharged condition, no release of corrosive fumes	Higher cost and at 1.2 volts cell, requires a greater quantity of cells to attain a rating of 125 volt DC. Little historic operation experience	Recommended for SHP at high altitudes and small unattended SHP
5.	Valve Regulated Lead Acid(VRLA) maintenance free batteries IS: 15549		300	200 – 4000	1.4 x base	Does not require water addition, no hydrogen emission	Little historic experience in powerhouses	Recommended for use in powerhouse below 5 MW when separate room is not made

<sup>1</sup>-Lifetime estimates can vary substantially depending on cell/plate construction

For hydro power stations durations taken for computation of battery capacity (as per “CBIP Technical Report No. 79 for attended station) are shown in Table 2.

**Table 2: Durations for computation of battery capacity**

S. No.	Type of load	Where standby battery is provided	Where standby battery is not provided
1	Steady and continuous load	3 hours	6 hours
2	Emergency light loads	1 hours	2 hours

For unattended stations duration may be suitably increased.

### **3.2.10 Safety Consideration**

Standard rack performance criteria should be evaluated to ensure compliance with plant requirements. Seismic considerations and other factors may dictate the need for special racks and special anchoring needs.

### **3.2.11 Battery charging Equipment**

Static charger sets are preferred for battery charging service. For units up to 5MW capacity one boost charger with dual float and for units above 5 MW two sets of boost and float should be provided so one will always be available. The charger capacity should be sufficient for float operation as well as boost charging capability.

### **3.2.12 Float Operation Term**

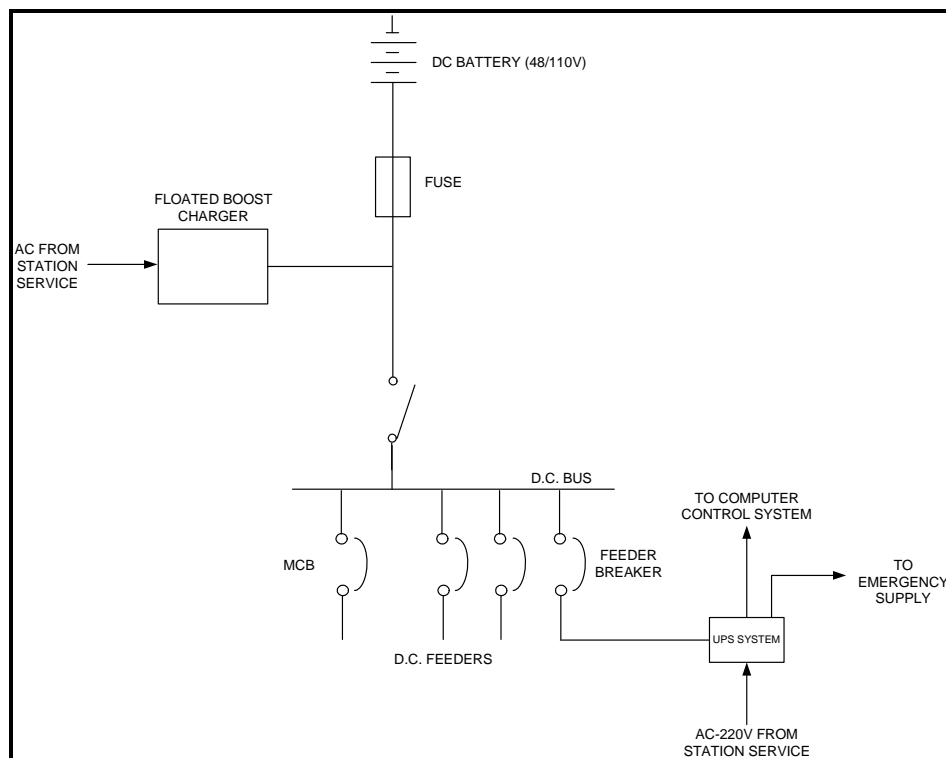
This term applies to the method of operation in which battery remains connected to the load and the charger continuously. Voltage of charger is substantially constant and just higher than open circuit voltage of the battery. To keep the battery in a fully charged condition, the charger sends through the battery charging current of a few milli amperes at a voltage which is sufficient to compensate for local action and leakage losses. The magnitudes of the charging current and the voltage should be recommended by the battery suppliers. The charger also supplies the entire DC load under normal condition.

### **3.2.13 DC Switchgear**

For reliability and flexibility, a DC distribution board with several outlets is preferable as this board provides connection of battery and charger to the various load circuits. Each circuit is protected by a fuse and controlled by a switch or circuit breaker which should be suitable for making and breaking inductive loads at voltages upto the maximum floating voltage and not merely the rated voltage. Cartridge fuses are recommended to be used as back up even when circuit breakers with protective releases are installed. The breakers and fuses should be carefully chosen from the consideration of recovery voltage after interruption of faults. The fuses where used should be properly coordinated to ensure operation even for the farthest faults and each circuit should be properly segregated. The DC switchgear should have short circuit rating equal

to about 10 times the maximum rated current if the associated equipment, without the current limiting feature on, and about 1.1 times, with the current timing feature 'on'. However, with the available standard DC switchgear usually having much higher short circuit ratings (4 kA), the above requirement poses no problem.

**3.2.14** A typical single line diagram with single battery system is shown in Fig 4 which can be used on smaller unit. Fused disconnecting switch may be used instead of circuit breakers. For larger unit above 5 MW 2 battery sets may be provided.



**Fig 4 : Typical DC system for SHP up to 5000 kW**

### 3.3 Uninterruptible Power Supply System (UPS)

Uninterruptible Power Supply System in SHP are required to provide electricity for computerized control and data acquisition system, communication system etc. when normal plant power system fail. As per IEEE: 944-1986 – Recommended practice for application and testing of uninterruptible power supplies for power generating stations; UPS systems are used to provide electricity for essential loads when normal plant power system fails. Loss of power to such loads as the plant computers, communication networks, security system and emergency lights.

UPS system is defined as one designed to automatically provide power without delay or transient during any period when normal power supply is incapable of performing acceptably.

On line static (solid state) UPS system with sine wave output are required. An off line system take about 25 ms for transfer to DC which may impair critical control by computer

system. Normal range of sizes for hydro plant up to 25 MW uninterruptible power supplies is given in Table 3 below:

**Table 3 : Normal range of size of UPS for SHP**

Plat size (MW)	UPS size (kVA)	Remarks
Above 5 - 25 MW	1 – 5 kVA	
Above 0.1 to 5 MW	1 or less kVA	
Micro Hydro	i) Electronic load controller (ELC) may use its own converter and conditioned DC supply system from UPS or otherwise ii) If remote group controlled, PC may be used with its own UPS	i) Use power line conditioner (power supply system) ii) May use standard single PC UPS

### **3.4 Power and Control Cables**

#### **3.4.1 Duty Requirements/Design Criteria**

- A. The cables should be suitable for installation in a tropical monsoon area having a hot humid climate. The reference ambient temperature to be considered for the purpose of this specification is 50<sup>0</sup>C (depend upon site).
- B. The derating factor for the various conditions of installation including the following should be considered while choosing the conductor size:
  - a. Maximum ambient air temperature.
  - b. Maximum ground temperature,
  - c. Depth of laying wherever applicable
  - d. Grouping of cables.
- C. The allowable voltage drop at terminals of the connected equipment should be maximum 1.0% at full load for choosing the conductor size. In case of squirrel cage induction motors, the cable size should be so chosen that the motor terminal voltage does not fall below 90% of the rated voltage, at the time of starting, if the motor is started with a D.O.L.(Direct on line) starter.
- D. The maximum continuous conductor temperature and the maximum allowable conductor temperature during short circuit are taken as 70<sup>0</sup>C and 160<sup>0</sup>C respectively in case of PVC insulated cables and 90<sup>0</sup>C and 250<sup>0</sup>C respectively in case of XLPE insulated cables.
- E. The minimum size of all 11 kV grade power cables and 415 V power cables connected to circuit breakers are chosen taking into account the following factors.
  - i. Fault level due to system contribution.
  - ii. Fault contribution of running motors.



- iii. Expected time up to which motor contribution to fault current persists.
  - iv. Maximum time for fault clearance (i.e. operating time of the backup protection relay plus the time of operation of the circuit breaker.)
  - v. Full load current of the circuit.
- G. The cables should in general comply with the requirements of the latest revision of IS: 7098 (part-11) for the 11 kV grade XLPE insulated cables and IS-1554 (part-1) for the L.T. PVC insulated power and control cables or the relevant IEC Standard. The design, manufacture, installation, testing and performance of the cables, should comply with the latest revisions of IS/IEC/ NEMA/ASTM standard.
- H. For 11 kV cables, conductor screen and insulation screen should both be extruded semi-conducting compound and should be applied along with XLPE insulation in a single operation by triple extrusion process. Method of curing for 11 kV cables should be "Dry curing/gas curing/steam curing". 11 kV cables should be provided with copper metallic screen suitable for carrying earth fault current. For single core armoured cables, the armouring should constitute the metallic part of screening. For 11 kV cables, insulation should be XLPE, while for other cables it should be PVC.
- I. Calculations should be made for selection of cables showing type of cable and conductor size selected voltage drop, temperature rise, under rated load and short-circuit conditions, to meet the design requirement.
- J. Cable schedule showing the various interconnections and also the routing diagram giving details of various openings are requirement to be prepared.
- K. For the sake of reliability, it is required to use only copper conductor cables for the following services:
- i. Excitation systems (Single Core)
  - ii. Battery and battery chargers (Single Core)
  - iii. Inverters
  - iv. All control systems
- L. As far as feasible, separate cables should be provided for circuit of different plant and auxiliaries, for circuits of different voltages, and for circuits used separately. To the extent feasible Power, control and instrumentation circuits should invariably be taken through different routes, which should not be laid together on the same cable tray, otherwise necessary measures should be implemented to avoid the undesirable effects.

### 3.4.2 Range of Cables

- i. Generator- Generator transformer/ Bus Bar connections (used in small hydro plants) should be by armoured power cables of copper conductors with unearthed grade EPR insulation non PVC jacket HD – HOFR (high density- heat, oil and flame retardant).

- ii. 11kV system - Power cable

The cable should be 11 kV grade, heavy duty, stranded, aluminium conductor, XLPE (cross linked poly ethylene) insulated, provided with conductor screening and insulation screening, galvanised steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC of type ST 2 outer sheathed.

- iii. 415 V System

The cable should be 1.1 kV grade, heavy duty, stranded aluminium conductor, PVC type. An insulated galvanised steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC of type ST1 outer sheathed. Cables may be either single or multi-core or both.

- iv. Control cables

The cable should be 1.1 kV grade, heavy duty, stranded copper conductor, PVC type-A insulated galvanised steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC of type- ST1 outer, sheathed Cables may be multi-core; depending upon the circuit requirements or both.

Size of control cables should not be smaller than:

- |                                       |  |
|---------------------------------------|--|
| a. Control circuits                   | 1.5 mm <sup>2</sup> to 2.5 mm <sup>2</sup> |
| b. PT circuits for energy measurement | 1.5 mm <sup>2</sup> to 2.5 mm <sup>2</sup> |
| c. CT circuits                        | 1.5 mm <sup>2</sup> to 2.5 mm <sup>2</sup> |

A summary of recommended cables used in hydro stations is given in table 4.

- v. Co-Axial Cable

Coaxial cable should be steel armoured and should be FRLS type. The cable should have braided tinned copper conductor. The capacitance of the cable is low so as to minimise attenuation in the carrier in the carrier frequency range. The impedance of the cable should be so as to match with the output impedance of the terminals and secondary impedance of the coupling units. The cable should be insulated to withstand a test voltage of 4 kV. Following type of H.F. cables are generally used.

1. Co-axial H.F. cable with 75 ohms impedance (unbalanced)
2. Test voltage in kV – 4 kV RMS for 1 minute
3. Size of conductor – 7 strands/0.4mm

The maximum attenuation at various frequencies is generally as shown in table 5.

### **3.4.4 Cabling**

#### **3.4.4.1 Scope**

The complete cable support system should enable proper laying of all power, control, instrumentation and telephone cables, and should provide necessary mechanical protection, ventilation and segregation for them. All hardware and anchoring arrangement should be provided. All steel members should be hot dip galvanised.

Power and control cables from powerhouse to hydro-mechanical equipment e.g. intake and draft tube gates and from gates to power house are to be properly provided.

#### **3.4.4.2 Design**

Detailed design and calculation should be carried out.

#### **3.4.4.3 General requirements**

No sub zero level cable vault/trenches should be provided below control building/switchgear rooms in main plant and switchyard areas.

Interplant cabling for main routes should be laid along overhead trestles/duct banks/directly buried. However, for tap-offs, same can be through trenches. Directly buried cable, if essential, should not have concentration of more than four (4) cables. Cables in switchyard area from main plant to switchyard control room are laid in duct bank/cable trenches. In switchyard area, cables are laid in RCC concrete trenches.

Cable entry from outdoor underground/cable routes to the buildings, if any should be above the finished floor level inside the building. PCC flooring of built up trenches should be sloped for effective drainage with sump pits and sump pumps.

##### **3.4.4.3.1 Cable trays, support system and pipes**

Cable trays, support system and pipes are as shown in Table 6.

**Table 4: Cables used in SHP**

Particulars	Power cables		Control cables	Trailing cables
	XLPE	PVC		
a) Conductor				
i) Material	Stranded Aluminium wire complying latest edition of I.S. 8130 - 1976		Stranded plain annealed copper	Tinned copper of class 5 of IS:8130
ii)Size	As required Min. 6 sq.mm size		As required, but min. 1.5 sq.mm.	As required, but min. 1.5 sq.mm
Iii)Shape	Circular/ Sector shaped circular only for 3.3 kV cables	Circular/Sector shaped.	Circular	Circular
b) Main Insulation				
i) Material	XLPE	PVC	PVC insulation shall be type I extended PVC 1.1 kV grade & free from voids	Heat resistant elastomeric compound based on ethylene propylene rubber (EPR)
ii)Continuous withstand temperature (deg.C)	90	70	70	90
iii)Short circuit withstand temp. (deg.C)	250	160	160	250
iv)Colour identification	As pre relevant codes and standards			
c) Inner sheath				
All armoured and multicore unarmored cables have distinct extruded inner sheath				
i) Material	PVC	PVC	PVC extended type 6 PVC	Heat resistant elastomeric compound
ii)Colour	Black	Black	Black	Black
d) Armour				
i)Material	Aluminium wire for single core cable and GS wire/flat for multicore cables as per Relevant IS. Minimum Coverage of 90%.		GS wire/flat as per relevant IS. Min. coverage of 90%	Nylon cord reinforcement
ii)Breaking load of joint	95% of normal armour	95% of normal armour		
e) Outer sheath				
i) Material (Polyethylene based halogen free material not acceptable)	PVC	PVC	PVC type 8 PVC with flame retardant low smoke properties. It should not stick to inner sheath & consistent in quality.	Heat & oil resistant & flame retardant heavy duty elastomeric compound
ii)Colour	Black	Black	Grey	Black
iii)Marking	-Cable size & voltage grade (by embossing) -marking "FRLS" @ 5 m (by embossing) -Sequential marking @ 1 m		Grey same as for power cables	Black same as for power cables
f) FRLS properties on outer sheath	Oxygen Index : Min. 29 (As per ASTMD 2863) Acid gas generation: Max. 20% (as per IEC 754-I) Smoke density rating : 60% (as per ASTMD 2843)			
g)Flammability	As per Swedish chimney test F3 as per 8EN 4241475. As per IEC 332 part-3:1992(Category B).			

**Table 5: Max. Attenuation at various frequencies**

S. No.	Frequency in kHz	Attenuation in db/km
1	60	1.4
2	300	3.3
3	500	4.7

**Table 6: Cable trays, support system and pipes**

S. No.	Item	Description
i)	Support system for cable trays	Prefabricated out of sheet steel and fully galvanised flexible type consisting of channels, cantilever arms and associated brackets & hardware, installed at site by bolting or clamping. These should be rigid enough to withstand max. possible loads during and after installation.
ii)	Type of cable trays	Cable tray for power cables are perforated. Separate trays are provided for control instrumentation cables.
iii)	Material of cable trays	Rolled mild steel, min. 2 mm thick for trays and 3 mm thick for coupler plate.
iv)	Finish of cable trays	Hot tip galvanised.
v)	Duct banks (if provided)	Heavy duty GI pipes/heavy duty PE pipes (10% spare of each size, subject to min 1) with suitable water-proof manholes. For corrosive areas, pipes should have anti-corrosion coating both inside & outside.
vi)	Pipe size	Suitable with 40% fill criteria.
vii)	Junction and Pull boxes	Hot dip galvanised sheet steel of 2 mm thickness.
viii)	Cable glands	Nickel-chromium plated brass, heavy duty, single compression type for unarmoured, and double compression type for armoured cables.
ix)	Cable lugs	Solderless tinned copper crimping type.
x)	HT cable terminations and joints	Proven design and type tested as per VDE 0278. Elastimold or equivalent fully insulated moulded terminations are preferred.

### 3.4.4.3.2 Cable Laying

Features of cable laying are as follows:

- A. Cables should be laid on overhead cable trays and supports, pulled through conduits/GI pipes and on racks in built up cable trenches and vertical race ways and clamped with aluminium clamps on walls, ceiling and structures and may be directly buried in ground.
- B. Cable laying should include termination of power and control cables (i.e on both ends of the cables), at equipment terminals, switchgear, control panels etc. All electrical equipments after installation are completed with cable terminal boxes, cables glands, cable trays, lugs and terminal blocks.

- C. All power and control cables are provided with aluminium tag of an approved type, bearing cable reference. Cable routing is done in such way that cables are accessible for any maintenance and for easy identification. Power and control cables are laid in separate cable racks/trays, power cables being on upper most racks/trays. Asbestos sheets are laid beneath power cable where they are running over control cables
- D. The racks/trays, in general, are supported at a distance of 1500 mm on horizontal and vertical run.
- E. Straight through jointing of cables is avoided. Terminations are done by crimping. Heat shrinkable polymeric or tapex type termination kits are to be used for the 11kV XLPE (cross linked poly ethylene) insulated cables.
- F. Buried cables are avoided as far as possible but if necessary it is covered with alternate layer of bricks and sand for mechanical protection. Steel markers are provided at every 20 meters along the cable route.
- H. All cables laid on trays/racks are neatly dressed up and clamped/tied to the tray/rack. Suitable Trefoil clamps are provided for single core cables.

Requirements of cable laying are shown in Table 7.

#### **3.4.4.5 Galvanising**

All cable trays and their fittings are hot dip galvanised after fabrication according to IS: 2629. The galvanising should be uniform, clean, smooth, continuous and free from acid spots.

#### **3.4.4.6 Support and supporting structures**

Angles, flats, channels, hangers, brackets clamps, nuts, bolts and other anchorage material are used for the installation of cables, cable trays, race ways and conduits. All steel members are suitably treated and galvanised or painted with 2 coats of approved paint.

### **3.5 Lighting System**

#### **3.5.1 General Requirements**

A comprehensive illumination system should be provided in the entire project i.e. all areas within the plant boundary. The system should include lighting fixtures, distribution boards, lighting panels, junction boxes, lighting poles, receptacles, switchboards, cables and wires, conduits, poles and masts, etc. The system should cover all interior and exterior lighting such as area lighting, yard lighting, street lighting, security lighting, etc.

**Table 7: Requirements of Cable Laying**

S. No.	Item	Description
1.	Identification tags for cables	To be provided at all terminations, on both sides of wall or floor crossing, on each conduit/duct/pipe entry/exit, and at every 20 m in cable trench/tray or buried run.
2.	Cable tray numbering	To be provided at every 10 m and at each end of cable way & branch connection.
3.	Joints	Joints for less than 250 m run of cable should not be permitted.
4.	Buried cable protection	With concrete slabs; Route markers at every 20 m along the route & at every bend.
5.	Road crossings	Cables to pass through buried RCC hume pipes.
6.	Transformer yard Handling area	RCC trenches to be filled with sand after cable laying
7.	Separation	At least 300 mm between HT power & LT power cables, LT power & LT control/instrumentation cables.
8.	Segregation	<p>All cables associated with the unit should be segregated from cables of other units. Interplant cables of station auxiliaries and unit critical drives should be segregated in such a way that not more than half of the drives are lost in case of single incident of fire. Power and control cables for ac drives and corresponding emergency ac or dc drives should laid in segregated routes. Cable routes for one set of auxiliaries of same unit should be segregated from the other set. Segregation means physical isolation to prevent fire jumping or minimum one hour fire rating.</p> <p>In switchyard, control cables of each bay should be laid on separate racks/trays.</p>
9.	Cable clamping	To be suitably clamped/tied to the tray; For cables in trefoil formation, trefoil clamps as provided required.
10.	Fire protection	Fire proof cable penetration seals rated for one hour when cable passes through walls and/or floors. This can be by suitable block system using individual blocks with suitable framework or by silicon RTV foaming system. In case foaming system is offered, damming board, if used, should not be considered for fire rating criteria. Any of the system used should be of proven type as per BS: 476 (Part-8) or equivalent standard.

### 3.5.2 Illumination Design Criteria

#### 3.5.2.1 General

The illumination system should be designed on basis of best engineering practice to facilitate normal operation and maintenance activities as per IS: 3646 part-II and should ensure

uniform, reliable, aesthetically pleasing, glare free illumination. The design should prevent glare/luminous patch seen on VDU (Visual display unit) screens, when viewed from an angle.

Table 8 gives the recommended values for different parts of power house and switchyard.

**Table 8: Recommended Illumination Values**

S. No.	Particulars	Average illumination level 'Lux'	Limiting Glare Index
1.	Control rooms: Vertical control panels Rear of control panels Control desks Switch houses	200 to 300 150 300 150	19 19 19 25
2.	Battery room	100	-
3.	Carrier room	300	-
4.	Offices and reception	300	19
5.	Cloak rooms	100	-
6.	Workshop/Repair bay	300	25
7.	Test room	300	19
8.	Outdoor switchyard	20	-
9.	Stairs	100	-
10	Corridors	70	16
11	Approach roads	20	-
12	Pathways	20	-
13	Car parks	20	-
14	Conference room	300	19
15	Store room	100	-
16	Cable gallery/floor	50	-
17	AC plant/DG set room	150	-

Out door switchyard average illumination level shall be 50 lux on main equipment and 20 lux on balance area of switchyard. In the out door switchyard, the area covered by transformer/reactor should have 50 lux.

**3.5.2.2** The lighting system of a particular area whether outdoor or indoor should be designed in such a way that uniform illumination is achieved. As far as possible any dark spots should be avoided. This requires careful placing of the luminaries, selection of proper mounting heights and provision of sockets in the marshalling kiosks and mechanism boxes of circuit breakers/disconnects switches for providing supplementary lighting wherever required. In outdoor switchyards, only the equipment/bus bar areas are illuminated. In outdoor area, luminaries should be directed as far as possible towards transformers, circuit breakers/disconnect switches, their mechanism boxes etc., where some operations may be necessary during emergency at night.



- 3.5.2.3** There are several classifications of the types of lighting such as direct, indirect, semi-indirect, diffusion, etc., The types of lighting or the combinations should be so chosen as would provide adequate level of glare-free illumination without creating undesirable shadows.
- 3.5.2.4** Direct lighting system is the most commonly used and it employs open dispersive reflectors, silver glass reflectors and angle reflectors. The simplest form of general diffusion fitting is the plain sphere of opal glass. The spherical form may be modified and any form, which the designer can think of may be used. The efficiency of the general diffusion fitting depends partly on shape but much more on the properties of the diffusing material used.
- 3.5.3.5** The choice of lamps, i.e., incandescent, fluorescent, mercury vapour, sodium vapour halogen etc., depends mainly on the nature of work, the number of hour of utilization annually, the cost of energy and the power available for illumination. Table 3.2 gives different types of lamps and fittings that may be used in different area of a substation.
- 3.5.2.6** Flood light fittings are in essence, projectors with parabolic reflectors. There are two types of floodlights: the wide beam type and the narrow beam type. Wide beam type is suitable where accurate control is not necessary and the light is projected only over a short distance. The narrow beam type is used where light is required to be projected over longer distances.
- 3.5.2.7** The foremost criterion in the design of illumination system of indoor area such as control room, workshop, repair bay, offices, etc., is that illumination at the working height throughout the area should be as uniform as possible so as to avoid eye fatigue. In practice, complete uniformity of illumination is difficult to achieve and a ratio of the minimum intensity to the maximum equal to about 70 percent is usually considered acceptable.
- 3.5.2.8** Energy conservation requirement. has to be kept in view while selecting type of lamp and type of fitting. While designing the lux level requirement, utilization coefficient factor may be considered to take care effect of dust, pollution etc. on reflectors of lighting fixtures.

The night time lighting of exterior areas is necessitated by operational requirement, security or decorative purposes or a combination of these. It is used for illuminating outdoor switchyards transformer yards, approach roads to substations, etc., Use of flood lights has been in practice for illumination of switchyards. However, flood lights generally cause glare, if not properly positioned and mounted at proper heights. As the lumen output of mercury/sodium vapour lamps is quite appreciable as compared to incandescent lamps, flood light units having mercury/sodium vapour lamps with medium and wide angle coverage, mounted at suitable heights are preferred. If the flood light is mounted at a height of 6 to 10m it would be away from the normal vision angle ( $8^\circ$ ) of a man approaching it and therefore, there would be no problem of glare. If the design of the flood lighting is followed in an orderly fashion, it is easy to obtain uniform illumination in the outdoor switchyard. The spillover light from flood lights provided in the switchyard is generally sufficient for fence lighting. Separate fence lighting is provided only in exceptional cases. Light fittings in the switchyards are mounted on substation structure/ lighting masts. Typical lamps and fittings generally provided in some identified areas are given in Table 9

**Table 9: Typical Lamps & Fittings in Some Identified Areas**

S. No.	Particulars of area	Type of lamps	Type of fittings
1.	Unloading-cum-repair bay	Mercury vapour sodium	High bay
2.	Store rooms, workshops	Fluorescent	Industrial
3.	Control room, offices	Fluorescent	Decorative
4.	Battery room	Fluorescent	Acid proof, Industrial
5.	Compressor room etc.,	Fluorescent	Industrial
6.	External lighting on building	Mercury vapour sodium	flood light
7.	Outdoor switchyard	Mercury vapour sodium vapour	flood light
8.	Fence lighting	Mercury vapour sodium vapour	Post type water tight, flood light
9.	Roads	Mercury vapour sodium vapour	Post type water tight street light fittings

**3.5.2.9** The purpose of street lighting in substations is to promote safety and convenience on the approach roads, service roads and side walls inside switchyard, etc., The aim should be to provide conditions of visibility adequate for accurate, certain and comfortable seeing.

### **3.5.3 Emergency Supply**

Power supply should be fed from 415/240 V normal ac power supply, station service board, and UPS system for emergency lighting. Lighting panels should be located at different convenient locations for feeding various circuits. These panels should be robust in construction with lockable arrangements and MCB for different circuits.

Emergency lighting should be provided in following areas :

- a) Generator room - 20 lux
- b) Operating floors of turbine hall - 20 lux
- c) Switchgear room - 15 lux (min. one lighting fixture between two rows of switchgear)
- d) Control and relay room - 100 lux with one power 5 Amps
- e) Cable spreader room - at least 10% of illumination (min. one lighting fixture at convenient location.)
- f) Battery room - at least 10% of illumination
- g) Exit points and stair cases - One light fixture
- h) All other strategic locations for safe personnel movement during any emergency.

DC lighting should come on automatically on failure of normal AC supply. In off-site areas/buildings DC lighting is to be provided through self-contained 4-hour duration fixtures located strategically.

Lighting panels, fixtures, receptacles, poles, masts, distribution boards, switch boxes, conduits, junction boxes etc. should be properly installed and earthed.

All outdoor fixtures should be weather proof type. Fluorescent fixtures, installed in other than control room areas should have electronic ballasts. For control rooms, the ballasts should be copper wound inductive, heavy duty type, filled with thermo-setting insulating moisture repellent polyester.

All luminaries and their accessories and components should be of the type readily replaceable by the available Indian makes. All fixtures and accessories should be of reputed make and non-corrosive type. Acrylic covers/louvres should be of non-yellowing type.

The constructional features of lighting distribution boards should be similar to AC/DC distribution boards described elsewhere. Outgoing circuits in PLS should be provided with MCBs of adequate ratings.

Wiring should be by multi-stranded PVC insulated colour code cable laid in GI conduits. Wiring for lighting circuits of AC, and DC systems should be run in separate conduits throughout. Minimum size of the wire should not be less than 1.5 sq.mm copper. Wire should conform to IS: 694 and wiring installation should be as per IS: 732.

Conduits should be of heavy duty type, hot dip galvanised steel conforming to IS: 9537. In corrosive areas, conduits should have additional suitable epoxy coating.

At least one 5/15A, 240 V universal socket outlet should be provided in offices, stores, cabins, etc. 15A 240 V AC industrial type receptacles should be provided strategically in all other areas. All these receptacles should be 3 pin type and controlled with a switch. Suitable numbers of 63 A, 3 phase, 415 V AC industrial type receptacles with control switches should be provided for the entire plant for welding purposes, particularly near all major equipment and at an average distance of 15 m. At least one 63 A receptacle should be provided in each off-site building.

Suitable number of ceiling fans in areas not covered by air-conditioning and ventilation system should be provided.

Street lighting should be with swaged/steeped tubular steel poles of swan new construction. The poles should be coated with anti-corrosive treatment and paint.

Area lighting should be with suitable lighting masts. Masts of adequate height should have lattice structure with ladder, cage and top platform. Alternatively they should have lantern carriage of raise/lower type with electrical winch provided inside the tubular mast.

### **3.6 Grounding System**

Earthing system consists of ground mat and equipment earthing. The grounding conductor consists of galvanised mild steel trips for ground network and mild steel rounds for ground rods and shall be designed as per IS: 3043 and IEEE: 80-2000. Earthing system network/earthmat shall be interconnected mesh of mild steel rods buried in ground in the plant. All off-site areas shall be interconnected together by minimum two parallel conductors.

Enclosures of all electrical equipment as well as all cabinets/boxes/panels/etc. should be earthed by two separate and distinct earth connections. Metallic pipes, conduits, cable tray section, etc. should be bonded to ensure electrical continuity and earthed at regular intervals as well as at both ends. Metallic conduits, pipes, etc. should not be used as earth continuity conductor. All hinged doors should be earthed by flexible braids of adequate size.

All steel structures should be duly earthed. Metallic sheaths and armour of all multicore cables should also be earthed at both equipment and switchgear end.

Earthing conductor should be buried at least 2000 mm outside the fence of electrical installations. Every alternate post of the fences and all gates should be connected to earthing grid by one lead. Earthing conductor embedded in the concrete floor should have at least 50 mm concrete cover.

Earthing connections with equipment earthing pads should be bolted type with at least two bolts, and joint surfaces should be galvanised. The connections should be painted with anti-corrosive paint after testing and checking.

Neutral of power transformers should be directly connected to two rod electrodes in treated earth pits, which in turn should be connected to station earthing grid.

The earthing terminal of surge arresters and voltage transformers, and lightning protection down conductors shall also be connected to station earthing grid through separate rod electrode.

### **3.7 Lightning Protection**

The lightning protection system should be designed as per IS: 2309. It should cover all buildings and structures in the plant, and switchyard areas. It should comprise horizontal/vertical air terminations, down conductors, test links and earth connections to the station earthing grid. All conductors should be of minimum 25x6 mm size and should be of galvanised steel only.

The down conductors of lightning protection system should have a test joint at about 1500 mm above ground level. Each down conductor should be connected to a 40 mm dia, 3 m long mild steel earth electrode as well as station earthing grid.

The lightning protection system should not be in direct contact with under ground metallic service ducts and cables, and should not be connected above ground level to other earthing conductors. All joints in the down conductors should be of welded type.

Hazardous areas handling inflammable/explosive materials and associated storage areas should be protected by a system of aerial earths as per IEEE: 142-2007.

### **3.8 Communication System**

Reliable communication system is required for operation of power plants as follows:

- i) Voice communication
- ii) Dedicated communication system for SCADA, circuit types of line protective relaying and telemetering etc.

Available communication media is as follows:

- i) Leased telephone lines
- xi) Metallic cable power
- xii) Power line carrier
- xiii) Radio frequency communication
- xiv) Micro wave (MW) communication system
- xv) Fibre optics
- xvi) Satellite communication

#### **3.8.1 Fibre Optic cable**

Communication between the central processor or distributed processor and the to other computer system (remote control stations) is a main function in system performance. Fibre optic cable is preferred because of fast transmission speed best noise immunity. In case of difficult terrain – radio communication can be considered.

In larger powerhouse or these controlling remote stations or a group of stations internal telephone system may be provided.

Selection of communication media for transmission lines interconnecting powerhouse with grid can be chosen based on site limitation cost etc. Fibre optic cable is preferred.

Voice communication between powerhouse and interconnected receiving station may be PLCC; radio frequency; communication; Landline (leased) based telephone line or mobile network based dedicated line.

#### **3.8.2 Codes and standards**

The contractor shall furnish detailed design and calculation for approval by purchaser. Codes and standards to be followed for are ANSI/IEEE: 1010 – 1987, US Army of Engineers Engineering Manual and Relevant National / International Standards

#### **3.8.3 Regulatory Requirement**

Govt. regulatory requirement and sanctions for the communication system shall be obtained by Contractor. Necessary assistance will be provided by Purchaser.

### **3.8.4 Internal Telephone System**

An electronic telephone exchange suitable for 10-15 subscribers should be provided in the powerhouse above 3 MW. The subscribers shall be located at various vulnerable positions to facilitate the communication. Standard PVC cables should be laid for these subscribers. Some of the important locations for subscribers may be as follows.

- i) Control room
- ii) Switchgear room
- iii) Turbine pit
- iv) Machine hall
- v) Unloading/erection bay
- vi) Cable spreading room
- vii) Drainage/dewatering motor starter panel
- viii) Switchyard
- ix) Compressor room near switchyard.
- x) Fore Bay
- xi) Bye pass gates control room
- xii) Pump house
- xiii) Security gates
- xiv) Offices

### **3.9 Transformer oil Purifier**

Normally a portable transformer oil purifier of a capacity to purify the largest transformer in 3 to 4 hours for all power houses having transformer of 1000 kVA and above.

For small transformer portable transformer oil purifier may be provided for cluster of nearby powerhouses as feasible.

## **4. MECHANICAL AUXILIARIES**

### **4.1 Overhead travelling crane**

#### **4.1.1 General**

Cranes are used in the power house for installation of plant and for maintenance and repair. Power house bridge crane (hand operated (HOT), semi-electrical and electrical overhead traveling crane (EOT)) is the principal overhead traveling crane for handling the turbines, generators and auxiliaries in a typical surface power house.

The crane comprises of main hoist to lift heaviest assembly of generating unit and an auxiliary hoist of much lower capacity for handling smaller parts.

#### **4.1.2 Number of Cranes**

The choice of providing one or two cranes with a lifting beam is an important consideration in power house because of following reasons especially in power house with large number of units (generally 5 units or more).

- i) Power house structural costs
- ii) Construction and erection advantage
- iii) 2 cranes with lifting beam will need additional crane clearance and increase in height of power house.
- iv) Value of down time

In small hydro stations for the range under discussion (up to 25MW capacity) only one crane is considered sufficient except for a well considered design for more than one.

#### **4.1.3 Crane Capacity**

Crane capacity in SHP is based conventionally on estimated load based on weight of heaviest part to be lifted with about 25% overload capacity. The rated load capacity of the main hoist should be capable of lifting the heaviest assembly specified and not less than weight of the generator rotor assembly including poles, shaft and turbine runner. The standards to be referred are IS: 3177 and IS: 807.

#### **4.1.4 Hoisting arrangement for SHP below 1 MW**

A hand operated or semi electrical travelling crane may be installed.

For micro capacity units (below 100 kW) powerhouses, manual monorail hoist may be used or erection/maintenance may be done by chain pulley block, mobile crane or manually.

### **4.2 Cooling Water System**

Cooling water system may be required in a powerhouse for the following.

- i) Generator air coolers and bearing coolers.
- ii) Turbine bearing coolers, wearing rings and gland. Turbine glands and wearing ring require water of suitable quality.
- iii) Transformer cooling

#### **4.2.1 Water Requirements**

- i) The water flow requirements are determined by generator and turbine suppliers but are dependant on water supply temperature and should take into account extremes in climate conditions for the site. Flow requirements are usually large and require dependable sources. Purity requirements are moderate permitting non potable supplies with limited silt content.
- ii) Gland and wearing ring requirements are obtained from turbine supplier. Quality requirements are nominal requiring the removal of abrasive material.
- iii) Transformer Cooling: Most plant in the SHP range under discussion utilize air cooled transformer.



### **4.2.2 Sources**

#### **(1) Penstock**

For units with heads up above 30 m, the preferred source of cooling water is a gravity supply from an inlet pipe. In multiunit plants, an inlet is provided for each unit with a crossover header connecting all units to provide a backup water supply to any one unit. Cross-overs between pairs of units only are not regarded as adequate since there would be no emergency source from an unwatered unit. The spiral case source is usually satisfactory for unit bearing coolers, as well as the generator air coolers, and can be adequate for gland and wearing ring use with proper filtering and adequate head.

#### **(2) Tail water**

For higher head projects, above 76 m, the usual source of cooling water is a pumped supply from tail water. This normally provides water of essentially the same quality as the spiral case gravity system.

#### **(3) Other sources**

The power stations having discharge with heavy silt load may be provided with closed loop cooling water system where only make up water is required, for which tube well may be a source.

However for gland sealing system potable water is used for cooling. Normally this is tapped from drinking water supply system.

### **4.2.3 Head requirements**

Normally the cooling water supply should provide a minimum of 68.9-kPa differential across the connection to the individual cooler headers. Available gravity head, cost of a pumped supply, and cost of coolers all enter into an optimum cooler differential requirement and require early design consideration to assure a reasonable figure for the generator and turbine specification. Gland and wearing ring differential head requirements should be obtained from the turbine supplier.

### **4.2.4 Treatment**

Water for coolers, glands, and wearing rings will normally require only straining or filtration. This should be verified from operating experience at nearby existing plants on the same stream. Where existing plants are remote or the project is on a previously undeveloped stream, a water analysis should be the basis of determining the likelihood of corrosion or scale deposits and the need of additional treatment. Typical strainer requirements for coolers permit 3-mm perforations, but strainer specifications for existing projects should be obtained as a guide to complete design requirements. Strainers should be the automatic type unless the system provides other backup provisions for continuous water supply or the power house is small. Unnecessarily fine strainers requiring more frequent servicing should be avoided. Filters are required for gland



water unless the supply is the potable water system. The system should provide for continuous operation when an individual filter requires cleaning.

#### **4.2.5 Pumps**

A pumped cooling water supply requires a standby supply for a pump out of service. This can be provided with two pumps per unit, each of which is capable of supplying cooler requirements, or one pump per unit consisting of a common pump discharge header to all units and one or more backup pumps. Other arrangements to provide backup capacity may also be acceptable. Pumps should be located such that flooded suctions occur at minimum tailwater. Continuously rising pump performance curves are required, and the pump should not exceed 1,500 rpm.

#### **4.2.6 Piping**

- i) Design considerations for piping include, velocity, pressure loss, pumping costs, corrosion allowance, equipment connection sizes and requirement, mechanical strength, temperature, expansion etc. .
- ii) Water takes off from the spiral case or the spiral case extension should be within 30 deg of horizontal center line to minimize debris and air.
- iii) A valve should be located as close to the casing as practicable for emergency shutoff.
- iv) Balancing valves should be located in cooler supply lines.
- v) A removable 0.9-m section of straight pipe should be provided in the generator bearing supply line for temporary installation of a flow meter.

### **4.3 Dewatering and Drainage System**

#### **4.3.1 General**

The Dewatering system provides the means for dewatering main unit turbines and their associated water passages for inspection and maintenance purposes. Drainage system provides for the collection and disposal of all powerhouse leakage and waste water other than sanitary. The safety of personnel and plant is of vital concern in this system and should have continuing priority throughout the design. It may be noted that following type of turbine will not require dewatering arrangement because they are set above maximum tail water level and can be accessed without dewatering.

- a) Impulse turbine
- b) Vertical Kaplan/Francis turbine with siphon intake

## **4.3.2 Dewatering System**

### **4.3.2.1 General**

The principal volumes to be dewatered in all powerhouses are the spiral case and draft tube. In addition, there is usually a considerable volume down stream of the head gates or the penstock valve.

### **4.3.2.2 Dewatering Procedure**

Normal procedure after unit shutdown requires: closing of the head gates or penstock valve; drainage of all unit water above tail water to tail water elevation through the drain; and spiral case or spiral case extension drain; placement of draft tube gates or stop logs; and draining the remaining unit water to sump with the sump pumps operating.

### **4.3.2.3 Dewatering Time**

Aside from safety, the required elapsed time for completing a unit dewatering is the major factor in dewatering system design. Unit downtime will usually be of a value justifying facilities to perform dewatering in 4 hr. or less. This can mean that in a typical plant all necessary valve, gate, and stop log or gate operations should be done in approximately 1 hr and draining of the pumping system in approximately 3 hr.

### **4.3.2.4 Dewatering Sumps**

Sump provision in most projects require either joint usage in both the dewatering and drainage systems, or separate sumps with the dewatering sump serving as a backup or overflow for the drainage sump. Sumps should be designed for maximum tail water head.

### **4.3.2.5 Dewatering Pumps**

Two dewatering pumps should be provided. Dewatering pump capacity should permit unwatering in 3 hr or less of pumping time with total capacity divided in two pumps of the same capacity. Either pump used alone should be capable of accomplishing the dewatering. Since unit dewatering will not be scheduled under powerhouse design flood conditions, rated dewatering pump discharge should be for a maximum planned tail water under which dewatering will occur.

Pumps of the deep well water lubricated type are normally used. Submersible motor and pump combinations units mounted on guide rails permitting the pump units to be raised or lowered by the powerhouse crane have also been used.

Generally float-type controls are used for pump control. Automatic lead-lag with manual selection of the lead pump is provided.

### **4.3.3 Drainage System**

The drainage system handles three general types of drainage as follows: rain and snow water from roofs and decks, leakage through structural cracks and contraction joints, and wastewater from equipment. Discharge is to tail water either by gravity or by pumping from a drainage sump. Roof and Deck drainage should normally be directly to tail water by gravity. Drainage of water sprinkler fire protection system if used should be included in the drainage system in the design. Gravity drainage system should be preferred wherever possible

#### **4.3.3.1 Float Drainage**

Drainage galleries should be provided for float drainage and conduits and pipes connecting the trenches to the drainage sump should be provided.

#### **4.3.3.2 Oil Storage or Purifier Rooms**

Oil storage or purifier rooms provided with water sprinkler fire protection system should have chilling drain with a gravel pocket of sufficient capacity to handle the sprinkling system flow.

#### **4.3.3.3 Battery Room**

Battery room floor and sink drains should be of acid resisting material, have a minimum 2% slope.

#### **4.3.3.4 Miscellaneous Area Floor Drains**

Miscellaneous floor areas i.e. turbine room, galleries, machine shop, toilet rooms etc. where leakage rainwater, water from disassembly, flushing, etc. is normally expected should have floors with continuous slope to the drain location. Any drains that come from a source that can add oil to the water should not drain directly to tail water but should first be routed to an oil separator facility.

#### **4.3.3.5 Pressure waste water**

Waste water from generator air coolers and bearing coolers etc. are normally piped directly to the tailrace. Some powerhouses also require pressure drains for transformer cooling water and air conditioning cooling water.

#### **4.3.3.6 Drainage Piping**

Drainage piping design considerations should be based on relevant standards.

#### **4.3.3.7 Dewatering and drainage Sump**

The drainage sump or joint dewatering- drainage sump should be located low enough to provide gravity flow from all drained areas under all dry powerhouse design tail water conditions and up to the float-operated alarm, sump water elevation. +

## 4.4 Compressed Air System (where ever applicable)

Compressed air system is required in powerhouse for operation and to facilitate maintenance and repair. Service air, brake air and governor air comprises the three systems needed in all powerhouses. Reliability, flexibility and safety are prime design considerations. This system is generally not provided for mini and SHP units up to 5000 kW capacity.

### 4.4.1 Brake Air System

- a. **General.** The brake air system comprises one or more semi-independent storage and distribution installation for providing a reliable of supply of air to actuate the generator braking systems. Air is supplied from the service air system, stored in receivers, and distributed through the governor actuator cabinets to the generator brake systems.
- b. **Air Requirement.** Air is required in the system to stop all generator-turbine units simultaneously without adding air to the system and without reducing system pressure below 520 kPa (75 psi). Storage capacity and pressure depends upon number of brake applications per stop, brake cylinder capacity and volume required for piping and verified by generator manufacturer.
- c. **Piping-Receivers.** Each subsystem includes a receiver, piping from the service air system to the receiver, piping from the receiver to the governor cabinets, and piping from each governor cabinet to the respective generator brake system normally.
- d. **Control.** Control for application of the brakes is normally included in the governor cabinets and provided by the governor supplier.

### 4.4.2 Governor Air System

- a. **General:** The governor air system provides the air cushion in the governor pressure tanks. When the governor system is to be placed in operation, the pressure tank is filled approximately one-fourth full with oil, and the tank is then pressurized to governor-operating pressure from the governor air system. Corrections to maintain the proper oil-air ratio are required at intervals during plant operation. The governor pressure tank size and operating pressure will be determined by the turbine servomotor volume.
- b. **Air Requirements:**
  - i) **Quantity:** Compressor delivery should be sufficient to effect a complete pressurization of a governor tank with the proper oil level in 4 to 6 hrs.
  - ii) **System Pressure.** The operating pressure should be approximately 10% above the rated governor system pressure.
  - iii) **Compressor.** The total air-delivery requirement should be provided by two identical compressor, each rated at not less than 50% of the requirement. Compressor should be heavy duty, reciprocating, water or air cooled, and rated for continuous duty.

### **4.4.3 Service Air System**

#### **4.4.3.1 General**

The service air system is a nominal 700 kPa system providing air for maintenance and repair, control air, hydro-pneumatic tank air, charging air for the brake air system, and in some cases, air for ice control bubblers.

#### **4.4.3.2 Service Air Requirement**

##### **4.4.3.2.1 Routine Maintenance**

Supply 25-40 lps for wrenches, grinders, hammers, winches, drills, vibrators, cleaning, unplugging intakes and lines, etc

##### **4.4.3.2.2 Major Maintenance and Repair**

Supply 140-190 lps (300-400 cfm) for sandblasting, painting, cleaning etc. Normally this capacity should be provided with portable equipment. For projects too remote from a government or commercial source of temporary portable equipment, installed capacity be provided.

##### **4.4.3.2.3 Ice Control Bubblers**

This may be required for SHP located high altitude ice prone areas. Supply 1 to 2 lps per three width of trash rack with bubblers operating on intakes for up to four units simultaneously (if required).

##### **4.4.3.2.4 Operational Requirements**

Supply 7 to 12 lps (15-25 cfm) with individual assumption as follows:

Brake system charging air	1 to 2 lps
Hydro pneumatic tank	3 to 5 lps
Control Bubbler	1 to 3 lps
Leakage	1 to 3 lps

##### **4.4.3.2.5 Standard Provision Basis**

It is found that the computed basis will usually require several arbitrary assumption and service factors to arrive at a total service air requirement. In lieu of the compound basis, the following standard provisions may be used as the basis of total air requirement:

1 to 2 unit plants	40 lps
3 to 4 unit plants	50 lps
Over 4 unit plants	60 lps

In addition, provide 175 lps (375 cfm) for major maintenance and repair. If this will be supplied with portable equipment, add computed ice control bubbler requirement to the above

standard provisions. If the 175 lps is to be installed, assume that ice control and major maintenance will be non-simultaneous requirements, and the 175 lps will cover the ice control bubbler requirements.

#### **(vi) Service Air Pressure**

A nominal 700 kPa pressure with system variations from 580 to 760 kPa is satisfactory.

#### **4.4.3.3 Compressors**

Compressors should be heavy duty, water cooled, flood lubricated, and cooled rotary screw type rated for continuous duty. Normally, aside from major maintenance, service air should be supplied by two identical compressors each of which is capable of supplying approximately 75% of the requirement. Where ice control bubbler demand exceeds 12 lps and there is no installed major maintenance compressor, it will usually be preferable to supply the bubbler demand from separate compressor. Installed major maintenance and repair capacity should be provided with a single compressor.

#### **4.4.3.4 Receivers**

Each air receiver should conform to design construction, and testing requirements of the ASME, "Boiler and pressure Vessel Code." Receiver capacity should provide a minimum 5 min-running time with no air being used from the system for the largest connected compressor on automatic start-stop control. One or more receivers may be used for the system. However, galvanized receivers are preferred, and sizes should be checked against galvanizing plant capabilities.

#### **4.4.3.5 Controls**

The two service air compressors should each be provided with selective manual or automatic control. They should have pressure switch lead-lag control automatic selection and conventional load-lag control automatic selection and conventional load-unload operation for manual selection. A major maintenance compressor or a separate ice control bubbler compressor should be on manual control with conventional load-unload provisions. Cooling water should be controlled to flow only when the compressor motor is energized. Automatic shutdown should be provided for low oil pressure, low oil level, and high-discharge air temperature.

### **4.5 Fire Protection System**

#### **4.5.1 General**

Arrangement of fire protection in hydro power station and switchyard is normally divided into following three groups.

- (i) Fire protection for generators
- (ii) Fire protection for generator transformers and other equipment in outdoor switchyard

- (iii) Fire protection of area and equipment and power house not covered under above two groups.

#### **4.5.2 General Consideration for Design of Fire protection System**

In view of a large number of oil-filled equipments in a Generating Station including outdoor switchyard, it is very important that proper attention is given to isolation, limitation and extinguishing of fire so as to avoid damage to costly equipment, reduce chances of serious dislocation of power supply and ensure safety of personnel. The first step in this direction is inherent in the design and layout of the powerhouse and substation itself, which should be such that if fire occurs in any equipment it should be limited and isolated so that it does not spread to other equipments. For this purpose the following are the general guidelines:

- (i) The spacing of the equipment should be considered. Extra space is not usually provided for fire isolation, but the space available is taken into account in deciding other isolation measures.
- (ii) Fire isolation walls should be provided between large oil-filled equipments such as two or more transformers placed adjacent to each other. These should be of adequate strength and of such size that the adjacent equipment is reasonably safe from the risk due to burning oil flying from the equipment on fire.
- (iii) In indoor areas automatic fireproof doors should be provided for rooms which house major oil filled equipment. The rooms should also be constructed with a view to isolating the fire.
- (iv) Soak pits or drain pits should be provided below large oil-filled equipment to drain off the burning oil falling below the equipment.
- (v) Minor items of oil filled equipment should be placed in beds of gravel or pebbles which will quench and prevent the spread of burning oil.
- (vi) Care should be exercised that any prospective fire can be easily approached for quenching. In closed spaces and buildings attention should also be given to evacuation of personnel. (Refer IS: 1646-2007).
- (vii) All oil pipes and cable trenches should be sectionalized by means of cross walls.

A well coordinated system of fire protection should be provided to cover all areas of the power house and substation and all types of likely fires. The details of fire protection have to be worked out on the basis of size, type and location of equipment in powerhouse and the substation, accessibility and degree of attendance. Care should be taken so that any fire can be fought from more than one source and dependence is not placed on single equipment for this purpose.

##### **4.5.2.1 Fire Fighting System in Powerhouse**

Powerhouse and substations should be equipped with fire fighting systems conforming to the requirements given in latest IS: 1646-2007 and fire protection manual Part-I issued by Tariff Advisory Committee statutory body under Insurance Act 1938.

Trailer pumps, where provided, should draw their water supply from ground tanks of suitable sizes, the location and distribution of which shall be such that no item to be protected is more than about 90 m away from any ground tank.

The more valuable equipment or areas forming concentrated fire risk should be covered by special fire protective systems. In this class are:

- (i) Generators
- (ii) Transformers, both indoor and outdoor:
- (iii) Oil filled switchgear
- (iv) Oil tanks and oil pumps
- (v) Oil, grease and paint stores

Although the substitution of bulk-oil and minimum oil circuit breakers by Air/Vacuum/SF<sub>6</sub> gas circuit breakers has reduced the risk of fires in electrical installations, considerable risk still exists on account of transformers, cables etc., which contain combustible insulating materials. Fires in live electrical equipment, motors, machinery etc. fall in class C category according to the tariff Advisory Committee Classification of Fires. It is necessary to provide efficient fire protection systems in the electrical installations. Fire protection system consists of the following:

- (i) Fire prevention
- (ii) Fire Detection and annunciation
- (iii) Fire extinguishing

#### **4.5.2.2 Fire Prevention**

Fire prevention is of utmost importance and should be given its due if risk of occurrence of fires has to be eliminated/ minimized. The safety and preventive measures applicable for hydro generating stations and substation as recommended by the relevant authorities must be strictly followed while planning.

All fire fighting equipment and systems should be properly maintained. Regular mock drills should be conducted and generating station staff made aware of importance of fire prevention and imparted training in proper use of the fire fighting equipment provided in various parts of the substation, control room building etc.

#### **4.5.2.3 Fire Detection and Annunciation**

Fire detection, if carried out at the incipient stage can help in timely containment and extinguishing of fire speedily. Detection can either be done visually by the personnel present in vicinity of the site of occurrence or automatically with the use of detectors operating on the principles of fixed temperature, resistance variation, differential thermal expansion, rate of rise of temperature, presence of smoke, gas, flame etc. Fire detectors of the following types are usually used for SHP above 100 kW.

- (i) Ionization type



- (ii) Smoke type
- (iii) Photoelectric type
- (iv) Bimetal type
- (v) Linear heat detection type

Ionization type detectors are used more commonly. However in areas like cable vaults, ionization smoke and linear heat detection type detectors are used. Smoke type detector is effective for invisible smoke, and photoelectric type for visible smoke. Smoke type detectors incorporate LEDs, which start glowing in the event of fire.

Detectors are located at strategic positions and arranged in zones to facilitate proper indication of fire location, transmission of audio-visual signals to fire control panels and actuation of the appropriate fire fighting systems. In the rooms with false ceilings, these are provided above the ceiling as well as below it. For the detectors located above the false ceilings, remote response indicators should also be provided.

Detectors are provided at the rate of one for a maximum area of 80 m<sup>2</sup> in the zones to be covered by the Fire Protection System

#### **4.5.2.4 Fire Extinguishing**

The Fire Extinguishing Systems used for fire protection of the various equipments/building in substations are the following:

- (i) CO<sub>2</sub> for enclosed areas
- (ii) Hydrant system.
- (iii) High velocity water spray system.
- (iv) Portable fire extinguishers.
- (v) Nitrogen injection fire prevention method for transformer only

These are described below briefly.

#### **4.5.2.5 Hydrant System**

Hydrant System is installed for the protection of the following areas from fire:

- (i) Control room building
- (ii) L.T. transformer area
- (iii) Diesel generator set building
- (iv) Fire water pump house
- (v) Suitable location in the switchyard.
- (vi) SHP above 100 kW and above be provided hydrant system as per IS: 1646.

Hydrants are the backbone of fire fighting system as these can help fighting fires of all intensities in all classes of fires and continue to be in service even if the affected

buildings/structures have collapsed. These keep the adjoining properties/buildings cool and thereby save them from the serious effects of fire and minimize the risk of explosions.

The hydrant system is supplied water from Fire Water Pump House. Fire Water Pump House is located by the side of Fire Water Storage Tanks constructed within the power house boundary limits. These tanks are made of RCC above ground such that these are easily accessible. Water from these tanks is pumped into the fire hydrant system with horizontal centrifugal pumps.

The hydrant system essentially consists of a network of pipes, laid both above ground and underground, which feed water under pressure to a number of hydrant valves located at strategic locations throughout the substation. Pressure in the piping is maintained with the help of hydro-pneumatic tanks and jockey pumps. Jockey pumps compensate for minor leakages also. The hydro-pneumatic tanks are pressurized with compressed air supplied by two air-compressors of which one is working at a time and other acts as standby.

Adjacent to the hydrants, hosepipes, branch pipes and nozzles are kept in hose boxes. In case of fire, the hoses with nozzles are coupled to the respective hydrants and water jet is directed towards the seat of fire.

On drop of pressure in the piping network below a preset value, the hydrant pump starts automatically and continues to run till it is stopped manually after fire has been extinguished.

The quantity of water to be available for fire protection and the number of fire water pumps depend on the total number of hydrants which are provided as per guidelines of Tariff Advisory Committee (TAC). The parameters of fire water pumps as per TAC guidelines are given below.

- (a) For the total number of hydrants up to twenty, one no pump of  $96 \text{ m}^3/\text{hr}$  capacity with a pressure of  $5.6 \text{ kg/cm}^2$  (gauge)
- (b) For the total number of hydrants exceeding twenty up to fifty five, one no. pump of  $137 \text{ m}^3/\text{hr}$  capacity with a pressure of  $7.0 \text{ kg/cm}^2$  (gauge)
- (c) For the total number of hydrants exceeding fifty five, up to hundred, one no. pump of  $171 \text{ m}^3/\text{hr}$  with a pressure of  $7.0 \text{ kg/cm}^2$  (gauge)

As per TAC guidelines, the jockey pump should have a capacity of  $10.8 \text{ m}^3/\text{hr}$ . and the hydro-pneumatic tank should have a capacity of  $18 \text{ m}^3$ . The effective capacity of the fire water tank should be not less than one hour of aggregate pumping capacity, with a minimum of  $135 \text{ m}^3$

All components of the hydrant system such as piping, valves, fittings, hoses, branch pipes, nozzles etc. should be of approved make acceptable to TAC.

#### 4.5.2.6 High Velocity Water (HVW) Spray System (Sprinkler System)

This type of Fire Protection System may be provided for the following types of equipment:

- (i) Generators with closed air circulation system and installed in an enclosed space  
e.g. bulb generators
- (ii) Power Transformer

This system is designed on the assumption that one generator/transformer is on fire at a time. For this assumption, the largest piece of equipment forms the basis.

High Velocity Water (HVW) Spray System consists of a network of projectors arranged around the equipment to be protected. Water under pressure is directed into the projector network through a deluge valve from a piping network exclusively laid for the spray system. Water leaves the projectors in the form of conical spray of water droplets travelling at high velocity.

The high velocity droplets bombard the surface of oil and form an emulsion of oil and water which does not support combustion. This emulsion converts a flammable liquid into a non-inflammable one. However, this emulsion is not of a stable character and therefore shortly after the water is shut off, oil starts to separate out from water which can be drained away, leaving the oil behind unimpaired.

The rate of burning of a flammable liquid depends upon the rate at which it vaporizes and the supply of oxygen to support combustion. It is the maximum when the rate of burning of the flammable liquid is the maximum and the surface of the liquid is near boiling point. The high velocity water spray system while forming an emulsion, intersperses cold water with the liquid, cools it and lowers down the rate of vaporization which prevents further escape of flammable vapors. During passage of water droplets through flames, some of the water gets converted into steam, which dilutes oxygen in the air supporting the fire and creates a smothering effect, which aids in extinguishing the fire.

An automatic deluge valve triggered by a separate system of quartzite bulb detector heads mounted on a pipe work array charged with water, at HVW spray mains pressure, initiates the HVW spray system operation. When a fire causes one or more of the quartzite bulbs to operate, pressure in the detector pipe work falls and this allows the deluge valve to open thereby permitting water to flow to all the projectors in the open pipe array covering the risk.

Water supply to HVW (high velocity water) Spray System:

- (a) Two pumps are provided for HVW Spray System. Of these, one is electric motor driven and the other diesel engine driven. The capacity and head of the pumps is selected to protect the biggest risk. It has been experienced that each pump having a capacity of 410 m<sup>3</sup>/hr is usually adequate for the biggest risk in substations.

- (b) These pumps are located in fire water pump house. Suitable connection with the Hydrant System is provided so as to allow flow of water from hydrant system to HVW Spray System but not in the reverse direction.
- (c) Standby diesel engine driven pump is a common standby facility for HVW spray as well as hydrant system,
- (d) These pumps are automatically started through pressure switches located sequentially in headers. However, stopping of the pumps is done manually after the fire gets extinguished.
- (e) The values of pressure of running water and discharge density given below are recommended for HVW spray system:
  - (i) Minimum pressure of running = 3.5 Bar at any projector at any instance.
  - (ii) Maximum pressure of running water = 5.0 Bar at any projector at any instance
  - (iii) Discharge density on ground surface =  $6.1 \text{ lpm/m}^2$
  - (iv) Discharge density on other surface = Not less than  $10.2 \text{ lpm/m}^2$

#### 4.5.2.7 Water Supplies

Water for fire fighting purposes should be supplied from the water storage tanks meant exclusively for the purpose. The aggregate storage capacity of these tanks should be equal to the sum of the following:

- (i) One-hour pumping capacity of Hydrant System or  $135 \text{ m}^3$  which ever is more.
- (ii) Half-an-hour water requirement for single largest risk covered by HVW (high velocity water) spray system.

The water storage tank made of RCC construction over ground should be in two parts.

Fire water pumps located in the fire water pump house should have pumping head suitable to cover the facilities for future stages also. The piping system should be designed to permit extensions without disruption in the existing system. The material of piping is mild steel as per IS: 1239/IS: 3589 medium grade. The piping laid, underground is coated and wrapped against corrosion as per IS: 10221 and the piping laid over ground consists of galvanised mild steel.

All equipment and accessories, constituting the HVW (high velocity water) spray system, such as flow control valve, heat detectors, projector nozzles, piping, valves, fittings, instrumentation etc., should be of approved makes acceptable to competent authority.

#### 4.5.2.8 Portable and mobile Fire Extinguishing

Portable and mobile fire extinguishers are provided at suitable locations for indoor/outdoor applications. These extinguishers are used during early stages of localised fires to prevent them from spreading. Following types of these extinguishers are usually provided.

- (i) Pressurised water type in 9.01 kg size
- (ii) Carbon Dioxide type in 4.5 kg size

- (iii) Dry Chemical type in 5.0 kg size
- (iv) Halon type in 5.0 kg size
- (v) Mechanical foam type in 50ltrs, 90ltrs.

For the quantities of these types and their applications, the norms given in TAC manual should be followed.

- (i) The make of these extinguishers should also be acceptable to TAC.
- (ii) Halon type fire extinguishers are now getting phased out on account of their negative effect on the atmosphere.
- (iii) The transformers shall be protected by automatic high velocity water spray system or by carbon dioxide or BCF (Bromochloro-difluoromethane) or BTM (Bromo-trifluoromethane) fixed installation system or Nitrogen injection and drain method.
- (iv) Nitrogen injection fire prevention method is being used by a few utilities at present.

#### **4.5.2.9 Instrumentation and Control**

Fire protection system should include suitable instrumentation and necessary controls to render the system efficient and reliable. There should be local control panels for each of the pumps individually as also for the operation of deluge valve of the HVW spray system. There should be a common control panel for the jockey pump and air compressors. Main annunciation panel should be provided in the control room for the facilities provided in the control room and for repeating some annunciation from pump house.

The following Annunciation is usually provided in the fire water pump house:

- (i) Electric motor driven HVW spray pump running/fails to start
- (ii) Diesel engine driven HVW spray pump running/fails to start
- (iii) Hydrant pump running/fails to start
- (iv) Jockey pump running/fails to start
- (v) Air compressor fails to start
- (vi) Hydro-pneumatic tank pressure low
- (vii) Hydro-pneumatic tank pressure high
- (viii) System header pressure low
- (ix) Fire in transformer/reactor
- (x) Fire in smoke detection system
- (xi) Water storage tank water level low
- (xii) High speed diesel oil tank level low

The following Annunciations should be available in the control room also:

- (i) Fire in transformer/reactor
- (ii) Hydrant pump/diesel engine operated HVW spray pump in operation
- (iii) Motor operated HVW spray pump in operation
- (iv) Fire/Fault in Zone 1

- (v) Fire/Fault in Zone 2
- (vi) Fire/Fault in Zone 3
- (vii) Fire/Fault in Zone 4 (depending on the number of zones)

All fire protection equipment should be covered by a regular and strict maintenance and test routine. The hydrant systems should be checked every week which may be possible during night shifts. Sprinkler systems should be checked at regular intervals. Portable equipment should be charged at specified intervals and checked regularly for loss of charge, damage, etc. Records of all tests and checks must be maintained.

Provision should be made to switch off the air conditioning equipment in case of fire.

Cable entry openings should be sealed to prevent the spreading of fire.

### 4.5.3 Generators

- (a) General : Generators with closed air-circulation systems are normally provided with automatic CO<sub>2</sub> extinguishing systems. Up to four generators may be on one system, with CO<sub>2</sub> cylinder storage based on discharge in a single unit (generally above 5 MW capacity). Standard generator are recommended upto 5 MW and these are open ventilated and not suitable for carbon dioxide fire protection.
- (b) System design:
  - (i) General design considerations are as follows:
    - CO<sub>2</sub> concentration of 30 percent should be maintained within the generator housing for a minimum period of 20 min without the use of an extended discharge.
  - (ii) CO<sub>2</sub> release should be actuated by the following:
    - Generator differential auxiliary relay
    - Thermo-switches in the hot air ducts of each air cooler.
    - Manual operation at the cylinders.
    - Remote manual electrical control.

The CO<sub>2</sub> fire extinguishing system normally consists of a sufficient amount of CO<sub>2</sub> to maintain an inert atmosphere during the deceleration of the machine. Two rates of discharge of CO<sub>2</sub>, are provided by two groups of CO<sub>2</sub> cylinders one group of cylinders, providing the initial discharge, to ensure a rapid build-up of CO<sub>2</sub> concentration, to put out fire and other group of cylinders, providing the delayed discharge to ensure concentration of CO<sub>2</sub> maintained for an extended period. Capacity of the bank is sized for protection of only one individual generator and CO<sub>2</sub> cylinders is arranged for the discharge to any one of the main units. The amount of CO<sub>2</sub>, for initial and delayed discharge, should be determined by the manufacturer, taking into account the volume of the air spaces in the generator enclosure and the deceleration time of the machine. Size and the number of cylinders required in each bank are accordingly determined. A set of identical cylinders is provided for immediate replacement after use.

- iii) Open ventilated generators up to 5 MW capacity may be provided water sprinkler system or portable system as per IS: 1646-1997.

#### **4.5.4 Transformers**

- (a) General: Fire protection at a transformer is provided to limit damage to other nearby transformers, equipment, and structure. It is assumed that a transformer fire will result in loss of the transformer. Water sprinkler systems are provided for outdoor oil-filled transformers
- (b) Outdoor transformers:
  - (1) General: Main power transformers are commonly located outdoors in the switchyard, on intake or draft tube decks. They are sometimes individually semi-isolated by walls on three sides. The frequency of transformer fires is extremely low, but the large quantities of oil involved and absence of other effective fire control measures normally justify installation of a deluge system where there is a hazard to structures.
  - (2) System design
    - (i) The Emulsifier System  
Deluge valves should be actuated automatically by a thermo-stat, manually by a switch in a break-glass station located in a safe location near the transformer, or manually at the valve. Where exposed transformers (without isolating walls) are located closer together than the greater of 2-1/2 times transformer height or 9 m, the system should be designed for spraying the adjoining transformers simultaneously with the transformer-initiating deluge.
    - (ii) The water sprinkler system  
System water supply is normally from the pool or water tank and should be a gravity supply if practicable. A booster pump should be provided if required. a pumped tail water source is an acceptable alternate. Two water intakes are required either of which can supply the rated delivery of the pump. Consideration must be given to providing a source of power for pumping when the circuit breakers supplying the transfer are automatically tripped because of a transformer fault.
- (c) Indoor transformers: Oil-filled indoor (auxiliary) transformers should be protected by CO<sub>2</sub>.
- (d) Outdoor oil-insulated: Oil-insulated power transformers located outdoors should be provided with chilling sumps which consist of a catchment basin under the transformer filled with coarse crushed stone of sufficient capacity to avoid spreading an oil fire in case of a tank rupture.



#### **4.5.5 Portable Fire Extinguishers**

Portable CO<sub>2</sub> hand held extinguishers are the first line of fire protection for powerhouse areas and equipment other than those specifically covered above and should be provided in locations as per relevant Indian Standard.

#### **4.5.6 Fire Detections**

- (i). Thermal detectors: Thermal detectors are best suited for locations within equipment such as generators or near flammable fluids.
- (ii). Ionization detectors: Ionization detectors are best suited for gases given off by overheating, such as electrical cables or a smoldering fire. Location near arc-producing equipment should be avoided. They are not suited for activating CO<sub>2</sub> systems.
- (iii). Photoelectric detectors: Photoelectric detectors are best suited for the particles given off by an open fire as caused by a short circuit in electrical cables. Their use in staggered locations with ionization detectors along a cable tray installation would provide earliest detection. They are not suited for activating CO<sub>2</sub> systems.
- (iv). Location: Detectors should be located at or near the probable fire source such as near cable trays or in the path of heating and ventilating air movement. In areas where combustible materials are not normally present, such as lower inspection galleries, no coverage may be appropriate.
- (v). Reliable detection: The earliest “reliable” detection is required. The detector type or types, location and adjustment should be carefully considered. The detector sensitivity adjustment should be adjusted to eliminate all false alarms. A fire detector system should be provided in the cable gallery and spreading rooms of all power house.
- (vi). Alarm system: The power plant annunciation and, if applicable, the remote alarm system should be used to monitor the fire detection alarms. An alarm system should be provided for each area. Properly applied, these systems will provide more reliable and useful alarm data than the alarm monitor specified in the fire codes.

#### **4.5.7 Isolation and Smoke Control**

Smoke and fire isolation is probably the most important fire control item. Smoke inhalation is one of the major causes for loss of life. The toxic fumes from a minor fire could require total evacuation of the powerhouse. Many of the existing heating, ventilating, and air conditioning systems contribute to spreading the smoke as they encompass the entire powerhouse or have a vertical zone composed of several floors. The fire area should be isolated by shutting down the ventilating system or exhausting the air to the outside where feasible to prevent the spread of smoke and to provide visibility for fire reentry to the area. In most cases, the available oxygen is sufficient to support combustion, and little can be gained by not exhausting the smoke. Smoke and fire isolation should be provided in areas where isolation can provide a real benefit. The requirements for fire stops should be considered on a case-by-case basis. Where cable tray pass through a floor or wall which could be considered a fire wall, or where cables leave a tray and enter a switchgear or switchboard through a slot, a fire-stop should



be considered. A 12.7 mm asbestos-free fireproof insulation fireboard can provide the basic seal with the voids being closed by packing with a high-temperature ceramic fiber. Single conduit or single cables which penetrate a fire wall can be sealed with a special fitting. Thick seals should be avoided as they could contribute to an excessive cable insulation operating temperature.

#### **4.5.8 Fire protection Scheme Recommended:**

##### **4.5.8.1 SHP of 5 MW and up to 25 MW capacity**

- (i) Generator – CO<sub>2</sub> protection if CO<sub>2</sub> protection is not feasible then water sprinkler system be provided.
- (ii) Generator transformer – Provide water sprinkler system protection
- (iii) Fire detectors, portable fire extinguishers, fire buckets and hydrants as per IS: 1646

##### **4.5.8.2 SHP of 100 kW up to 5 MW capacity**

- (i) Generator – Water sprinkler system for generator above 1000 kW unit size
- (ii) Generator Transformer – water sprinkler system above 1000 kW unit size
- (iii) Fire detectors, portable fire extinguishers, fire buckets and hydrants as per IS: 1646

##### **4.5.8.3 SHP up to 100 kW**

Portable fire extinguishers, and hydrants, as considered necessary and as per provisions of Indian standard requirements (IS: 1646).

#### **4.6 Ventilation and Air Conditioning**

##### **4.6.1 General**

Power house ventilation and air conditioning is required to maintain temperature and quality air conditions suitable for operating requirement, plant personnel and visitors. Ventilation and air conditioning system for surface hydro power stations should be designed in accordance with IS: 4720-1982.

##### **4.6.2 Types of Ventilation**

The ventilation may be of following types:

- (a) Natural, that is, by forces set in motion by the heat of sun, namely, winds; and
- (b) Forced or artificial, that is, by extraction or propulsion.

##### **4.6.3 General Rules for Design**

###### **4.6.3.1 Natural Ventilation**

- (i) Thorough ventilation of power house building should be aimed at by the provision of adequate windows and ventilators.
- (ii) Provision of Windows and Ventilators - The object of providing windows and ventilators is two-fold, that is, to get fresh air and light. The minimum area of windows and ventilators to be provided in power house building should be one-tenth of the floor area. However, efforts should be made to increase it to one-fifth of the floor area. Windows

should be well distributed and be located on windward side at low level and should not, as far as possible, be obstructed by adjoining structures or partitions. When wind direction is variable, windows should be provided on all sides, if possible. Effort should be made to develop cross-ventilation. For protection against fire, it is preferable to provide steel doors and windows in power house and auxiliary rooms. Reference may be made to IS: 1038-1975 and IS: 1361. The ventilators should be fixed as high as possible for proper expulsion of warm air. Full advantage should be taken of sunshine which is important in ventilation its availability depends on the orientation of the power house which in turn may depend on site condition. In providing openings, measures to guard against entry of birds, moths, etc, should be taken.

#### **4.6.3.2 Forced Ventilation**

- (i). Forced ventilation system is designed keeping the inlet fan capacity 10 percent more than the exhaust fan capacity.
- (ii). Unassigned rooms and storage rooms should be carefully considered, so that sufficient ventilation may be provided in those which might be used for purpose requiring additional ventilation in the future.
- (iii). In portions of the power station building where moisture condensation is anticipated, dehumidified air should be supplied to prevent condensation, as condensation causes deterioration of paint, corrosion of metal surfaces and breakdown of insulation on electrical equipment.
- (iv). The quantity of air required for the power station building should be worked out from the number of air changes preferred for the various premises of the building as given in Table 10.
- (v). One air change per hour means that the quantity of air equivalent to the total volume of the room is supplied to and exhausted from the room each hour. This air may be all outside air or a part of the-circulated air, depending upon the oxygen content.
- (vi). The proportion of outside air to the circulated air supplied to a room depends upon temperature conditions, number of occupants and kind of equipment installed in the room.
- (vii). The number of air changes per hour provided for any room is dependent upon the number of occupants. The air should be changed at the rate of  $1.5\text{m}^3/\text{min}$  per person and not less than  $0.3\text{m}^3/\text{min}$  of this air should come from outside sources.
- (viii). The number of air changes per hour provided for rooms containing equipment generating heat should necessarily be increased, depending on the amount of heat to be carried out by the ventilating system.
- (ix). For medium climates, the maximum temperature rise of air carrying off heat of transformers should be limited to  $20^\circ\text{C}$ , and for hot climates the temperature rise should be limited to  $16^\circ\text{C}$ ; however, the final temperature of the air exhausted should not exceed  $45^\circ\text{C}$ .
- (x). Air supplied to rooms containing special mechanical or electrical equipment should be filtered air circulation maintained at a minimum, through diffusers, to

prevent the accumulation of dust on sensitive mechanisms. The relative humidity of air supplied should not be higher than 65 percent.

- (xi). Rooms which may contain air contaminated with objectionable or harmful odors, carbon dioxide gas or smoke, should be exhausted directly to the outside of the building.
- (xii). When heating or cooling units are provided in the power house, their effect on the quantity and temperature of air circulating through the building should be considered.
- (xiii). The spacing of supply and exhaust openings in long rooms or galleries should be such that sufficient air changes per hour are provided along the full length of the room.

**Table 10 : Preferred Number of Air Changes**

<b>Power House Premises</b>	<b>Preferred air Changes Per hour</b>
Main generator room, dark room, light and heavy storage rooms, dewatering and drainage sumps, record room	2
Passage, approach gallery, pipe gallery, ventilation equipment room, governor gallery, cable gallery, dewatering drainage-pump room or gallery	4
Oil storage and oil purification rooms, service (pump ) gallery, oil sludge room, compressor room, terminal board room, machine shop, tool room, pipe shop, electrical laboratory, fan room, battery room, telephone and communication equipment room	6
Offices, reception room, toilets, and control room	8

#### **4.6.4 Fans**

Forced air ventilation is provided by propeller, axial or centrifugal type fans powered by electric motors. Propeller fans may be used either to supply or exhaust where no duct system, filters or other restrictions are in the air passage. When duct system is used, axial or centrifugal fans may be used for any type of operation involving the movement of air and may be accompanied by filters, and coolers or heaters where cleaning and tempering of supply air is required. Choice of a particular type of fan may be made by consulting the fan manufacturers data, which give full operating characteristics with a preferred range of operation for a particular fan.

## 4.6.5 Air Intake and Exhaust -Openings

**4.6.5.1** Openings are provided for intake and exhaust of air where outside air is required for ventilation. Where natural ventilation is used, the opening of windows is sometimes sufficient. For forced ventilation, special openings are required. The number of openings for intake and exhaust of air depends on the space arrangement in the building, on the size of the building and the design of the ventilation system. Small power plants may have one opening of each type. For larger power plants, separate outside air intake should be installed for the control, service and main unit bays. Each intake should be provided with storm louvers, screens, and dampers for controlling the mixture of outside and circulated air. The obstructive effect of the louvers should be compensated for by making the gross area of the initial intake twice the area of the connecting duct. When filters are used, the area should be increased to accommodate the required filter area.

**4.6.5.2** Air opening may be placed anywhere on the exposed walls or roof of the power plant building, except that, in order to reduce dust intake, air intake should be at least 1.25 m above ground or deck level.

**4.6.5.3** Air is exhausted from the building through exhaust openings provided with louvers or by axial-flow exhaust fans located near the roof in the main generator room. Normally, the number of exhaust openings may be more than the air inlet openings, since the spaces to be exhausted are seldom located in the same general area, nor do they have common requirements. Individual centrifugal fans and connecting ducts are usually installed to exhaust air from toilets, battery rooms and oil storage rooms.

**4.6.5.4** The size of air openings is dependent on noise level, and to a lesser degree, on horse power requirements, since the smaller the opening the higher will be the noise level and the resistance. The size of air openings may also be worked out from the air velocity as recommended in Table 11, which will be found to give satisfactory results in designing conventional systems.

**Table 11: Recommended and maximum duct velocities for systems in power house buildings**

S. No.	Designation	Recommended Velocities	Maximum Velocities
i)	Outer air intakes	150	370
ii)	Filters*	110	110
iii)	Heating coils*	180	210
iv)	Air washers	150	150
v)	Fan outlets	500-730	850
vi)	Main ducts	370-550	670
vii)	Branch ducts	250-300	550
viii)	Branch risers	250	500

\*These velocities are for total face area and not the net free area; other velocities in the table are for net free area. The net free area is the total minimum area of the opening in the face of a coil, grille, register or louver through which air can pass.

#### **4.6.6. Air Cleaning**

It is desirable to clean the air entering the power plant building in order to remove the air-borne dust particles which, if allowed to enter the building, may have an abrasive effect on rotating machinery, interfere with the operation of electric or electronic devices, and may, otherwise settle on equipment, giving a dirty appearance. The air filters are usually located upstream of the fan. The size of the air filters may be determined by the recommended velocity of air passing as given in Table 11. The choice of the air filter may be made by reference to the manufacturer's catalogues.

#### **4.6.7 Air-Conditioning**

**4.6.7.1** When the desired temperatures and humidity inside the hydro power station are not obtainable by ordinary ventilation, air-conditioning may be resorted to by heating or cooling the entering air to the desired temperature to maintain comfortable working conditions in the premises occupied by working personnel. The premises where it will be desirable to provide air-conditioning are control room, offices, reception room, first-aid room, test laboratory and telephone and carrier communication room. For air-conditioning reference may be made to IS: 659-1964.

**4.6.7.2** In general, all rooms, used by sedentary personnel should be maintained at 22°C with a relative humidity of about 50 percent, or in special cases local radiant type portable heaters may be used for the space actually occupied. Operation of the air-conditioning system should be independent of the main ventilating system and the control of the system should be automatic by means of thermostatic devices. Heating and cooling load computations may be based on currently accepted standard practice.

#### **4.6.8 Ducts**

**4.6.8.1** Where positive ventilation requires ducts for proper air distribution, considerable advantage may be achieved by incorporating the ducts into the building structure and by having the interior surfaces carefully finished to render them smooth and air-tight.

**4.6.8.2** Where metal duct work is installed, it should be fabricated from galvanized steel or aluminum sheets, and should conform to IS: 655-1963.

**4.6.8.3** The transfer of air by ducts; from source to delivery point, should be as direct as practicable with the fewest possible bends. Flexible connections should be provided between fans and ductwork to prevent the noise of fan vibration being transmitted directly to the sheet-metal ducts.

**4.6.8.4** The size of the air ducts should be worked out from the permissible air velocities given in Table 11.

**4.6.8.5** Supply and exhaust ducts of acid battery rooms should be painted with acid resistant paint both inside and outside.

**4.6.8.6** Ducts should be suitably insulated wherever required.

#### **4.6.9 Air Distribution Control**

To regulate the flow of air in a ventilating system, control dampers should be provided throughout. At outside air intakes, multi-louver dampers should be used to control the amount of air admitted. A similar damper is required on inside air intakes to control the amount of re-circulated air. These two dampers should be interconnected to permit regulation of the proportion of outside air to inside air used in the ventilating system. These may be operated manually or automatically. Back-draft dampers are used where it is desired to prevent a reverse flow of the air, such as the air supply duct to a battery room. Exhaust ducts from rooms containing a fire hazard should have dampers which can be automatically and manually closed in case of fire. Discharge openings, provided with propeller exhaust fans, should be fitted with motor or mechanically operated type multi-louver dampers, which will open and close automatically when the fan motor starts and stops.

#### **4.6.10 Air Conditioning and Ventilation System Recommended**

##### **4.6.10.1 SHP above 100 kW and up to 25 MW capacity**

Provide air conditioning by individual air conditioning units in the required areas (control room).

Provide ventilation system for required no. of air changes by exhaust fans or forced air fans.

##### **4.6.10.2 SHP Micro Hydro Range**

Provide exhaust fans in the generator hall.

#### **4.7 Water Level Sensing**

Fore bay water level sensing is required for all powerhouses.

Tailrace level sensing is required for all canal fall powerhouses for optimum power generation or avoid.

### **5. Design and installation of grounding system for generating station and step up sub stations including earth mats and equipment grounding**

#### **5.1 Introduction**

Grounding system comprises interconnected ground facilities for SHP including ground mat below the powerhouse, tailrace and step up substation, and grounding system network for equipment and safety. The guidelines pertain to design and installation of grounding system for generating station and step up sub stations including earth mats and equipment grounding. System ground fault current and site soil resistivity are the primary basis for design of grounding system. Accordingly the guidelines are divided into following three categories.

- a) Hydro power stations connected to electrical distribution systems up to 11 kV – up to 1000 kW.
- b) Hydro power station connected to sub-transmission system up to 33 kV – up to 5 MW.

- c) Hydro stations connected to transmission system at 66 kV and above – up to 25 MW

## **5.2 Design Objectives**

Design objective in generating station grounding are as follows:

- a) Provide safety ground for protecting personal from injury.
- b) Equipment ground to trip faulted circuit for protection and alarm
- c) To limit potential difference across communication or control lines leaving the station during power system faults.
- d) Neutral ground to provide ground reference of electrical system
- e) Minimum noise interference in electronic control , instrumentation and protection system
- f) Lightning protection

## **5.3 Parameters to be Considered for Designing Earthing System**

- i) Soil resistivity
- ii) Resistivity of the surface material
- iii) Magnitude of fault current
- iv) Duration of the fault current
- v) Material of the earth mat conductor
- vi) Earth mat geometry

### **5.3.1 Site Soil Resistivity Measurements and Installation**

Site soil resistivity measurements should be carried out by 4 probe method to determine average resistivity as detailed in Annexure 1.

Resistivity of soil can vary within extremely wide limits. It depends on the type and nature of soil. Table 12 is indicative of the resistivity of various types of soils and other materials.

## **5.4 Effect of Moisture, salts and Temperature**

It may be noted that the resistivity of a rock is not unique to it and that there is considerable overlapping of resistivity ranges of several rock types, depending on clay content, water saturation, quality of water, salinity and porosity. Dry soil is generally very poor conductor of electricity. Resistivity is much smaller below subsoil water level than above it. Also, if variation in soil resistivity during a year is considered, soil resistivity below water table is more constant than that above this level. The amount of water held in soil is dependent on weather conditions, time of the year and nature of subsoil. In hydro plants, power plant and tail race mat is under wet condition of soil. The soil resistivity may be designed accordingly. The switchyard mat may be designed for dry condition of soil, if necessary provision for pouring water into the earthing rod sumps every few days to keep the soil surrounding the earth pipe permanently moist be made as shown in Fig 5.



**Table 12: Resistivity of various types of soil and other material**

S. No.	Type of Soil	Resistivity (ohm-m)	
		Average	Usual variation
1.	Surface soil (loan –clay and sand and decayed organic matter)	25	5 – 50
2.	Clay (stiff viscous earth chiefly aluminium silicate), black clay	30	8 – 100
3.	Sand and gravel	100	40 – 300
4.	Sand clay and gravel mixture	150	50 – 250
5.	Shale (fine grained sedimentary rock of mud and clay), sandstone wet (sedimentary rock chiefly quartz cemented together), slate, schist	-	5 – 500
6.	Sandstone dry		1000>10000
7.	Surface limestone (chiefly calcium carbonate)		100 – 10000
8.	Concrete, new or buried in earth	100	25 – 500
9.	Concrete dry	10000	200 - 1000000

Source: CBIP Manual 302-2007.

#### 5.4.2 Magnitude of Fault Current

Magnitude of fault current is calculated from the fault level studies. The duration of fault is taken as 1 sec. for voltages above 33 kV and 3 sec for lower voltages.

#### 5.4.3 Material and Size of Conductor

Electrical material does not affect initial earth resistance. Material resistant to corrosion in the type of soil at site is required. Mild steel electrodes with corrosion allowance is mostly used. It is cheaper and easily available.

Size of conductor for earth mat (steel) may be determined as follows in accordance with As per IEEE-80-2000 based on thermal stability

$$A \text{ (for welded joint)} = 12.30 \times I \times \sqrt{t_c} \text{ mm}^2$$

$$A \text{ for bolted joint} = 15.13 \times I \times \sqrt{t_c} \text{ mm}^2$$

Where

A = Area of cross section of the conductor in mm value applicable for steel

I = Fault current rms in KA

t<sub>c</sub> = Time of current flow (1 second for above 33 kV & 3 seconds below 33 kV)

#### 5.4.4 Station Ground Resistance

(i) Earthmat – Consisting of strip and ground rod electrodes

$$R_g = \frac{\rho}{4} \sqrt{\frac{\pi}{A}} + \frac{\rho}{L}$$

R<sub>g</sub> = Station ground Resistance in ohms

ρ = average soil resistivity in ohm m.

A = Area under earthing mat in square meters.



L = Total Length of buried conductor in meters.

Note: In case of a grid rod combination, a combined length of horizontal conductors and ground rods is used.

(ii) Ground resistance of rod/pipe electrodes (Fig-5)

$$R_g = \frac{100 \rho}{2\pi L} \log_e \frac{4L}{D} \text{ ohms}$$

Where

L = length of rod or pipe in cm, and

D = diameter of rod or pipe in cm.

(iii) For Plate Electrodes (Fig 5 )

$$R = \frac{\rho}{4} \sqrt{\frac{\pi}{A}} \text{ ohms}$$

A = Area of both sides of plates in square meters

(iv) Effect of Depth of Burial

To reduce the depth of burial without increasing the resistance, a number of rods or pipes are connected together in parallel (see Fig 5). The resistance in this case is practically proportional to the reciprocal of the number of electrodes used so long as each is situated outside the resistance area of the other (see Fig 6). The distance between two electrodes in such a case is preferably kept not less than twice the length of the electrode.

## **5.5 Grounding System for Powerhouse & Switch Yard**

### **5.5.1 General Requirements of Earthing System for Generating Station and Switchyard**

The requirements as per Indian Electricity Rules as follows:

- a) All medium voltage equipment shall be earthed by two separate and distinct connections with earth through earth electrode. In the case of high and extra high voltages the neutral points shall be earthed by not less than two separate and distinct connections with each having its own electrode at the generating station or substation and may be earthed at any other point provided no interference is caused by such earthing.
- b) Earth electrode shall be provided at generating stations, sub-stations and consumer premises in accordance with the requirements.
- c) Each earth system shall be devised so that the testing of individual earth electrode is possible. It is recommended that the value of any earth system resistance shall not be more than 5 ohms. In case common earth is used for systems of different voltages at a transformation point the combined resistance to earth should be 1 ohm or less for power station and large sub-station.

### **5.5.2 Current Carrying Capacity**

Any conductor, electrode or connection used in a grounding system should be large enough to carry the following currents without excessive heating:

- (i) Fault currents of magnitude and duration such as to produce maximum heating effect.
- (ii) The current caused by a direct lightning stroke, or induced by a lightning stroke may be relatively high but are usually of short duration and, therefore, generally present no problem for grounds that meet the other electrical and mechanical requirements.
- (iii) The current that may be expected to flow in the grounding system as a result of sustained neutral currents.

### 5.5.3 Control of Ground Potentials and Gradients

The grounding system should within reasonable limits, provide a low impedance path to ground for fault currents, neutral currents and lightning discharges, with uniform or near-uniform potentials of earth surfaces in the area under consideration. This result should be accomplished without the occurrence of hazardous potential differences between any surface on which a person may be standing and any surrounding structures or objects within his reach; and also without the imposition of dangerous difference of potential on equipment and circuits.

In situation where the impedance is such that potentials in the vicinity cannot be kept reasonably safe, special arrangements of grounding system should be devised.

Safe body current of an average Indian human being as per CBIP Manual on earthing of AC Power System 2007.

$$I = \frac{0.116}{\sqrt{t}}$$

Where I is rms current through human body (50 kg wt) in amp., t is duration of shock in seconds (time)

#### Maximum Touch and Step Potential

$$\text{Tolerance for sustained touch potential} = \frac{165 + 0.25\rho}{\sqrt{t}}$$

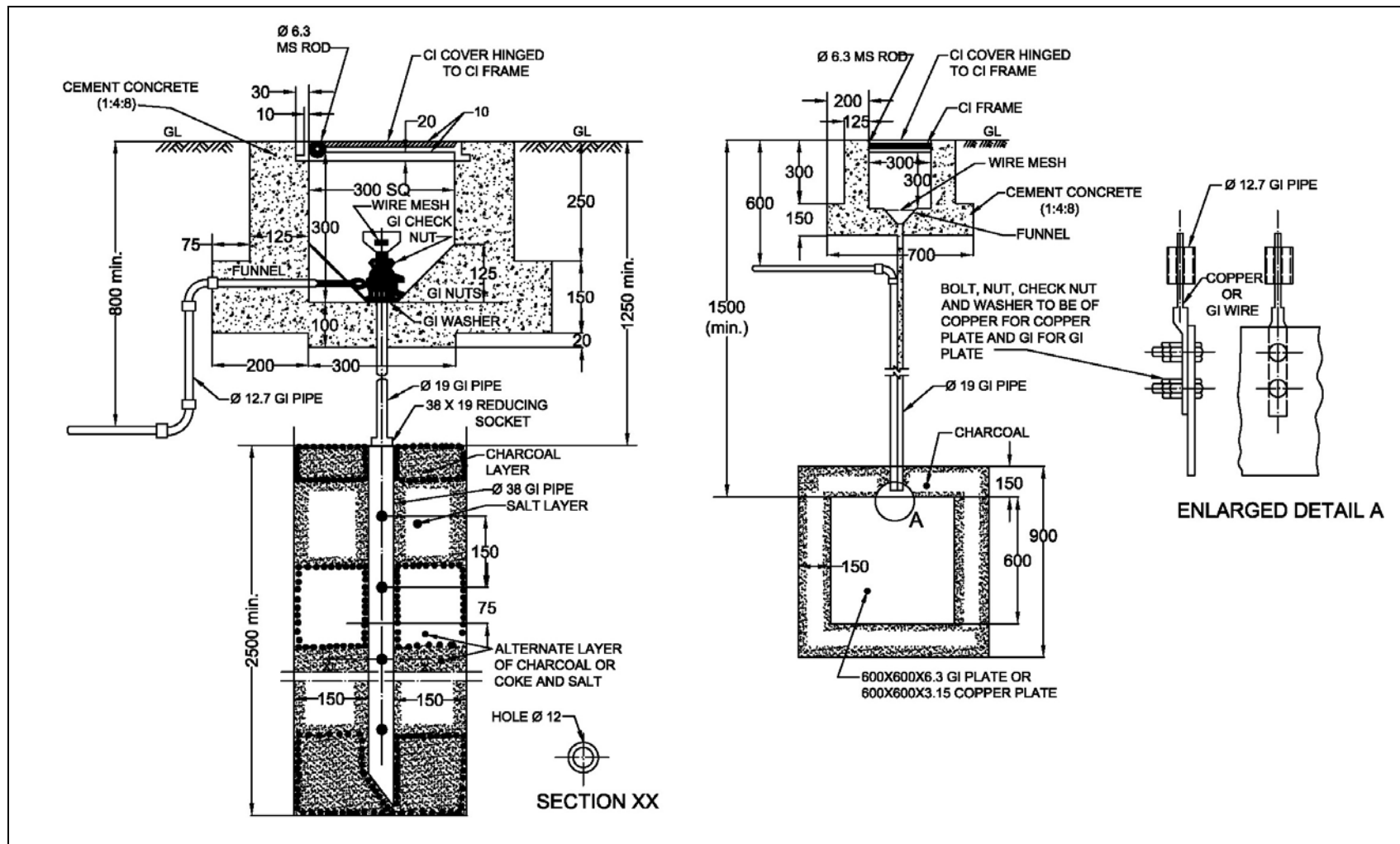
Where,

t = Duration of sustained shock contact in seconds (0.5 seconds as the fault is expected to be cleared much earlier)

ρ = Soil resistivity of top soil layer in ohms-meters.

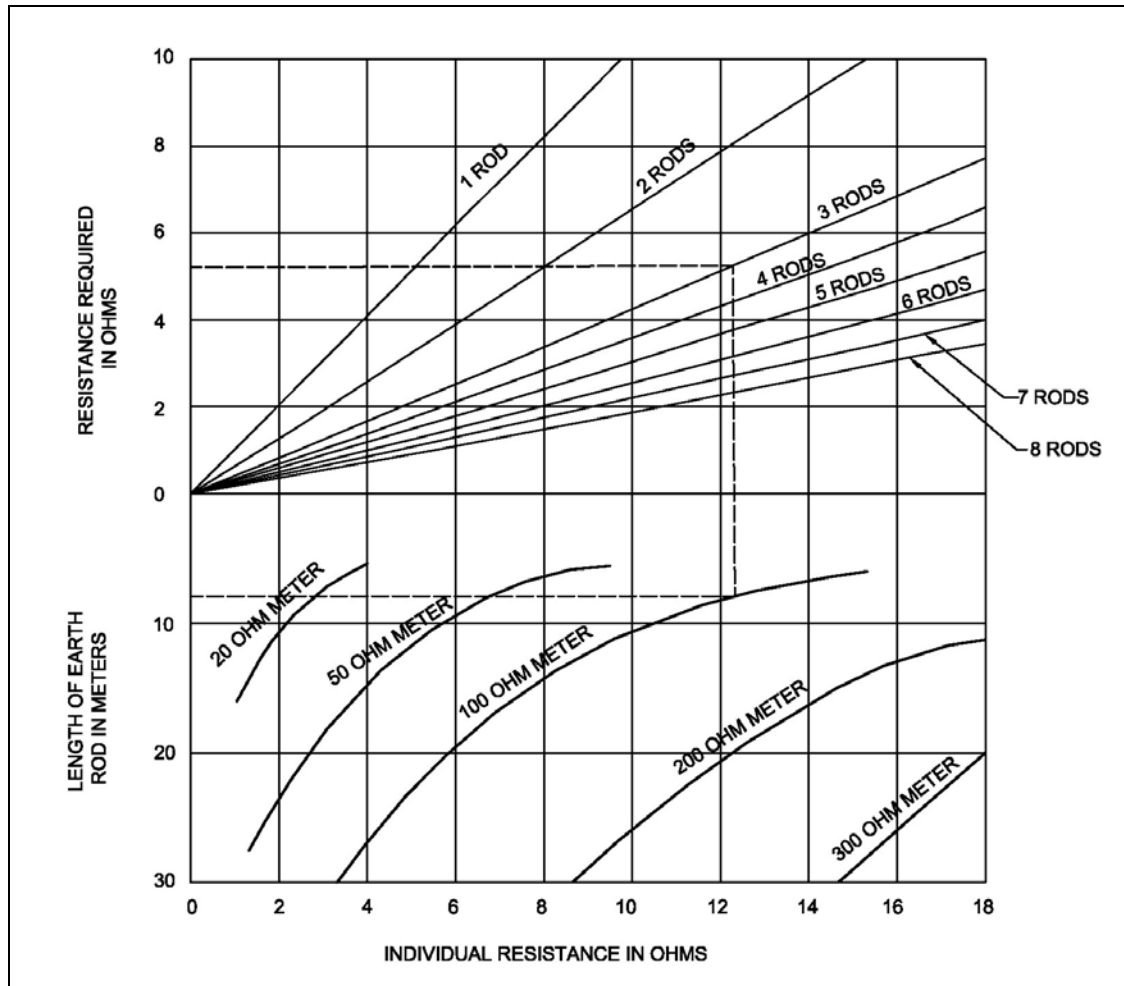
Maximum safe step voltage is given by the following:

$$E_{\text{step}} = \frac{165 + \rho \text{ volts}}{\sqrt{t}}$$



Note: Three or four buckets of water to be poured into sump every few days to keep the soil surrounding the earth pipe/plate permanently moist

**Fig 5: Typical Illustration of Pipe and Plate Earth Electrode**  
(Source: National Electrical Code: SP-30-1985 of Indian Standard Institute Refirmed-2005)



**Fig 6: Resistance of Electrodes at Various Depths and Soil Resistivity**  
 (Source: National Electrical Code: SP-30-1985 of Indian Standard Institute Refirmed-2005)

## Maximum Value of Station Voltage Rise (Transfer Potential) and Station Ground Resistance

The maximum voltage rise of the station ground bus over the potential of a remote point>equals the product  $I_g \times R$  where  $I_g$  is the largest current expected to flow into the ground during power system fault through station ground resistance  $R$ . This voltage appears across communicating or control lines or metal pipes etc. leaving the station.

Maximum potential rise of the station ground bus to about 5000 volts (USBR Practice). Some utilities have adopted much higher values especially in high resistivity areas.

For a ground fault current of  $I_g$  and transfer potential of 5000 volts ground grid resistance ( $R_g$ ) required is worked out as follows:

$$R_g = \frac{E_{transfer}}{I_g} \text{ ohm}$$

Where

$$\begin{aligned} R_g &= \text{Combined ground resistance} \\ E &= \text{maximum permissible transfer potential} \\ I_g &= \text{maximum ground fault current} \end{aligned}$$

In difficult conditions (high resistivity) and large currents the transfer potentials have been kept higher and up to 20,000V have been used. In such cases due care is taken to insulate outgoing low voltage control or communication lines or pipes if any from the station property or avoided.

## Ground Resistance of Powerhouse and Substation

Experience data of the resistance to ground of substation and powerhouse earthmats as per practice of some power utilities in India and abroad is given in Table 13.

**Table 13: Resistance to ground of power plant, tailrace and substation ground mats for SHP and Step up Substations**

Sub Station Voltage	IEEE 80 (2000)	CBIP 290(2006)	TNEBEA Power Engineer's Hand Book	U.S. Army Corps 1994	UPSEB 1978
		(1)	(2)	(3)	(4)
11kV	1 – 5 ohm	5 ohms	Major substation 1.0 ohm	SHP upto 1500 kW – 1 ohm	5 ohm for 11 kV
33kV		-			2 ohm for 33 kV
66 kV	1 ohm or less than	1 ohm for EHV Substation with high fault levels	Small substation 2.0 ohm	SHP above 1500 kW – 0.5 ohm	-
132 kV					
220 kV					

## Maximum Ground Fault Current

Maximum ground fault current in SHP for 1 ohm ground resistance and 5000 volts transfer potential is worked out as follows:

$$I_g = \frac{5000}{1} = 5000 \text{ A i.e. 5 kA}$$

Ground fault current (grid current) in distribution sub-station (upto 33 kV) may not exceed 2500A and 66 kV and 132 kV may not exceed 5000A and may be assumed for design.

### 5.5.4 Mechanical Reliability

The design and installation of conductors, electrodes and connections of a grounding system should be adequate to minimize the possibility of mechanical injury in order to maintain the reliability and continuity of the grounding system.

### 5.5.5 Electrical Reliability

The design and installation of the grounding system should be such as to maintain permanently the performance requirements stated above. This point is of particular significance with regard to electrical connections.

### 5.5.6 Resistance to Corrosion

The design and installation should be suitable for preventing deterioration from corrosion. For this purpose, the installation should be compatible with the surrounding soil, atmosphere and adjacent underground plants.

### 5.5.7 Low Impedance for System Operation

The impedance of the grounding system should be sufficiently low to stabilize system potentials with respect to ground; to provide positive operation of over current devices; to improve voltage regulation and to restrict neutral potentials to suitably low values in those circuits where the grounding system is required to carry portion of the neutral current.

### 5.5.8 Provision for test and Inspection

It is important that the condition of the grounding system at each installation may be known at any time. Therefore, the design of the grounding systems should be such as to permit adequate testing and inspection.

### 5.5.9 Grounding Material

Steel grounding material is used due to cost considerations and easy availability with adequate sizes for earth fault currents, mechanical considerations and provision for corrosion etc. for duration of life of the civil structure.

Minimum size of steel earth mat conductors based on thermal stability for welded joints is given by following formula (CBIP Manual).

$$A = I \times 12.30 \sqrt{tc}$$

Where,

$$\begin{aligned} A &= \text{Cross sectional area in mm}^2 \\ I &= \text{Current in kilo amperes} \\ tc &= \text{Time of current flow in seconds (1 sec.)} \end{aligned}$$

The ground mat is laid below the power plant and substation structures. Taking the life of hydro power plant building as 100 years, table 14 gives the effective cross sectional area after 75 years of the ground conductors for some common sizes of MS flats in low resistivity areas.

**Table 14: Effective of cross sectional area after 75 years**

S. No.	Standard M. S. flat		Loss due to corrosion		Effective cross Section area after 75 years (col. 3 – col. 5)
	Size Maximum	Cross-sectional area mm <sup>2</sup>	In weight grams	In cross sectional area mm <sup>2</sup>	
1	2	3	4	5	6
1.	25 x 6	150	9.3	120	30
2.	35 x 6	210	12.3	160	50
3.	50 x 6	300	16.8	210	90
4.	50 x 8	400	17.4	220	180

Assuming the ground fault current of 2500A for 33 kV substation and assuming a growth factor of three the fault current for determining the minimum size of earthing conductor may be assumed as 7500 A.

$$A = 7.5 \times 12.30 \text{ mm}^2 = 92 \text{ mm}^2$$

Standard size of 50 x 6 ms flat as per IS: 1730-1989 and CBIP 223-1992 is generally provided as grounding buried conductor to take care of future expansion and corrosion in moderately corrosive soils.

Size of grounding conductors recommended for earthing system including equipment grounding is given in table 15 for uniformity.

**Table 15: Size of grounding conductors recommended for earthing system including equipment grounding**

Equipment	Buried conductor	Conductor above ground & in trenches
Main station grid	25 mm dia. & 2.5 m long MS rod; 50 x 6 MS flat	50x6 mm GS flat
Switchgear/MCC	--	50x6 mm GS flat
415 V distribution boards	--	50x6 mm GS flat
HT motors	--	50x6 mm GS flat
LT motors above 125 kW	--	50x6 mm GS flat
LT motors - 25 to 125 kW	--	25x6 mm GS flat
LT motors - 1 to 25 kW	--	25x3 mm GS flat
Fractional HP LT motors	--	8 SWG GS wire
Control panel & control desk	--	25x3 mm GS flat
Push button stn. & Junction box	--	8 SWG GS wire
Cable trays, cols. & structures	--	50x6 mm GS flat
Bus duct enclosures	--	50x6 mm GS flat
Rails & other metal parts	--	25x6 mm GS flat
Eqpt. earthing for switchyard equipment	--	50x6 mm GS flat and 50x6 mm GS flat

## **6 GENERATING STATION GROUNDING DESIGN- POWERHOUSE AND SUBSTATION**

### **6.1 Design Procedure**

- i) Grounding system in the power plant generally consist of the following.
  - a) Generating station ground mat
  - b) Tailrace ground mat
  - c) Substation ground mat

All the three mats are interconnected.

- ii) Practical design of grid should usually start with an inspection of the layout plan for equipment and structures.
- iii) A continuous grounding conductor should surround the grid parameter, to enclose as much ground area as practicable.



- iv) Within the grid; grounding conductors should be laid in parallel lines and preferably at reasonable uniform spacing of 3 m to 6 m.
- v) Depth of burial of grounding conductor may be fixed from 150 mm to 600 mm depending on the nature of the soil.
- vi) The preliminary design should be adjusted, so that the total length of the buried grounding conductor, including cross connection and rods, is at least equal to that computed in para 5.4.4, in order to keep the local potential differences within acceptable limits.
- vii) A typical earth mat is shown in fig 19. In a very high resistivity soil, it might be desirable to drive the rods/deeper.
- viii) If low station resistance is not otherwise obtained; one or more ground beds or wire mesh or rods or another loop at location of low soil resistivity away from the station area can be installed and interconnected.

**Notes:**

1. For having low station ground resistance, a simple loop encircling the largest area available, is the most economical design. Other consideration such as potential gradient control etc. may dictate a grid.
2. With dimensions or grid generally encountered, resistance of the grounding conductor, the cross sectional area; depth of burial and increase in the number of meshes within a grid, has very little affect on the total station grid resistance.
3. Selection of material and its dimensions are governed mainly by mechanical strength; corrosion; & current carrying capacity considerations.
4. Spacing; length; size and depth of burial of grounding conductor are governed mainly from potential gradient considerations. So far as internal gradients are concerned, these can be kept to any desired value by keeping the general mesh spacing throughout the station, reasonably uniform and sufficiently close, so that the mesh potentials, even at corners are within acceptable limits. Another alternative possibility is to use a somewhat wider mesh over most of the area and correcting the situation near the corners by using closer mesh.
5. To reduce touch voltage from outside, a perimeter earth conductor be laid outside the fence at the same depth as the conductor of grid earth conductor. This conductor is made part of earth electrode is electrically connected to the fence. Generally rods cost less than deep grid for equal resistance and are preferable.

## **6.2 Generating Station Ground Grid Design**

Difference between substation and generating station grounding grid design are as follows:

Persons inside the power house are not exposed to many of the step and touch voltage condition of sub-stations. IEEE guide 665 and CBIP Pub. No. 302-2007 recommends that separate grid for step and touch voltage criteria is not required in generating station. Ground mat be laid as follows:-

- a) Outer grid conductor comprising the largest rectangle enclosing the power house should be provided at a distance of 1 m from building. Spacing of buried earth conductors should be about 3-4m.
- b) A similar earth mat be laid under the tailrace and interconnected with powerhouse mat.
- c) The sub-station ground mat should be interconnected to generating station grounding grid.
- d) Adequate number of risers a minimum of two should be taken from the earth conductors laid under the floor for safety grounding separate risers be taken for neutral grounding.
- e) Inside the powerhouse building an earth ring be installed along outer wall of each floor of the building.

### 6.3 Design Values

To meet the design objective given above, values of following item must be determined.

- a) Value of soil resistivity for surface layers and deeper layers at the station site area.
- b) Maximum and sustained values of ground fault current
- c) Maximum safe value of potential gradient (potential difference) and station voltage rise to avoid hazard to life and equipment.
- d) Maximum acceptable value of ground grid resistance
- e) Material and size of grounding conductor (steel).

### 6.4 Site Soil Resistivity

Average Value of resistivity be assumed for design for 30% variation in apparent resistivity (Annexure 1).

### 6.5 Ground fault Current

Single line to ground fault is considered for determining earth fault current. Symmetrical component of this current  $I_G$  assuming zero fault resistance and neglecting resistance (positive, negative and zero sequence) which is negligible at the time of initiation.

$$I_G = \frac{E}{X_1 + X_2 + X_0}$$

Where,

$E$  = Nominal phase to neutral voltage

$X_1$ ,  $X_2$  and  $X_0$  are positive, negative and zero sequence reactance

$I_f$  = symmetrical single phase to earth fault current

$$I_f = 3 I_G$$

Grid current  $I_G$  is the part of the current which is returned to local generators via neutral.

$$S_f = S_f I_f$$

Where  $S_f$  is fault current division factor. In case SHP generator transformer are  $\Delta/Y$ . Current fed to the fault from generator transformer does not return through earth as it cannot flow through Delta winding and

$$I_f = I_G$$

The single line to ground fault current can be calculated by sequence impedance network or by simulating the system network with digital computer software.

Value of grid current adopted for earth mat design should be increased by a factor of say 1.5 to take care of future change and use of decrement factors to determine effective current during a given time interval depending upon fault clearance time.

## 6.6 Magnitude of fault Currents and Grid Current at SHP

Magnitude of fault Current calculated for 2 units rated 8 MW, 11 kV and 0.85 p. f. connected to 33 kV through 11 MVA 11/33  $\Delta/Y$  transformer by 12 km long lines. SLD is shown in Fig. 7 (Example is given in CBIP Pub. 302-2007).

Maximum grid current - 1373A

For design of earth mat:

-Single line to ground fault current

-On 33 kV bus at SHP - 4485 A

-Grid current ( $I_G$ ) - 1373 A

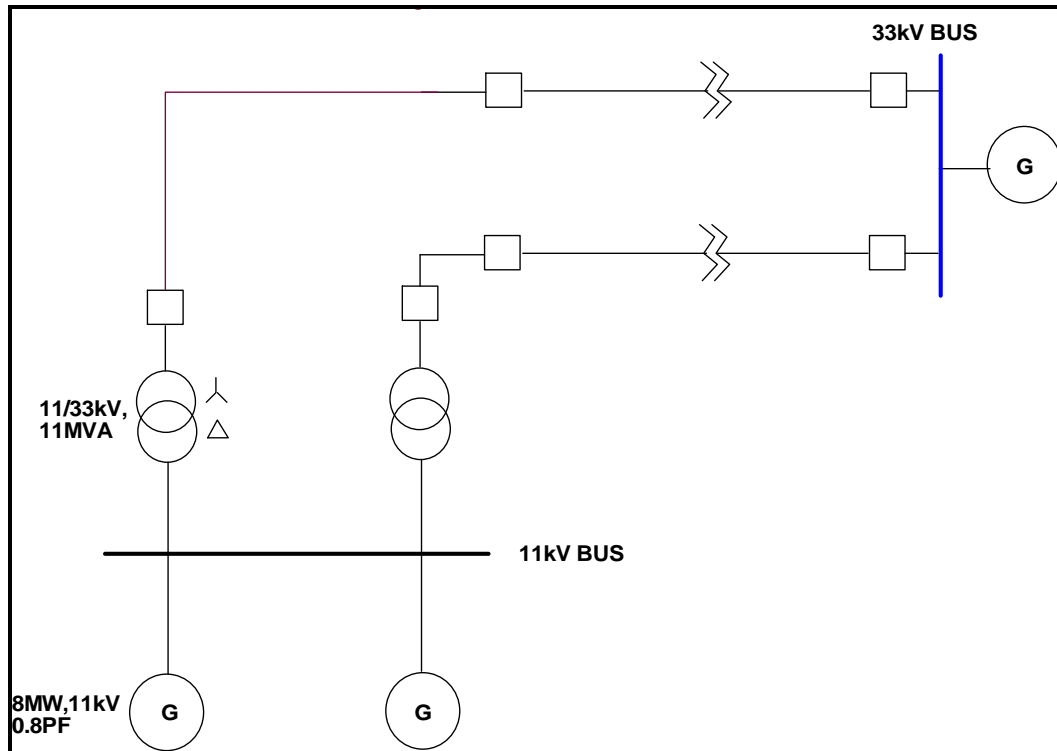
## 6.7 Design of Grounding Systems for SHP up to 100 kW capacity generating at 415 V

For such power station earthing is to be provided as per REC Standards-1994: “Specification and construction standards” and Indian Electricity Rules as shown in Fig 8. Neutral should be earthed by a separate earth rod.

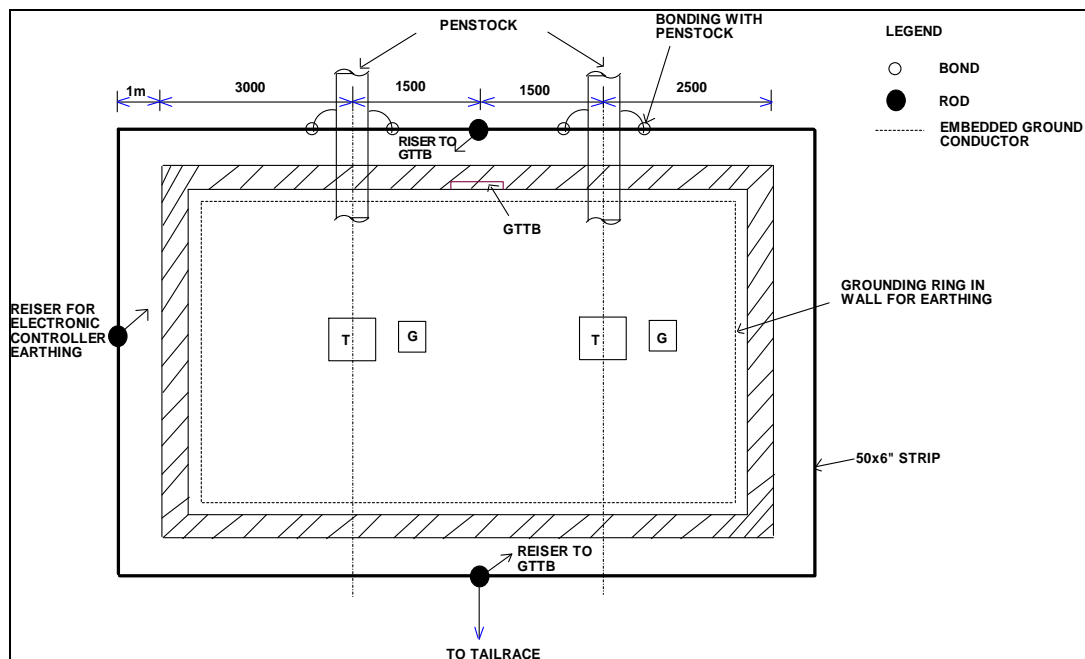
In case an 11 kV pole mounted station is provided then it may be earthed as shown in Fig 8 and Fig 9. The neutral electrode should be at least one pole span away from the generator neutral.

As per Indian Standard hydro generators with generation voltage at 415V require earthing by 2 separate and distinct connections with earth. Further neutral ground is to be provided for reference of electrical system.

Further step up substation if at 11 kV also requires three electrodes for earthing and lightning arrestor. Substation earth mat be designed for safe mesh potential (safe touch and step potential).



**Fig. 7: SLD for 2x8MW units, 11 kV and 0.85 p.f. connected to 33 kV through 11 MVA 11/33 Δ/Y transformer by 12 km long lines**



**Fig 8: Grounding System for SHP below 100 kW capacity generating at 415 V and transmitting at 11kV**

Ground Resistance for various values of earth resistivity are shown in Table 16

$$R_g = \frac{\rho}{4} \sqrt{\frac{\pi}{A}} + \frac{\rho}{L}$$

**Table 16: Ground Resistance for various values of earth resistivity**

Ground Resistance	Soil Resistivity (ρ) in ohm meter					Remarks
	10	25	50	100	200	
R <sub>g</sub>	0.85	2.1	4.2	8.5	17	In case of high resistivity i) Extend the ring on the tailrace site ii) Connect with the switchyard mat iii) Use deep driven rods

**Notes:** Soil Resistivity should be taken in wet condition, which will be much lower

## **6.8 Grounding system design for SHP up to 5 MW and connected to grid at 33 kV and below and earth resistivity up to 100 ohm meter**

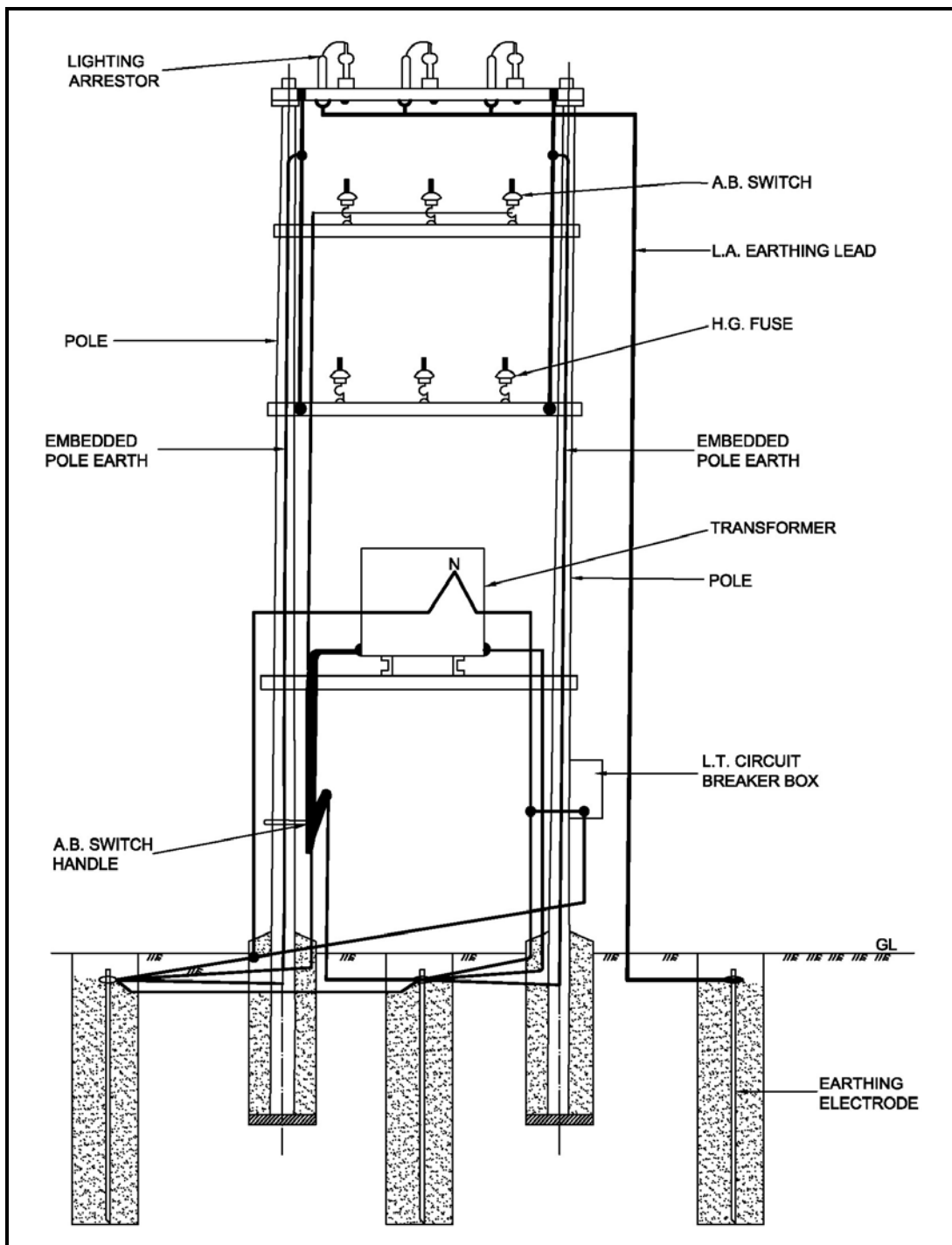
### **6.8.1 General**

Design is based on design practices for generating station and sub-station.

### **6.8.2 Earthing Practice of Sub Station**

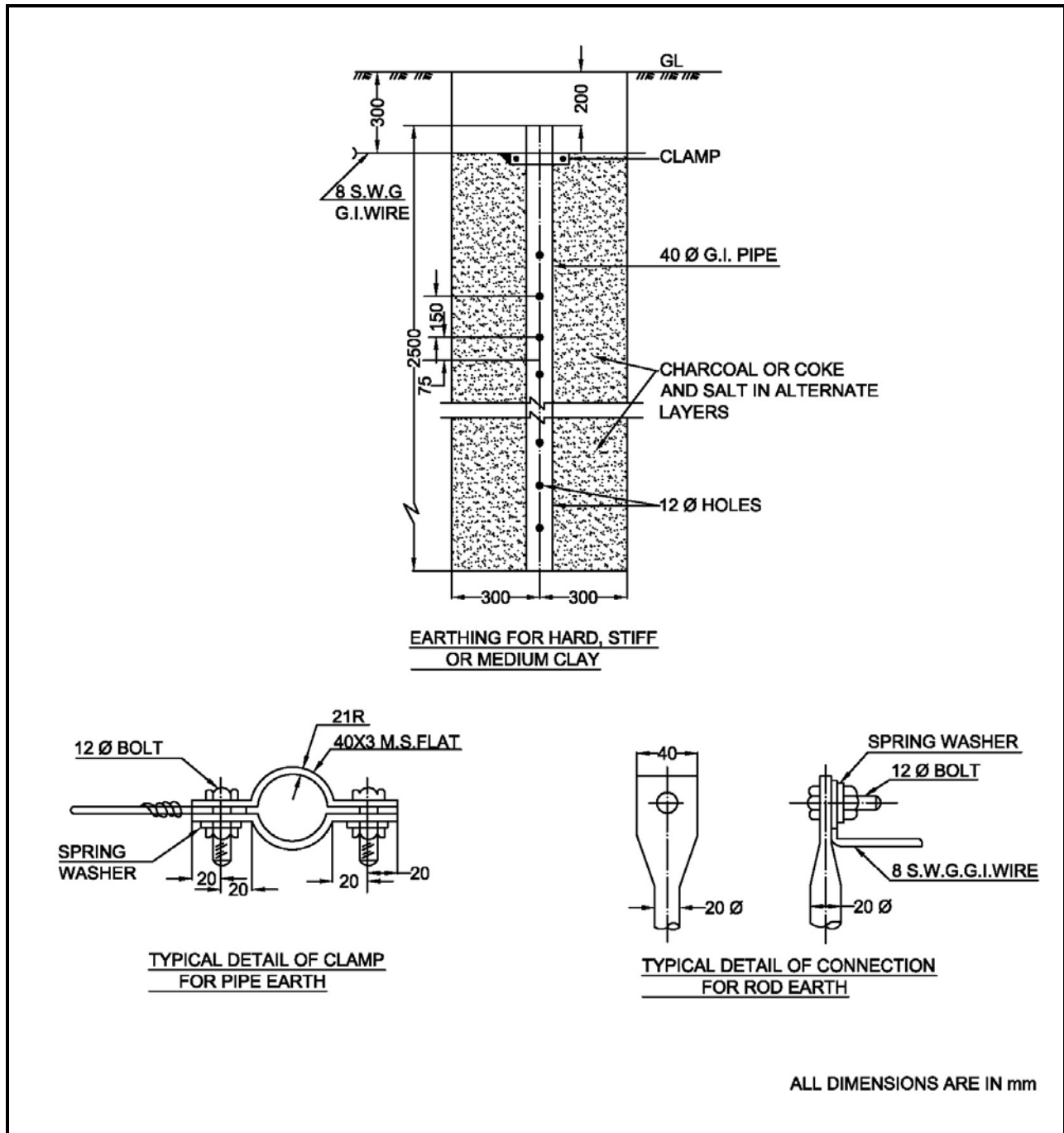
11 kV substations earthing (as per CBIP: 250-1996) is shown in Fig 11 and Fig 12.

33 kV substations earthing (as per CBIP: 223-1993) is shown in Fig 13.

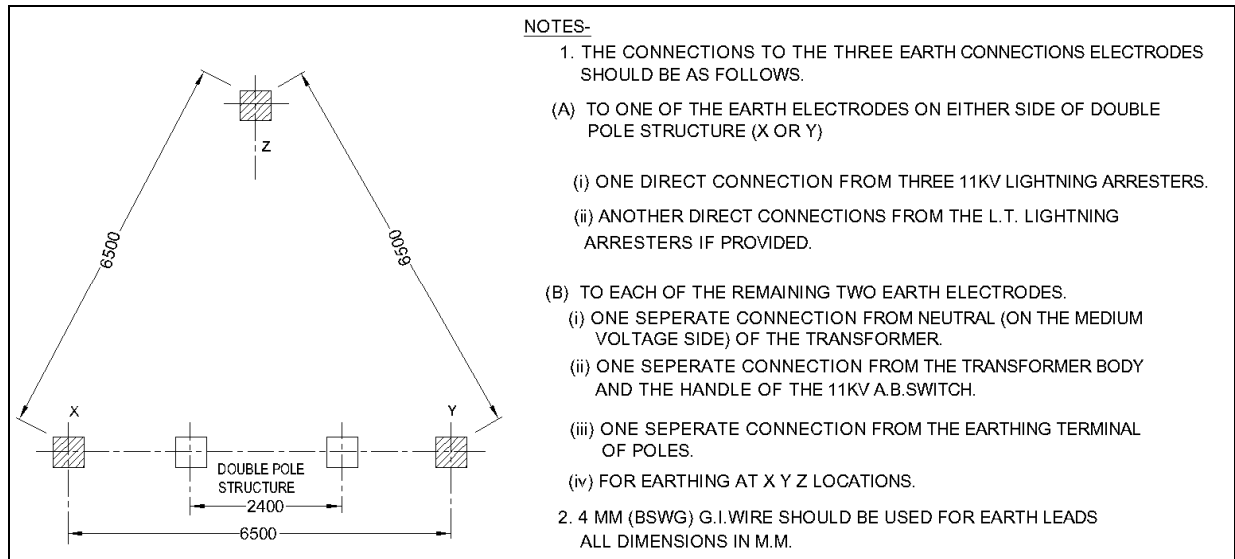


**Fig 9 : Earthing Arrangement for Distribution Sub-Station (Pole Mounted)**  
(Source: CBIP: 250–1996)

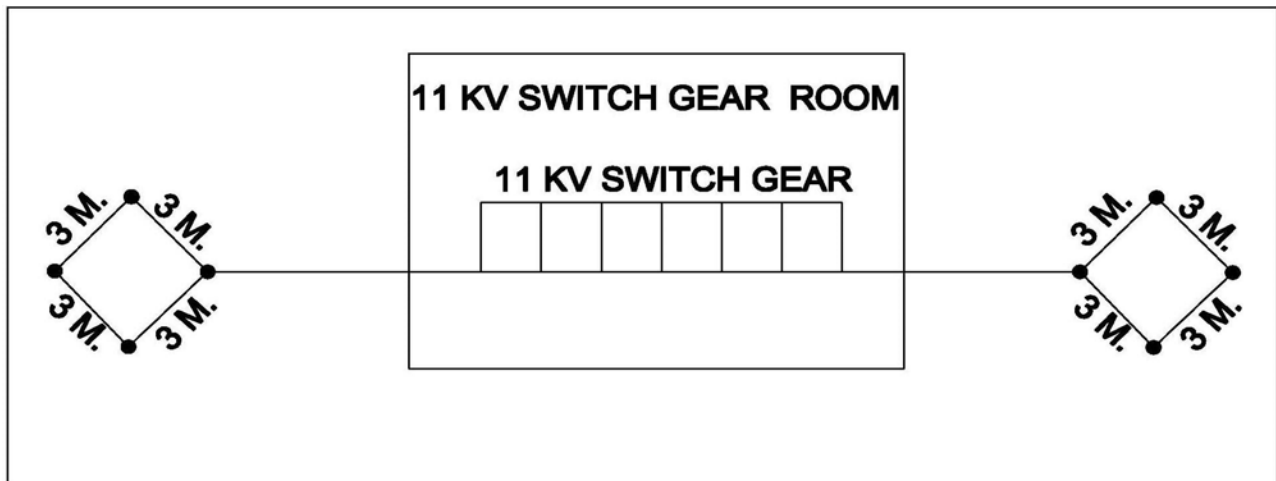
- Notes:**
1. Neutral electrode G should be one span away from powerhouse neutral
  2. Special arrangements below A. B. Switch handle be made as per IS: 3043 in case earthing resistance is more than 5 ohms.



**Fig 10: SHP up to 100 kW Capacity – Earthing System**

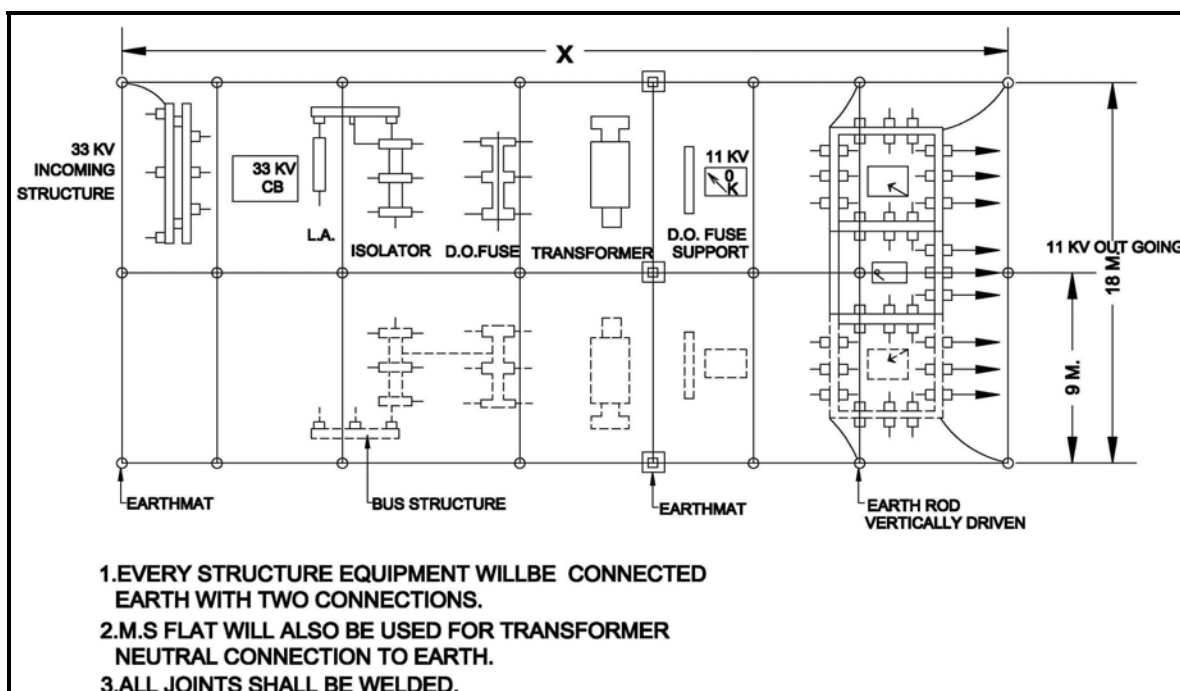


**Fig 11: 11 kV/433-250 V, Distribution Sub Station Location of Earth pits and Connections (Source: CBIP: 250-1996)**



**Fig 12: Grounding Arrangement for 11 kV Sub Station**





**Fig 13: Earthing Arrangement in 33/11 kV Substation**  
 (Source: CBIP: 223-1992)

#### Sub-Station Earth Mat for 33 kV Sub Station (UPSEB Practice-1978)

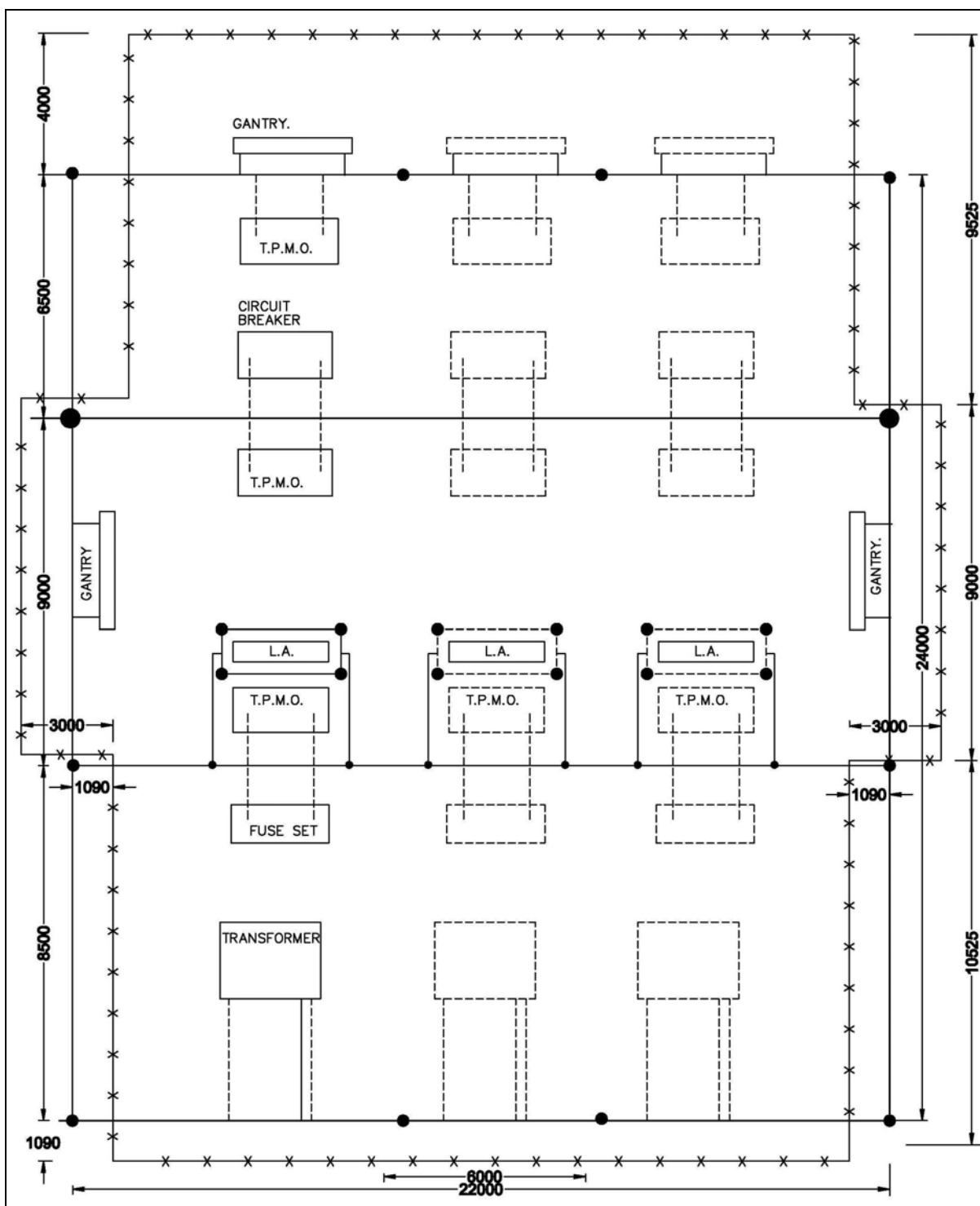
For 33 kV Substation having capacity up to 10 MVA the earth mat be designed as per UPSEB Guidelines as tabulated in Table 17 below:

**Table 17: Design of earth mat for 33 kV Substation having capacity up to 10 MVA**

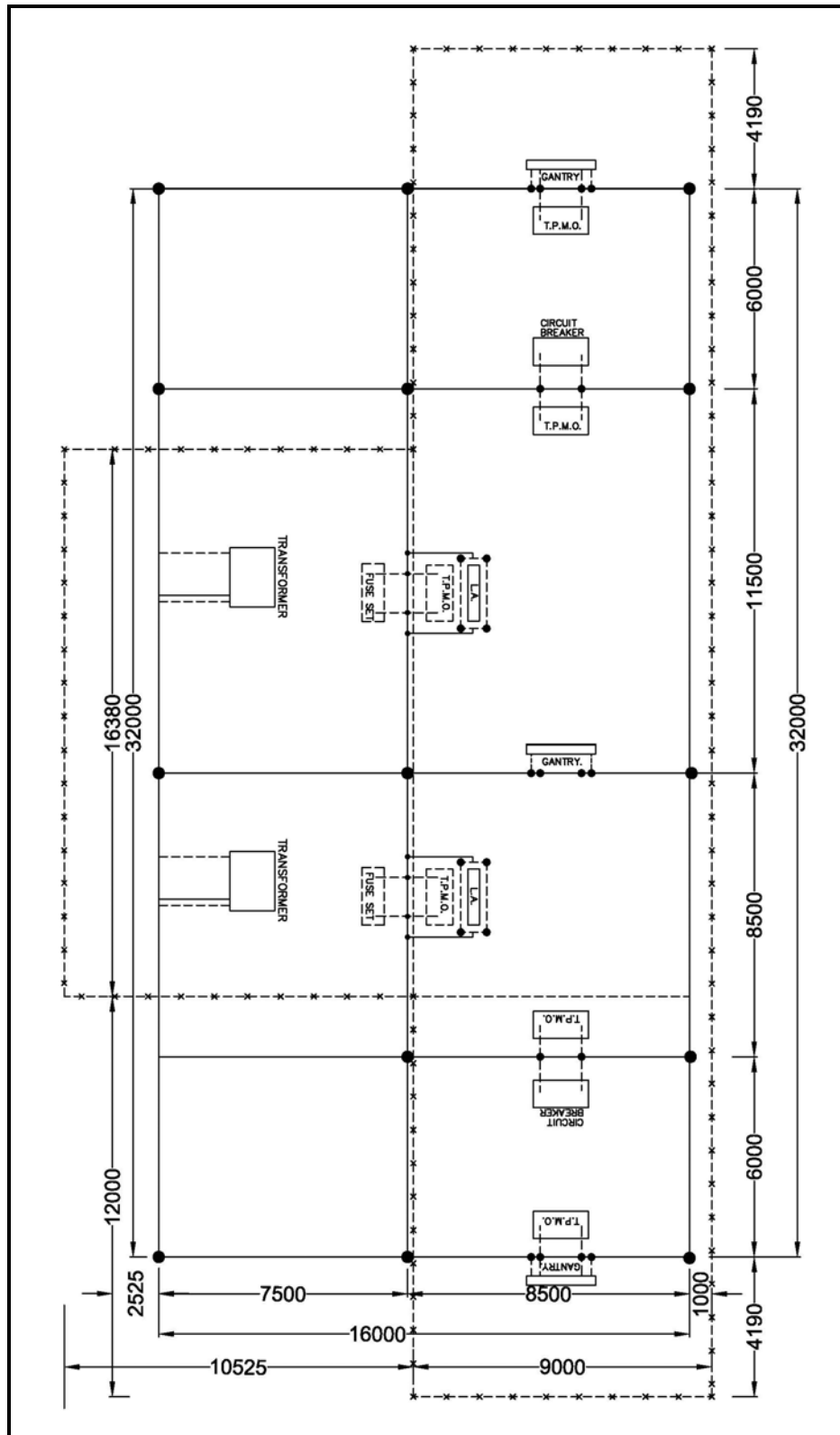
S. No.	Soil Resistivity	Size of Earth Mat	Drawing No.
1.	20 to 70 ohm-meters	22 M x 24 m	5.4
2.	- DO -	16 M X 32 m	5.5
3.	Up to 250 ohm-meters	21 M X 42 m	5.6

Except in the hill regions, the soil resistivity generally varies from 20 to 70 ohm-meters. Thus the actual resistance of sub-station earth mat will be even less than 2 ohms. At each substation soil resistivity should be measured by 4 electrodes method. Where it is within the range, the proposed earth mat may be laid. However, it is more than 70 ohm-meters the earthing system will have to be designed separately.

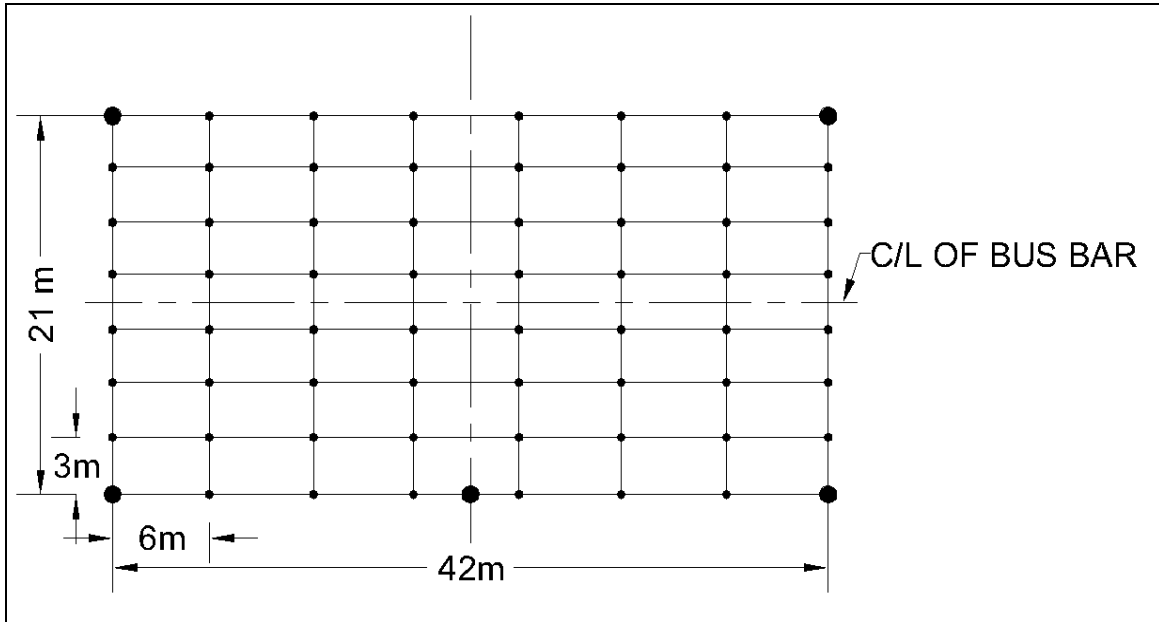
Fig 14 shows grounding arrangement for 33 kV S/S with feeders at right angle to bus bars (for layout of S/S), Fig 15 shows grounding arrangement of 33/11 kV Sub-Station with two feeders (parallel to bus bar) in opposite direction , Fig 16 shows grounding arrangement for 33/11 kV S/S with earth resistivity 250 ohm-meter and Fig 17 shows typical power plant ground mat and network.



**Fig 14: Grounding arrangement for 33 kV S/S with feeders at right angle to bus bars (for layout of S/S)**



**Fig 15: Grounding arrangement of 33/11 kV Sub-Station with Two Feeders (Parallel to bus bar) in opposite Direction**



**Fig 16: Grounding arrangement for 33/11 kV S/S  
with Earth Resistivity 250 ohm-meter**

### 6.8.3 Allowable values of resistance of grounding system

It is recommended that earth resistance of grounding system for 33 kV substations should not be more than 2 ohms and that for 11 kV sub stations and power house not more than 5 ohms.

**6.8.4 Earthmat** is laid under Generating Station, sub-station and tailrace and interconnected to each other so as to achieve overall earth resistance of not more than 2 ohms for 33 kV sub-station and 5 ohm for 11 kV sub-station.

### 6.8.5 Earthmat under Generating Station

As per IS Medium voltage (415 volts) generators require earthing by 2 separate and distinct connections with earth. Further neutral ground is to be provided for reference of electrical system. Normally neutral is grounded through resistance and ground fault current is limited by the resistance. Therefore three electrodes are sufficient.

Further step up substation if at 11 kV also requires three electrodes for earthing and lightning arrestor.

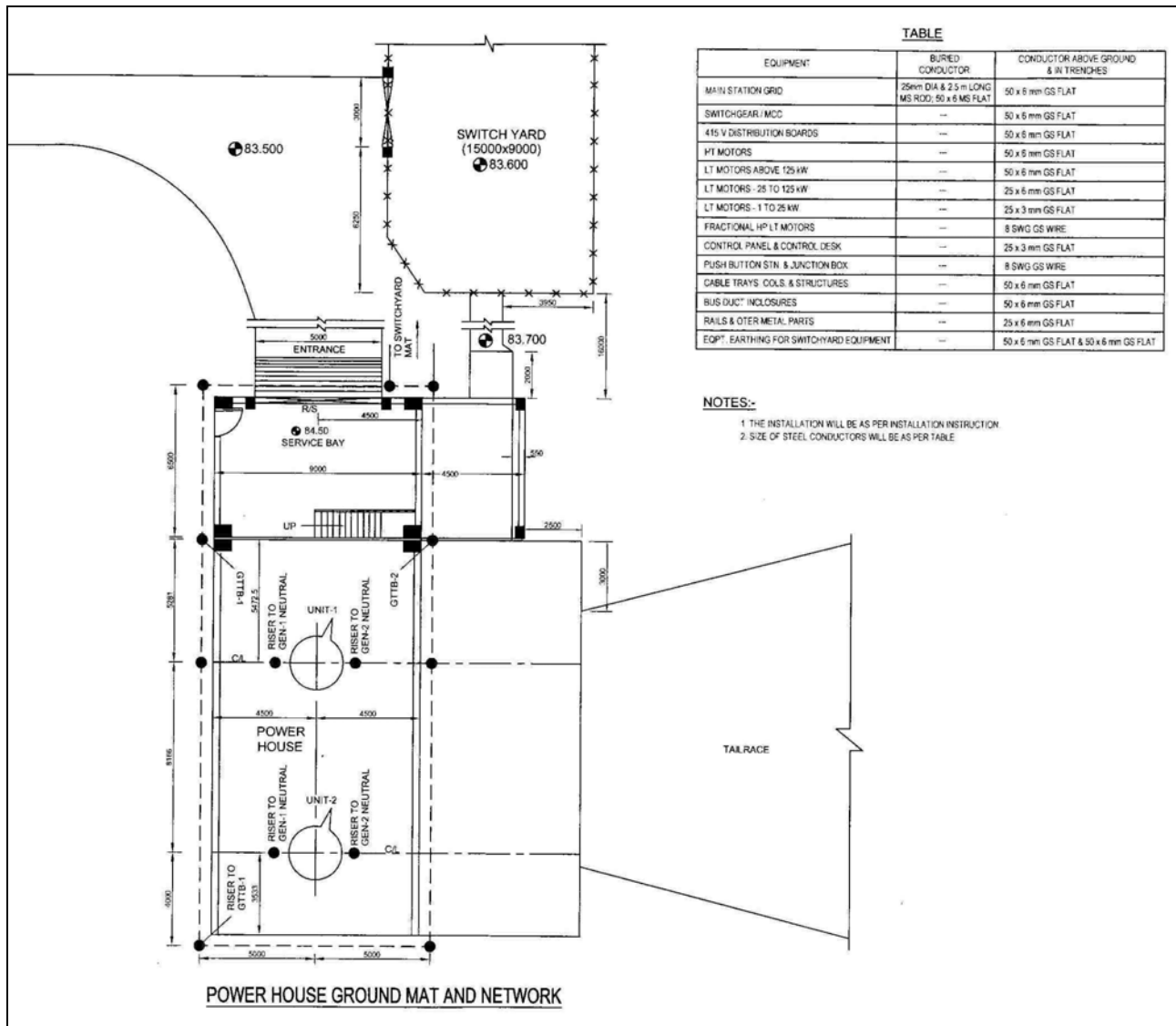
For purpose of uniformity in design following be adopted for all generating stations.

- Provide an outer grid conductor comprising largest rectangle enclosing powerhouse. The conductor should be 1 m from outside well.

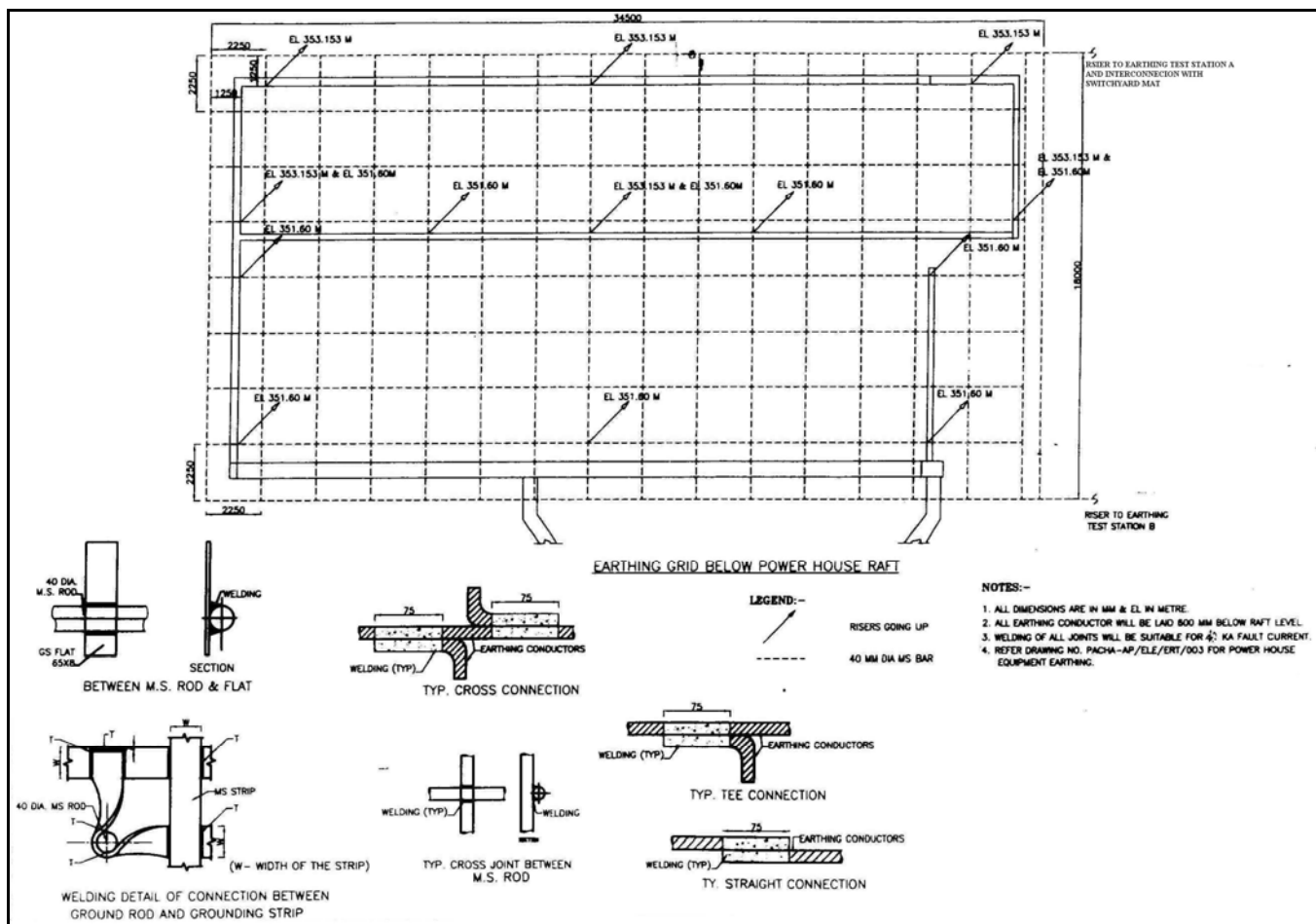
- b) Provide earth conductor in between at spacing of about 4 m.
- c) Provide interconnection with sub-station grounding system if required.

### 1.6.8.6 Typical Examples of earth mats

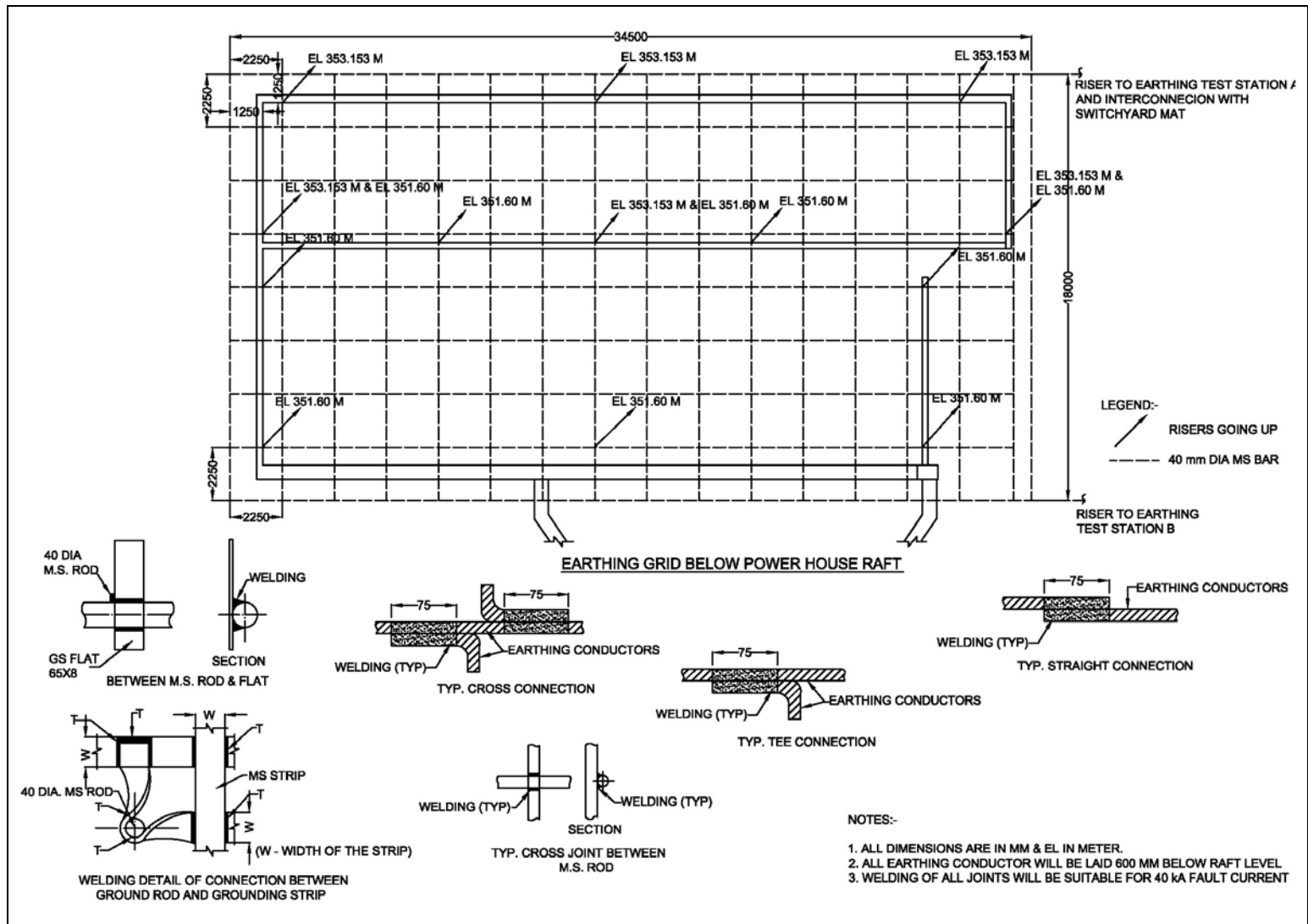
These are shown in Fig 17(a), Fig 17(b), Fig 18(a), Fig 18(b) and Fig 19.



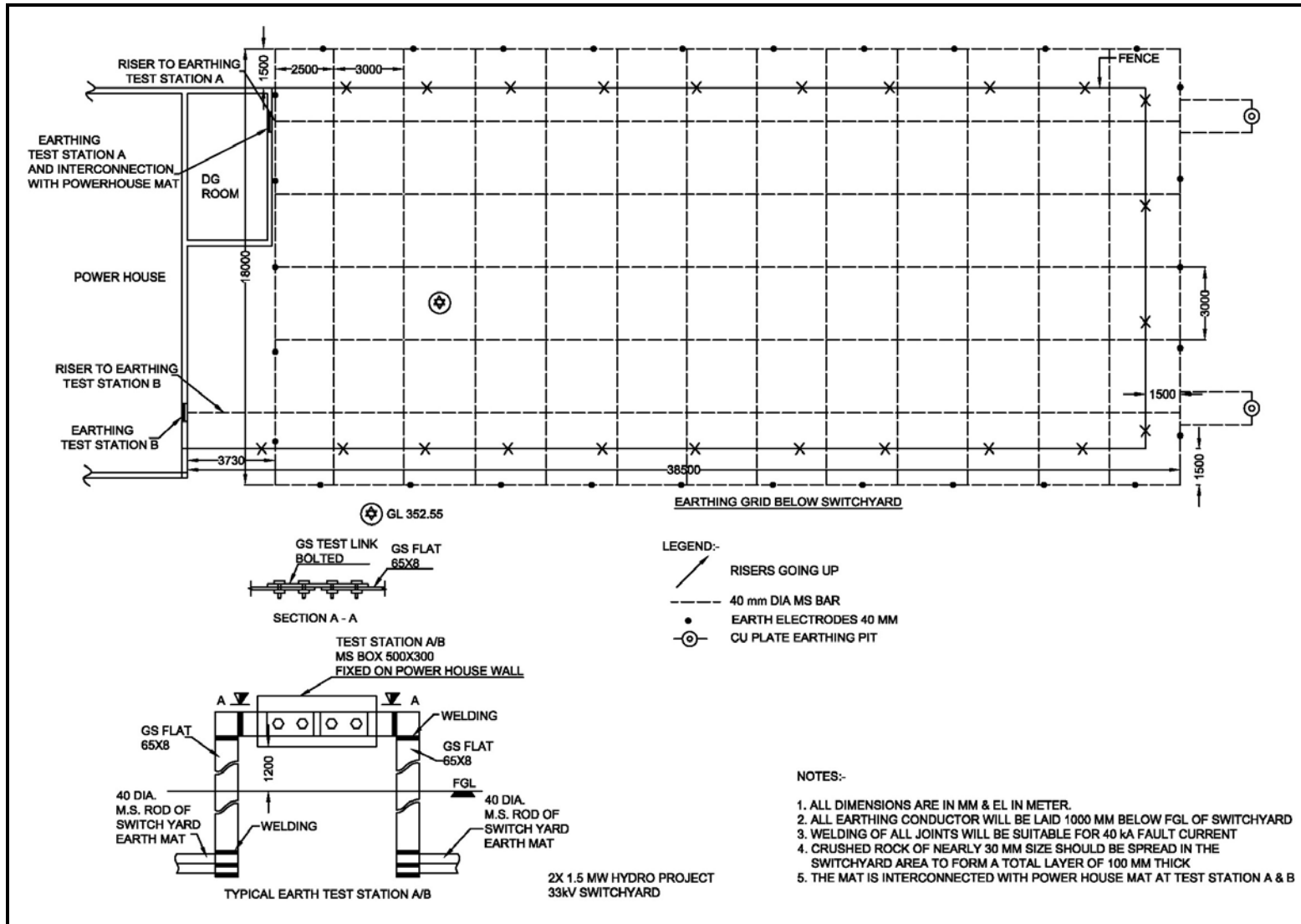
**Fig 17 (a) : Typical Power Plant Ground mat and Network**



**Fig 17(b): Typical Power Plant Ground mat and Network**

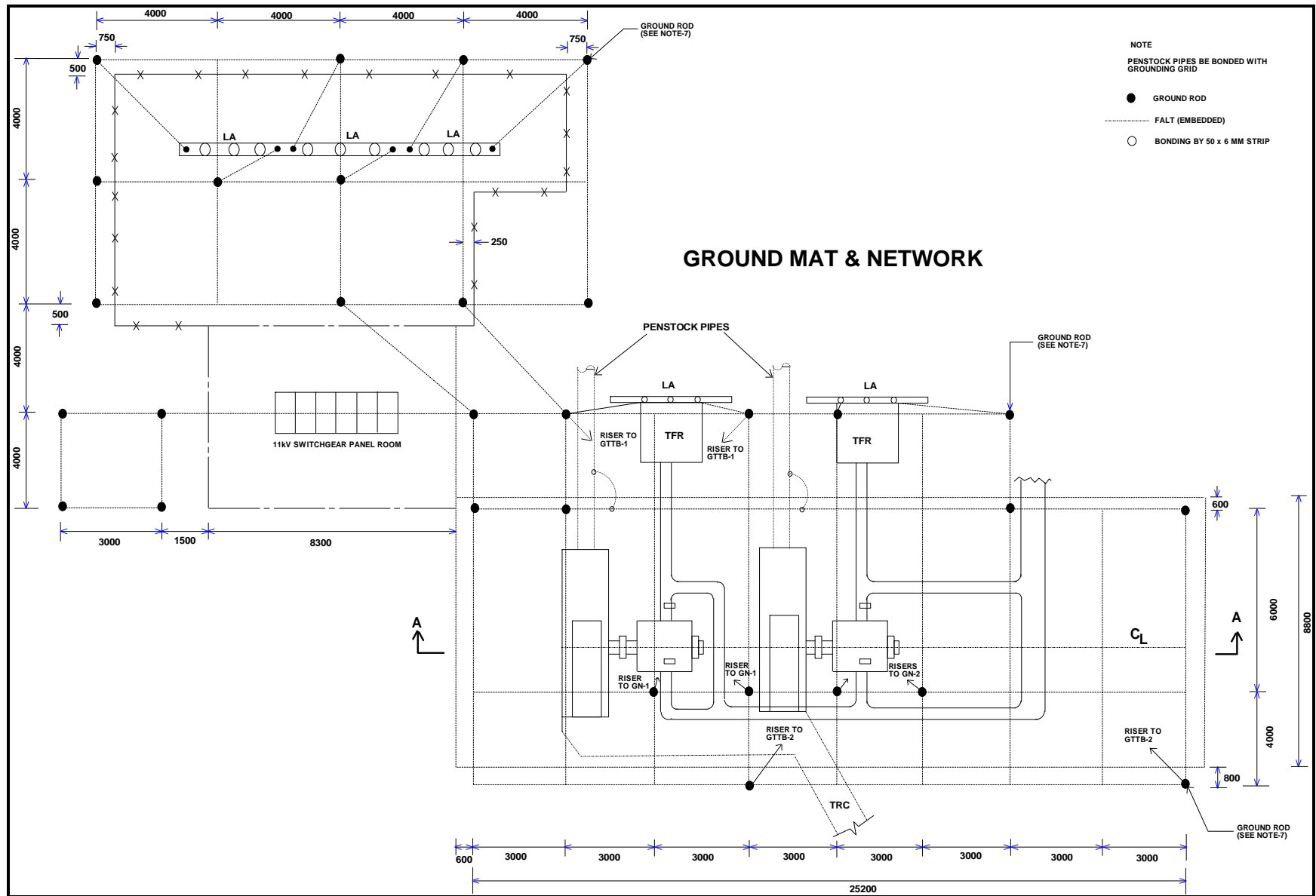


**Fig 18 (a): Typical Layout for Powerhouse Earth mat for 2 x 1.5 MW Project**



**Fig 18 (b) : Typical 33 kV Switchyard Earth mat for a 2x1.5 MW Project**





**Fig 19: Typical Earth mat of a Hydro Power Plant**

## 6.9 Grounding System SHP above 5 MW or Interconnected with grid above at 66 kV and above

Detailed design on the basis of earth fault current and soil resistivity measurements should be done. A ground mat should be laid under the powerhouse; sub-station and tailrace. The three mats should be interconnected.

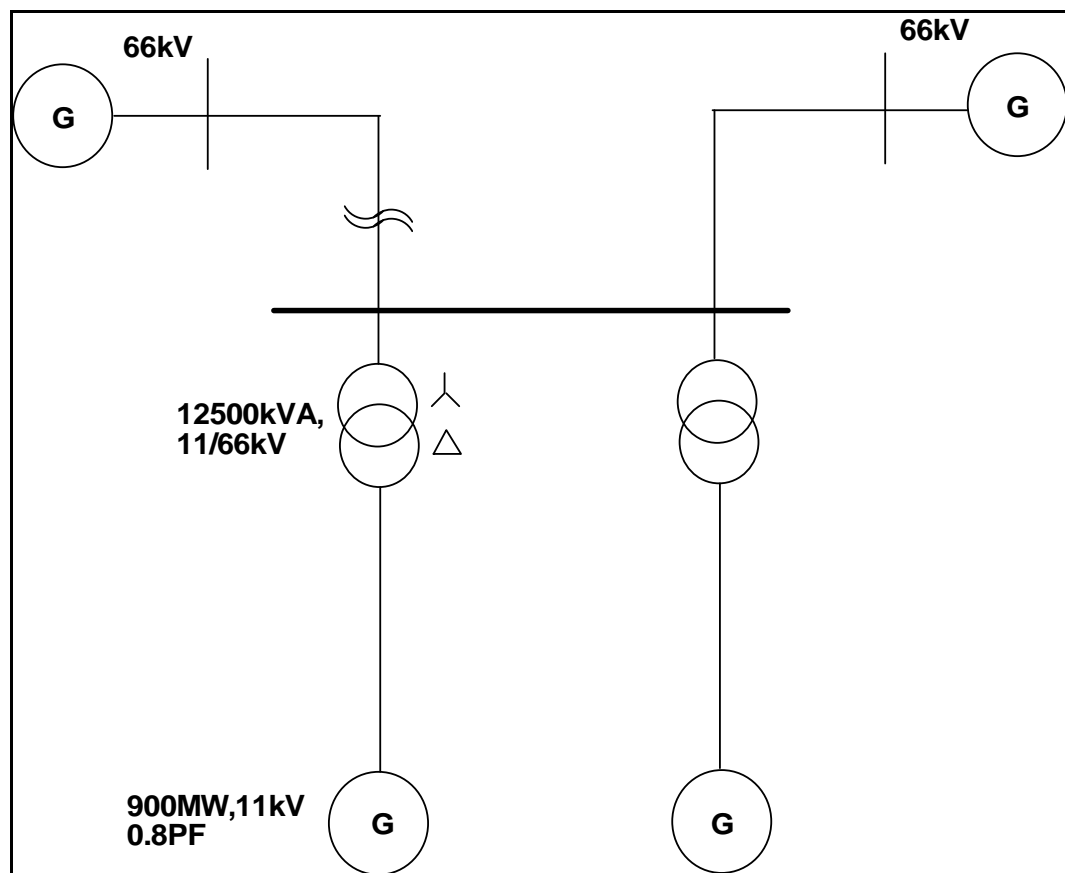
### 6.9.1 Typical Examples

#### (2 x 9 MW Capacity SHP)

Single line to ground fault current for a typical Power Plant interconnected with grid at 66 kV is shown in Fig 20 is as follows:

Single line to ground fault current = 31.5 kA (specified)

Grid current for earth mat design = 18.9 kA (calculated)



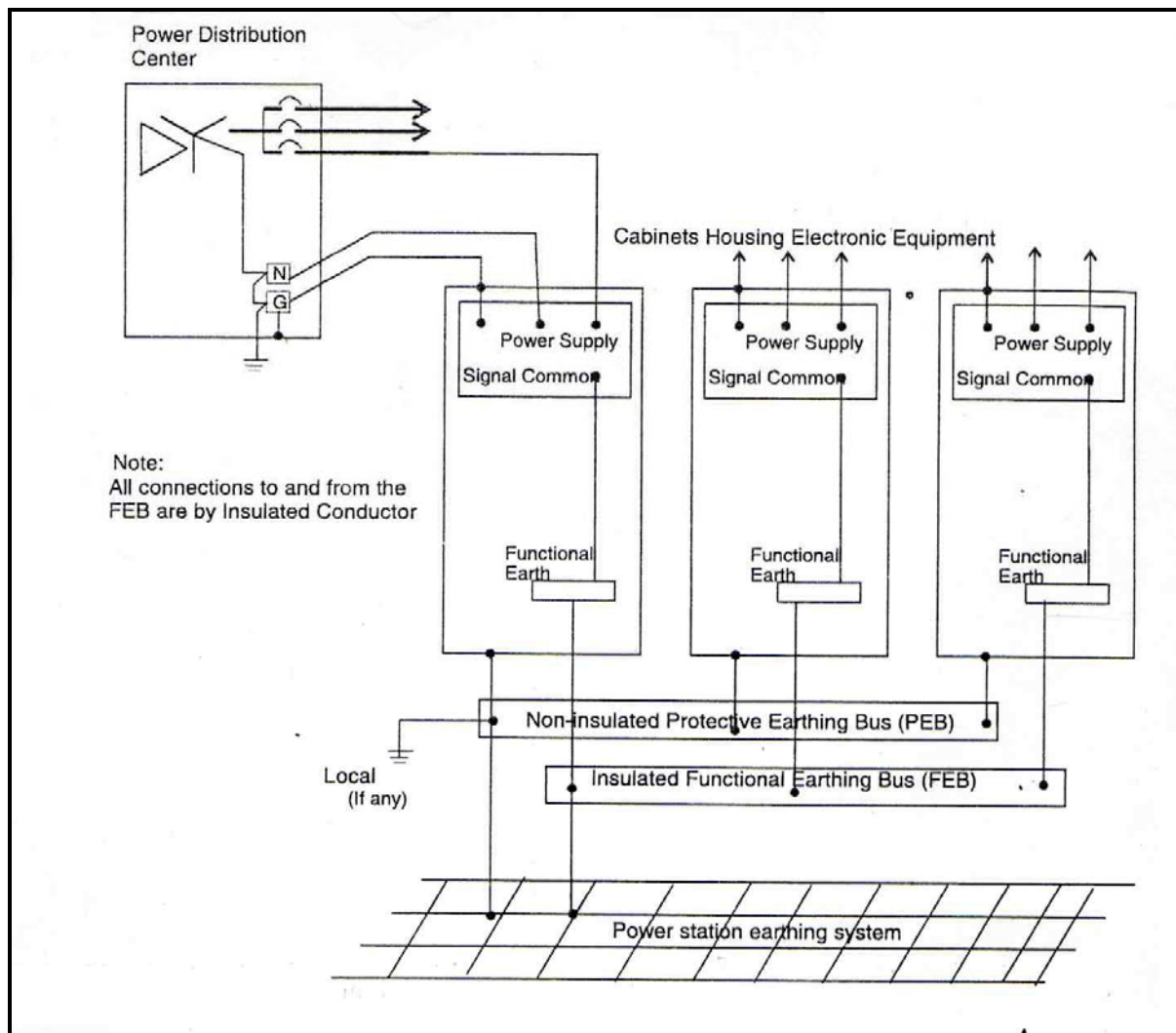
**Fig 20: Typical Power Plant interconnected with grid at 66kV**

The earth mat for 2x9MW typical powerhouse is shown in Fig 21.



## 6.10 Earthing Electronic Equipment

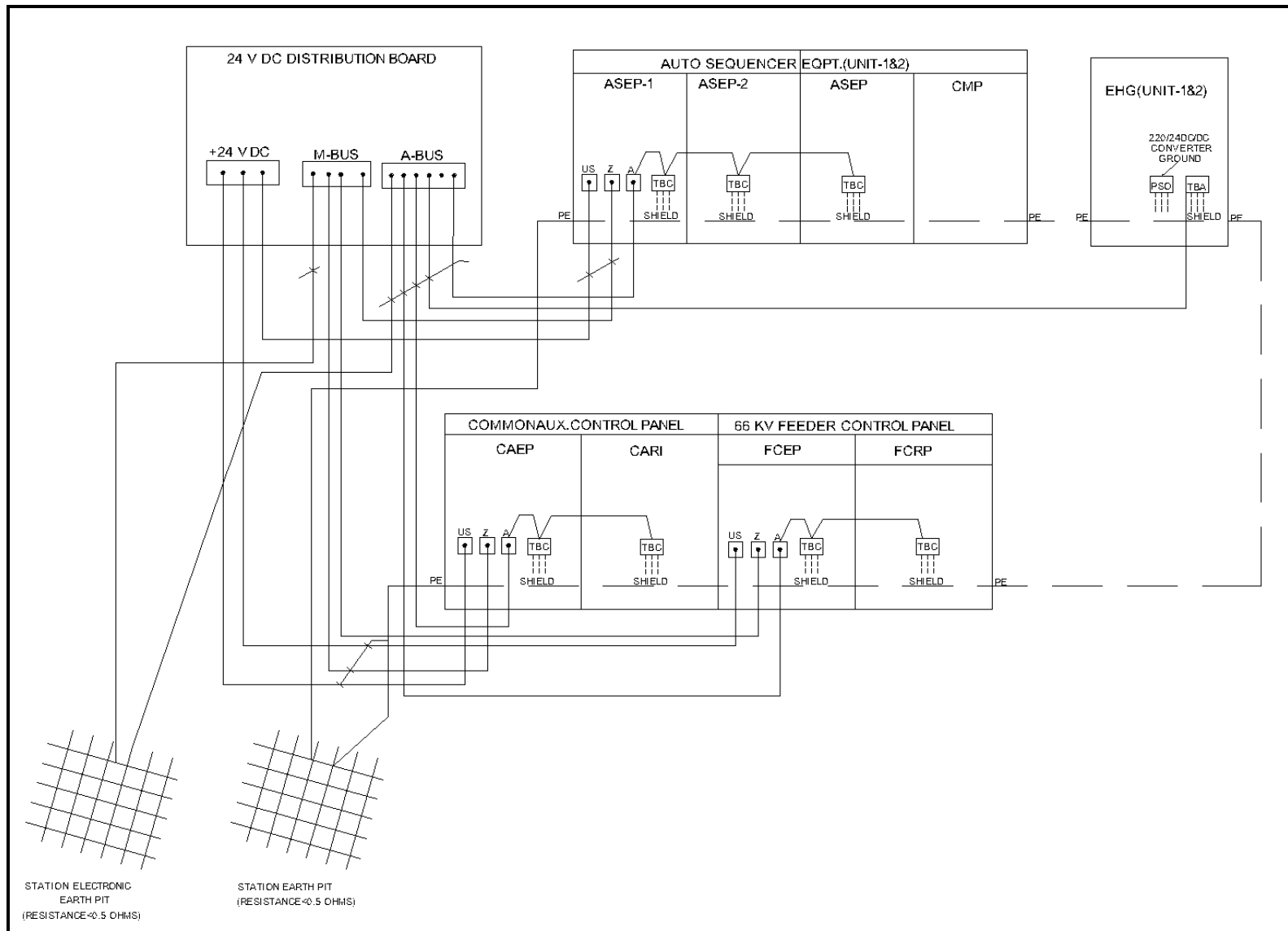
Control and protection is being increasingly provided by digital/analogue electronics in hydro studies. Protective earthing for personnel safety and functional earthing for proper functioning of equipment against overvoltages and noise interface is required. This may be provided as per CBIP Pub. 302 and as per recommendations of supplier. Typical protective and functional earthing recommended in this publication for low operating frequencies (say below 30 kHz) by single point earthing is shown in Fig 22. The digital control equipment earthing proposed for 2 x 9 MW power units is shown in Fig 23.



**Fig 22: Single Point Earthing System with Cabinets in Close Proximity for a 2x9 MW Power plant**

## 6.11 Installation

Detailed instruction for a installation of the Grounding system are enclosed at Annexure 2.



**Fig 23: Earthing of Computerized Electronic Equipment for 2 x 9 MW Powerhouse**

## SOIL RESISTIVITY MEASUREMENTS

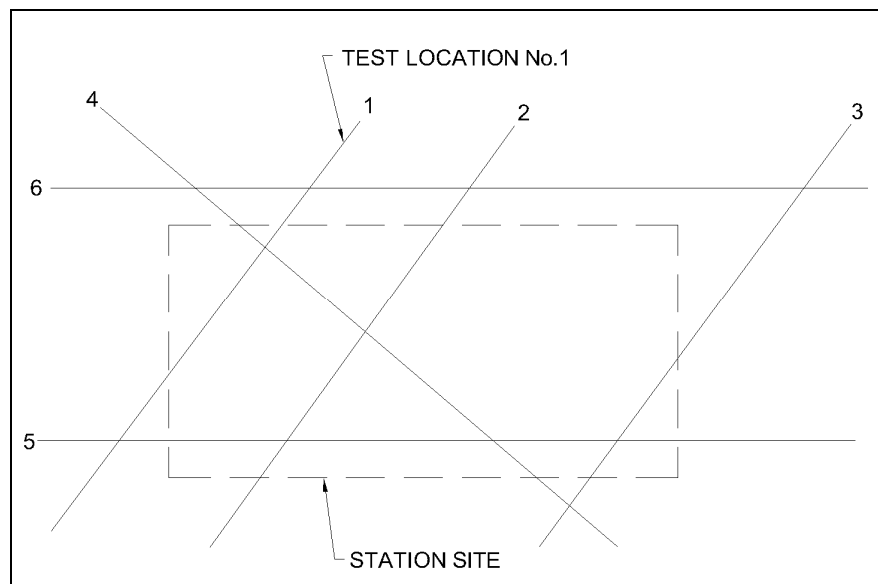
### 1. Soil Resistivity Measurements

#### 1.1 Period of Tests

Estimates based on soil classification permits only a crude approximation of the resistivity. Therefore for obtaining an accurate data on the soil resistivity, field tests at the site are very essential. Further in order to know the effects of temperature and moisture content, the tests may be performed in the hottest month of June before rains; then sometime in the month of September and again in the coldest months of December/January.

#### 1.2 Test Locations

The area at the station site should be covered adequately by conducting resistivity measurements at several positions as shown in Fig 1 and with different probe spacings to get an indication of any important variations of resistivity with location or depth.



**Fig 1: Resistivity Test Locations**

#### 1.3 Extent of Probe - Spacings

It can be shown that the portion of the earth, which has an influence on the station ground resistance, extend down to a depth roughly equal to the station equivalent radius “ $r$ ” (the radius of a circle, having the same area as the station grounding net-work). This means that to establish the nature of the soil at a given site for grounding design; the resistivity tests should be performed, as far as practicable, with probe spacings up to the station equivalent radius.

## 1.4 Formulae for Equal Probe Spacing

Resistivity measurements should be done by the conventional 4-probe method described by Dr. F. Wenner of the U.S. Bureau of Standards. This consists of driving two current probes and two intermediate potential probes into the earth at equal distance apart and in a straight line, to a depth, as shown in Fig 2. An earth tester circulates a current  $I$  between the outer two probes. Due to this current, a potential difference is established between the two potential electrodes equal to  $I \times R$  where  $R$  is the resistance of the earth between the potential electrodes. The ratio  $IR/I$  i.e., the resistance of the portion of the earth between two inner electrodes is indicated directly on the earth tester. Using this value of the resistance, the resistivity of the soil is found out from the equation.

$$\rho = \frac{4\pi SR}{1 + \frac{1+2S}{\sqrt{S^2 + 4Z^2}} - \frac{2S}{\sqrt{4S^2 + 4Z^2}}} \quad (1)$$

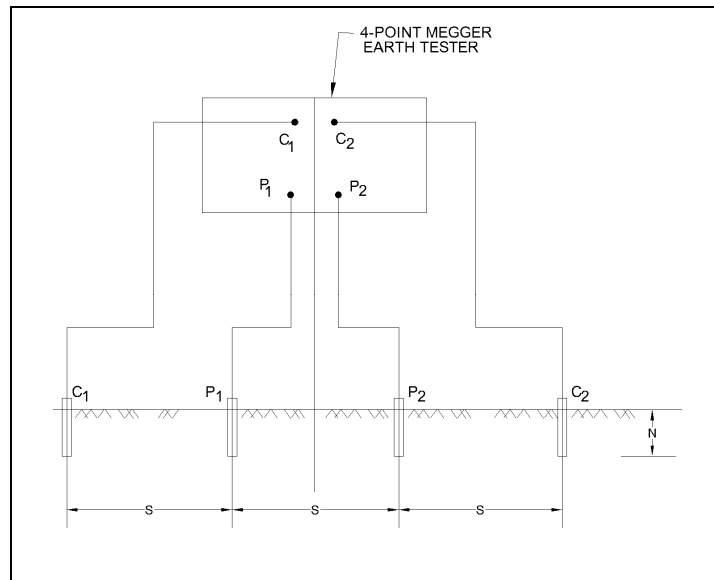
Where,

$\rho$  = resistivity of soil in ohm-meters.

$R$  = resistance measured on the instrument in ohms.

$S$  = Probe spacing in meters.

$Z$  = depth to which probes are driven, in meters.



**Fig 2: Measuring Earth Resistivity with Equal Probe Spacings**

- (ii) When  $Z$  is less than  $1/15^{\text{th}}$  of the probe spacing; the foregoing equation can be further simplified to

$$\rho = 2\pi SR \quad (2)$$

- (iii) For very large probe spacings equal to station radius “R”, which might easily be several hundred feet, 4-electrode method with equal probe spacings of that order is hardly practicable. Further, One short-coming of this method has been the rapid decrease in magnitude of potential between the two inner probes, when probe spacing is increased to relatively large values. This has often resulted in inadequate sensitivity and inability to obtain low resistivity readings at wide probe spacings because of the range of limitations of test instruments.

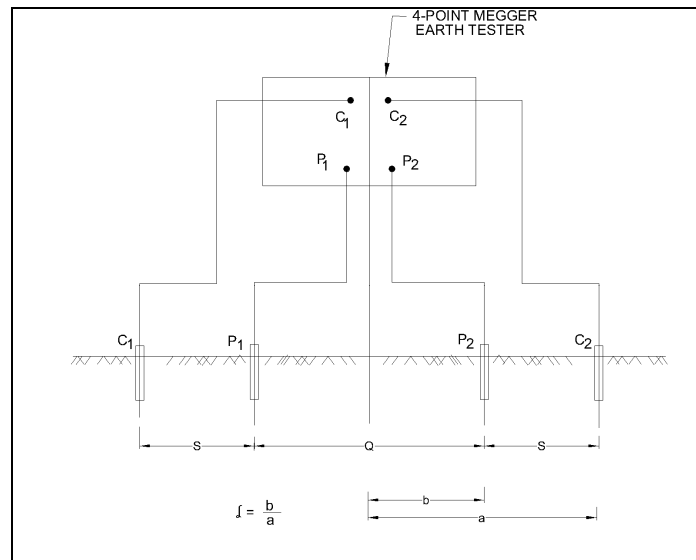
## 1.5 Formulae for Unequal Probe Spacings

- (i) A method of expanding the range of measurement and thus improving sensitivity is by increasing the potential probe spacing as described by L.S. Palmer and A.L. Kinyon. The spacing is increased equally in each direction, keeping each potential probe a like distance from its adjacent, current probe as shown in Fig 3 and the resistivity is calculated from the formulae.

$$\rho = \pi R \frac{S^2 + S}{Q} \quad (3)$$

Where,

- $\rho$  = the measured resistivity of soil in ohm-meter  
 $S$  = distance from  $C_1$  to  $P_1$  and  $C_2$  to  $P_2$  in meters  
 $Q$  = distance from  $P_1$  to  $P_2$  in meters  
 $R$  = instrument reading in ohms



**Fig 3: Measuring Earth Resistivity with Unequal Probe Spacings**



(ii) The above equation can also be written in the following form.

$$\rho = \frac{1 - \alpha^2}{2\alpha} \cdot aR \quad (4)$$

Where,

$\alpha$  = ratio of distance between potential electrodes to that between current electrodes

A = one-half distance between current probes

## 1.6 Testing Kit

A soil resistivity testing “Kit” should consist of

- i) 4-terminal Megger Earth Tester range 0-2; 10;100;1000;10000 ohms 1 No.
- ii) Electrodes, about one meter long ..... 10 Nos.

Note: The electrodes should have cross-bars welded near the top of the rod of facilitation their extraction from the ground.

- iii) Leads, P.M.C./ insulated; 2.5 mm<sup>2</sup> (1/1.80 Al.)
  - 150 meters reel .... 1 No.
  - 75 meters reel .... 2 Nos.
- iv) Short instrument leads.
- v) Sledge hammer, 5 to 8 lbs. 2 Nos.
- vi) Measuring tape 100 ft... 1 No.
- vii) Tools-pliers, wrenches, clips etc.

Note: For test connections; test procedure and correction factors if any; reference should always be made to the instruction booklet supplied with the instrument.

## 1.7 Earth Resistivity Curves

For a homogeneous soil, the value of resistivity thus obtained will be independent of the probe spacing. In actual fact, the ground is never homogeneous. There may be wide horizontal changes and significant vertical variations in the soil structure. However, as the lateral changes in the composition of soil are usually small and gradual, compared with vertical ones; the soil resistivity is normally considered as a function of depth only.

Further in a 4-probe method, the penetration of current and hence the resistance is roughly limited to a depth corresponding to the probe spacing. Thus more frequently than not, the resistivity as measured by the 4-probe method will vary with probe spacing. This variation usually indicates, a soil resistivity, which varies with depth. A plot of the measured resistivity should therefore be drawn against the probe spacing known as “Earth Resistivity Curve”. At a particular site, a number of such curves are drawn for different locations as shown in Fig-4 and an average curve is evolved. This average resistivity curve is then analysed.

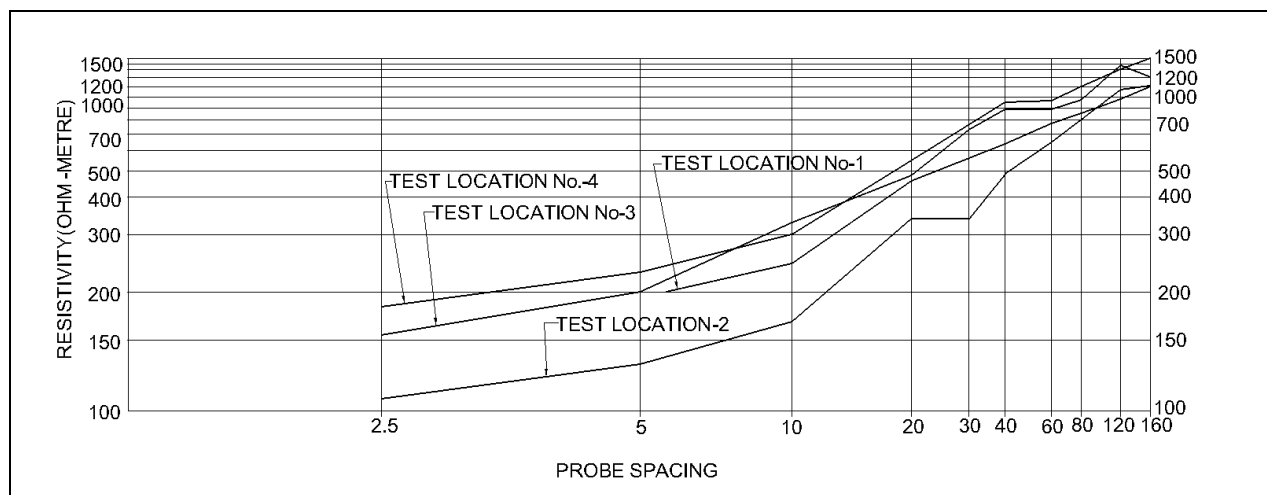
Resistivity measurement records should include temperature data and information as to the dry; or moist condition of the soil at the time the resistivity is measured. Metallic objects (like rails, pipes, wires etc.) buried, or in contact with the soil can invalidate readings made by the method described above, if they are close enough to alter the test current flow pattern appreciably. All data available on buried conductors known or suspected to be in the area studied should therefore be recorded and tests should be done at such locations twice, with probes in two mutually perpendicular directions.

## 1.8 Uniform (Homogeneous) Soil

If the variation in the resistivity is less than 30%; the soil in the vicinity of test location can be considered homogeneous and an average value determined from the resistivity curve is adopted for design purposes. If the variation is more than 30%, the soil cannot be treated as uniform and the analysis of the curve is needed.

## 1.9 Non-Uniform Soil

In the non-uniform soil, where the soil resistivity varies markedly with probe spacing, a designer would like to know the value of apparent soil resistivity “ $\rho_a$ ” that he should adopt for the design purposes; so that the calculated resistance of the grounding system approximately equals the measured resistance after the installation of the grounding system. This may be done in accordance with C.B.I.P. (Central Board of Irrigation Power) manual No. 302-2007 as shown in Fig 4.



**Fig 4: Resistivity test curves for the Month of June**

(Source: CBIP:302-2007)

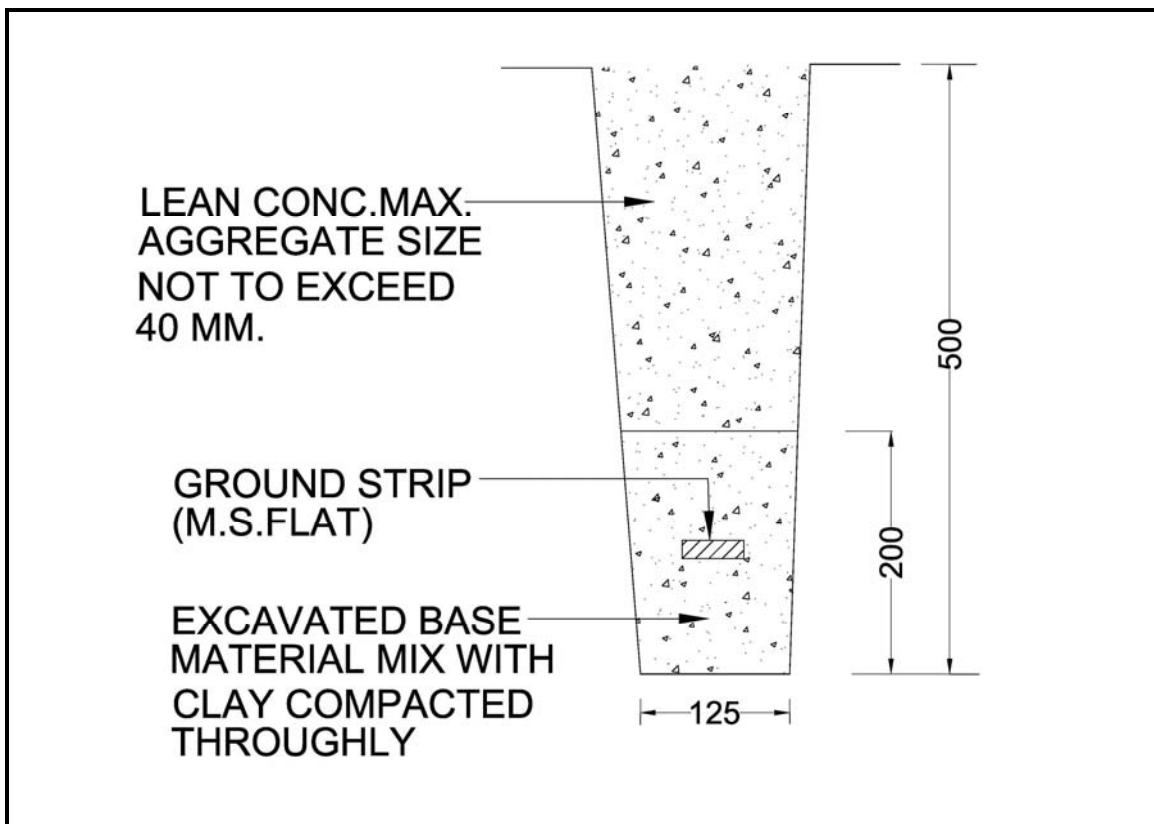
## INSTALLATION OF GROUNDING SYSTEM

### 1. General

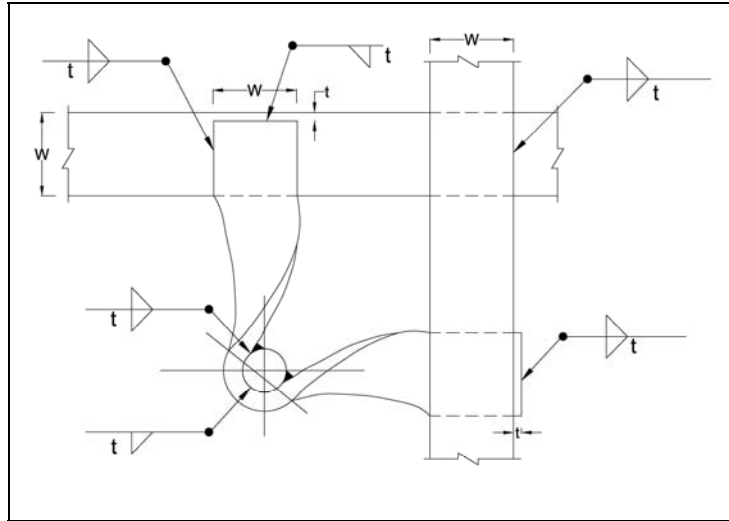
- (i) Grounding conductors shall consist of mild steel strips for ground net-work and mild steel rounds for ground rods.
- (ii) Grounding strips used for end connections to the equipment are galvanised.
- (iii) Connectors like bolts, nuts, etc. used for grounding the equipment are galvanised.

### 2. Ground Mats and Test Terminal Boxes

All grounding strips in the ground mats are laid in position as per typical methods shown in Fig 5 and Fig 6, unless otherwise stated. When the grounding strips have been laid in trench, it shall be covered with excavated base material mixed with clay if possible and filled up to half the depth of the trench. The remaining half of the trench shall be filled with lean concrete so that the strip remains securely in position. A thick coat of bitumen may be applied over it if necessary so that it does not bond with the concrete which may be placed over it.

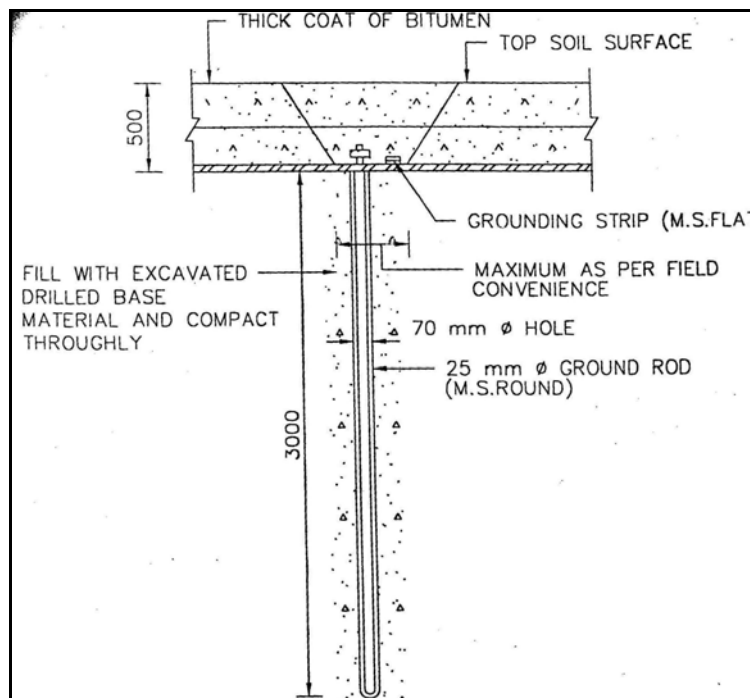


**Fig 5: Installation of Ground Strip of Ground Mat**



**Fig 6: Welding Detail of Connection between Ground Rod and Grounding Strips (typical)**

- 2.1** The ground rods are fixed in position first by drilling a vertical hole of about 70 mm dia into the ground, then placing the rod centrally inside. Drilled base material mixed with clay, if available, are then poured into the hole all around by little and compacted at short intervals by ramming with a suitable dia hollow C.I. pipe having a socket at the lower end. In locations where there is clay or soft soil, the ground rods can be driven in the ground by an augur (Fig 7).



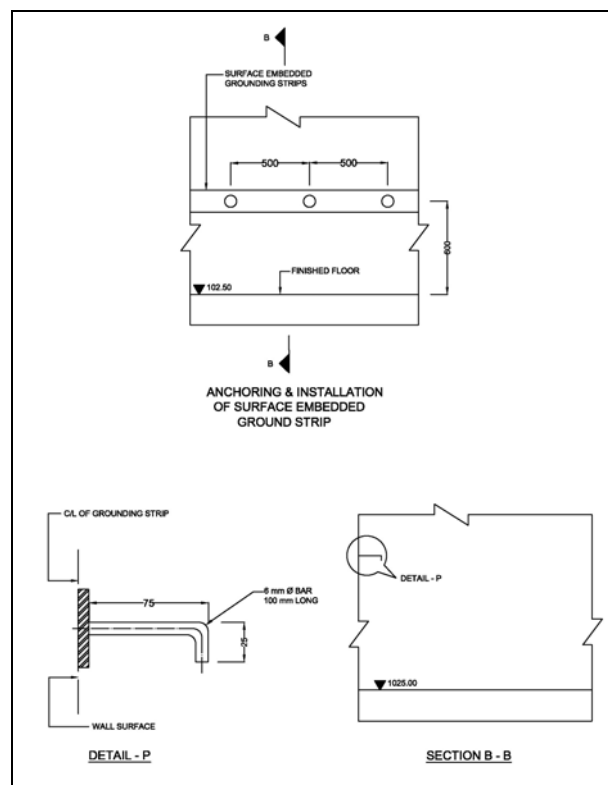
**Fig 7: Installation of ground Rod**

- 2.2 In the installation of grounding strip the field authorities are in a better position than the designer to judge whether the mat is adequately anchored. They should feel free to add additional anchors but should never use less than those indicated on the drawings.
- 2.3 For rust protection, welded joints in the soil shall be thoroughly brushed, provided with a coat of Shalimastic H.D. paint and wrapped with asphalt saturated cotton fabric tape/hessian cloth impregnated with Shalimastic H.D. Paint followed by another coat of shalimastic H.D. paint.

Alternatively welded joints may be protected by grouting concrete of not less than 40 mm thickness.

### 3. GROUNDING NET-WORKS

- 3.1 Installation of grounding strips are carried out in accordance with the grounding system network drawings, but field may deviate to clear possible obstructions keeping in view the technical requirements.
- 3.2 The route of embedded grounding strips between two connected points are by the shortest distance.
- 3.3 Main grounding strips inside the power plant building are laid surface embedded on the walls as per Fig 8 so that these can be tapped easily later on for connection to the individual equipment, which may or may not have been covered in the net work drawings.

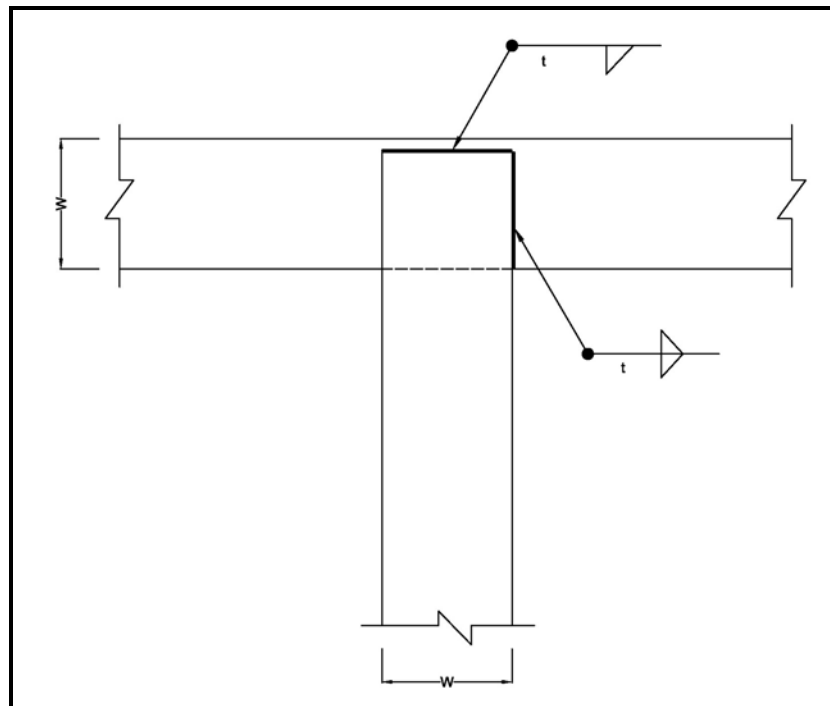


**Fig. 8: Anchoring and installation of surface embedded ground strips**

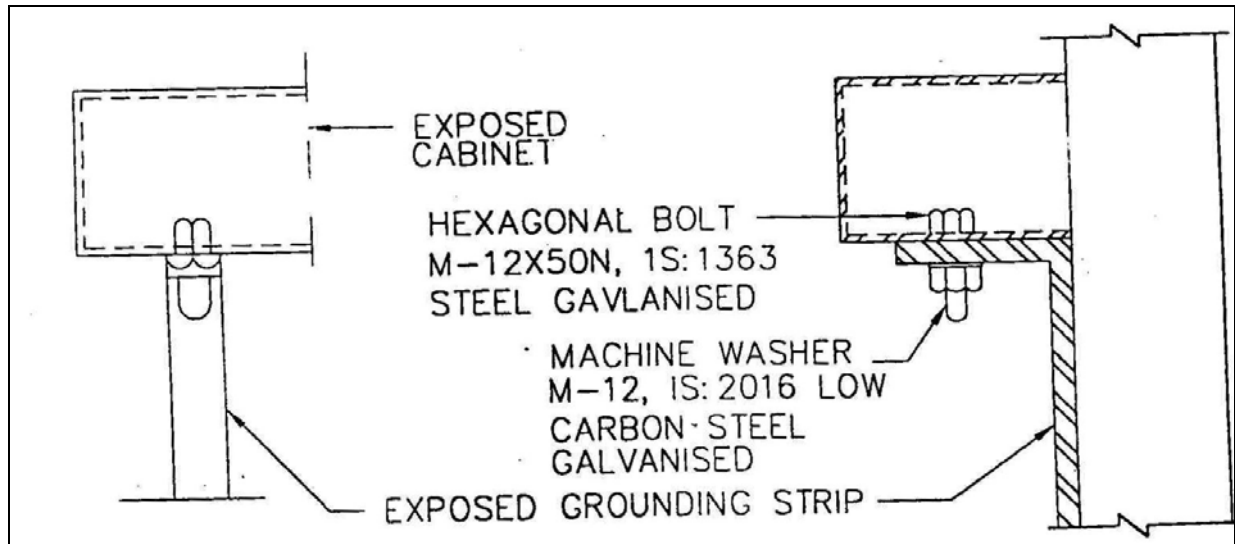
- 3.4** Embedded equipment such as frames for lighting distribution boards, power outlets, misc. recesses etc., are grounded by electricity welding the grounding strip to such equipment. For all other equipment, which is to be installed at a later stage, grounding strip stub of at least 3000 mm length is provided near such equipment for grounding. For equipment fixed on the wall, stubbing should be from the wall and not from the floor or the tapping for this purpose shall be taken from the surface embedded grounding strip on the walls by an exposed grounding strip. It means that any tapping for grounding purpose taken only from grounding ring laid surface embedded on the walls.
- 3.5** Cable racks on the walls and in cable trenches is welded directly to the grounding strips provided for the purpose. Cable racks installed on the floor and fixed under the ceiling is grounded at two points. (preferably entrance ends) and the different sections of the racks is bonded separately by a grounding to ground the entire cable rack effectively.

#### **4. Jointing Of Grounding Strips**

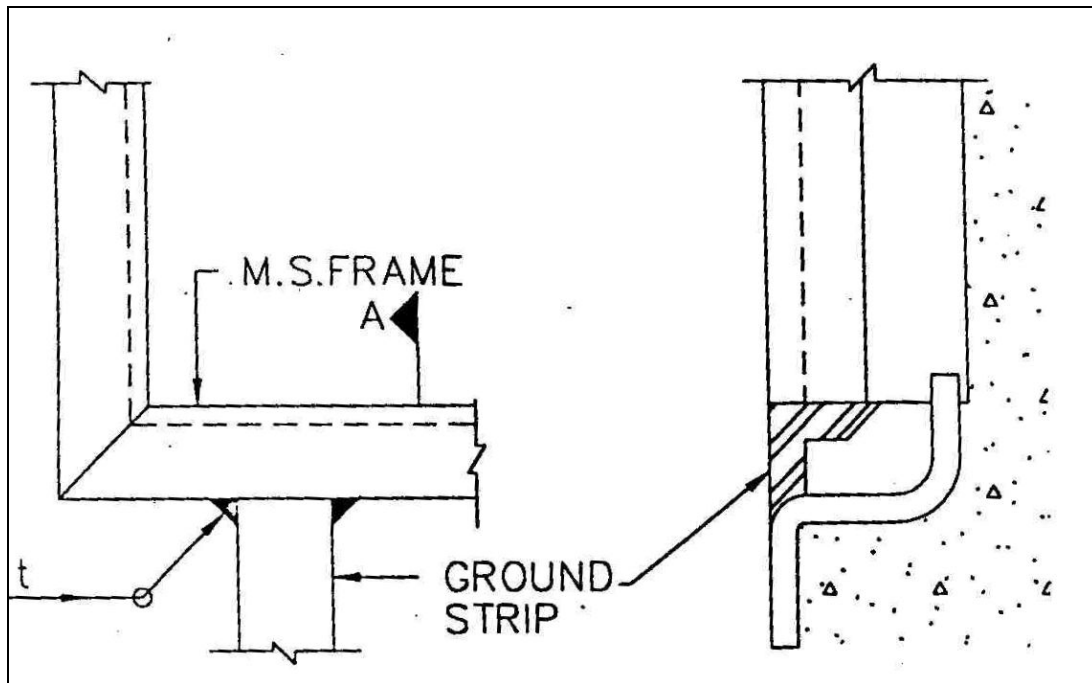
- 4.1** All joints between grounding strips and between grounding strips and ground rods are by electrical welding. At the time of welding, the jointing surface is cleaned by sand blasting or by other convenient means. The joint is clamped tightly to ensure that a good surface contact exists. For straight joints between ground strips an overlapping not less than twice the width of plate should be made for welding typical angle joints and t-joints are shown in Fig 9 and Fig 10 respectively. Typical welded connection between ground rod and ground strip is shown in Fig 11. Typical details of welded joints are shown in Fig 12, Fig 13 & Fig 14.



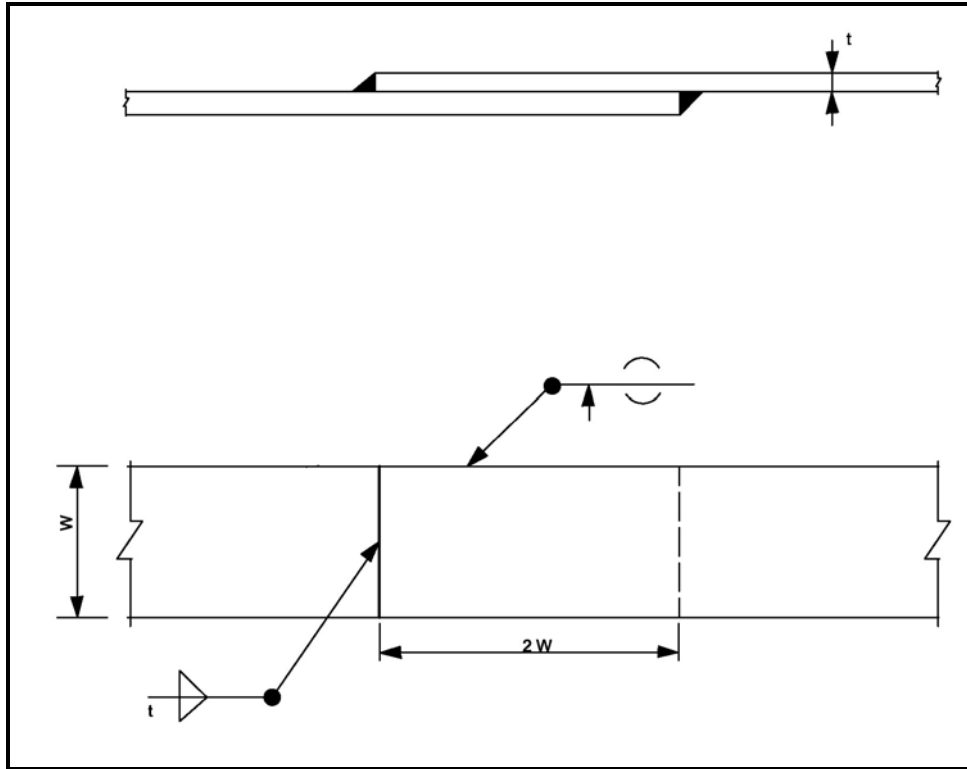
**Fig 9: Welding Detail of Tee Joint (Typical)**



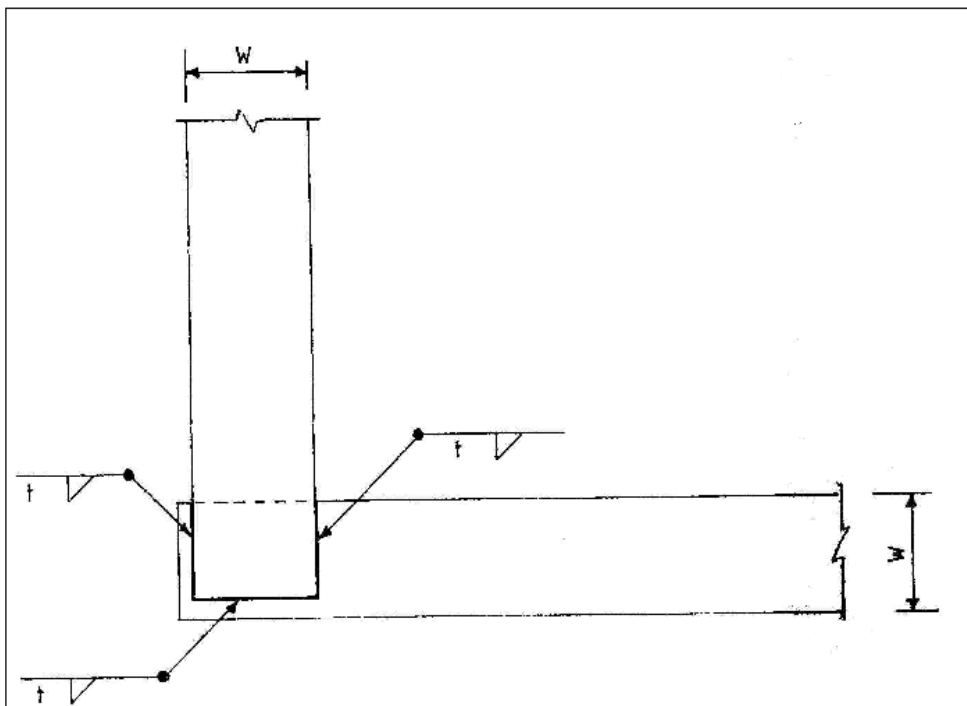
**Fig 10: Welding Connection to Exposed Cabinet**



**Fig 11: Welded Connection to Recess Frame**

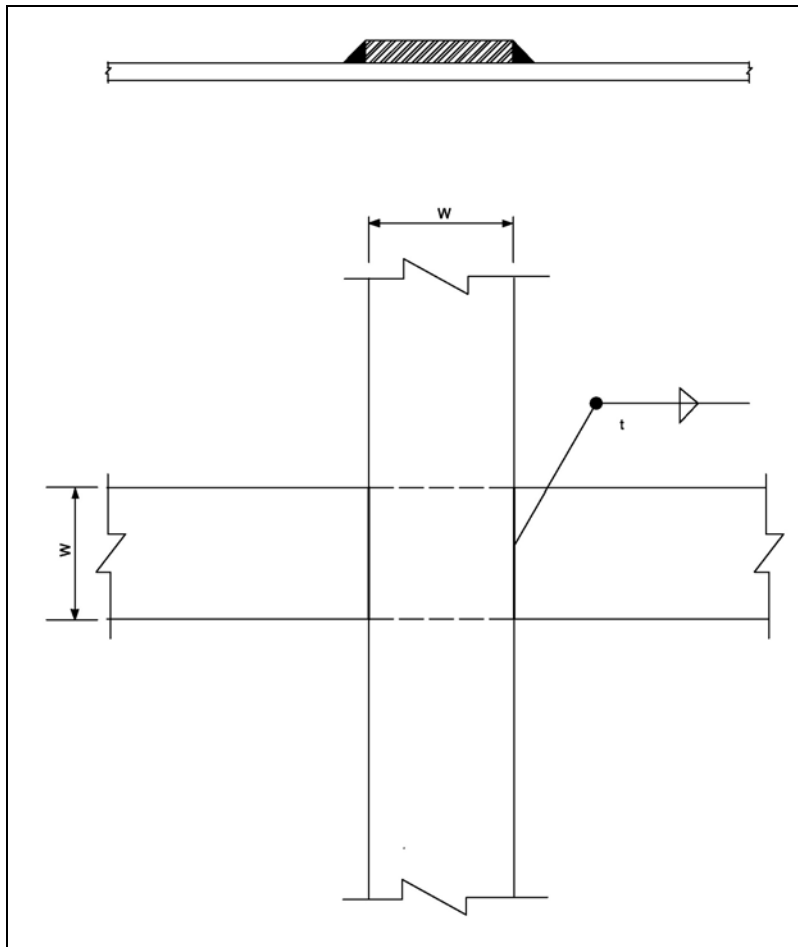


**Fig 12: Welding Detail of Straight Joint (Typical)**



**Fig 13: Welding Detail of Angle Joint (Typical)**





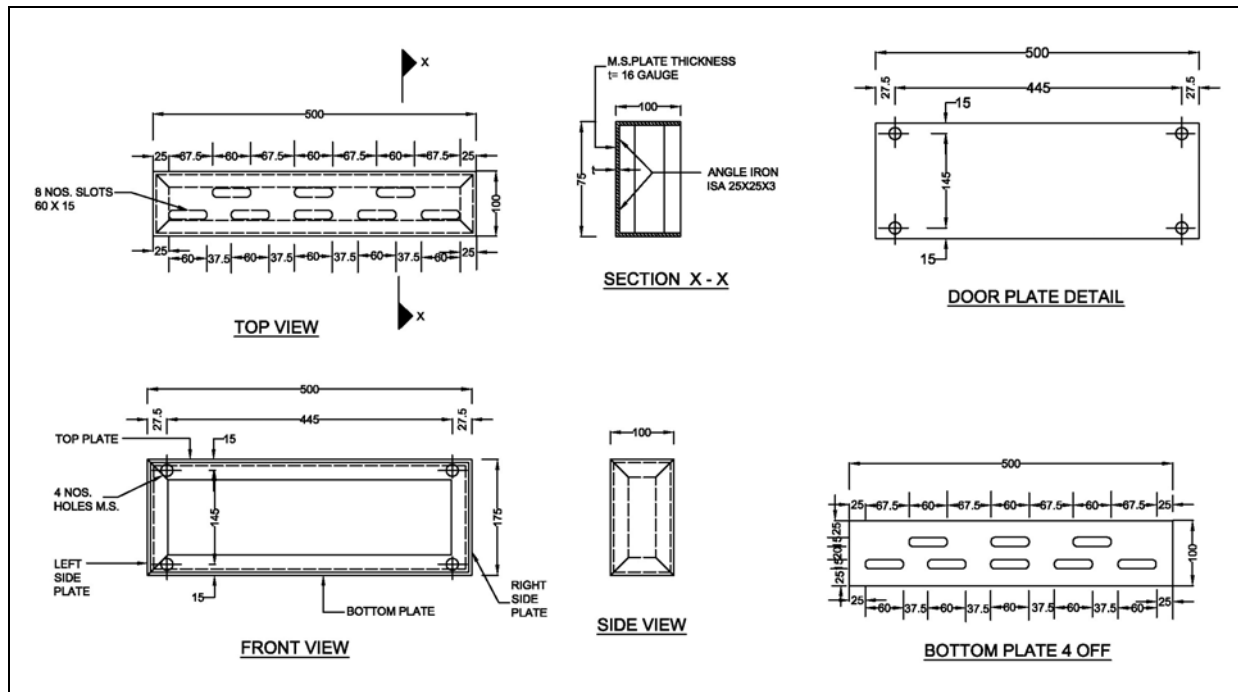
**Fig 14: Welding Detail of Cross Joint (Typical)**

## 5. Connections to Equipment

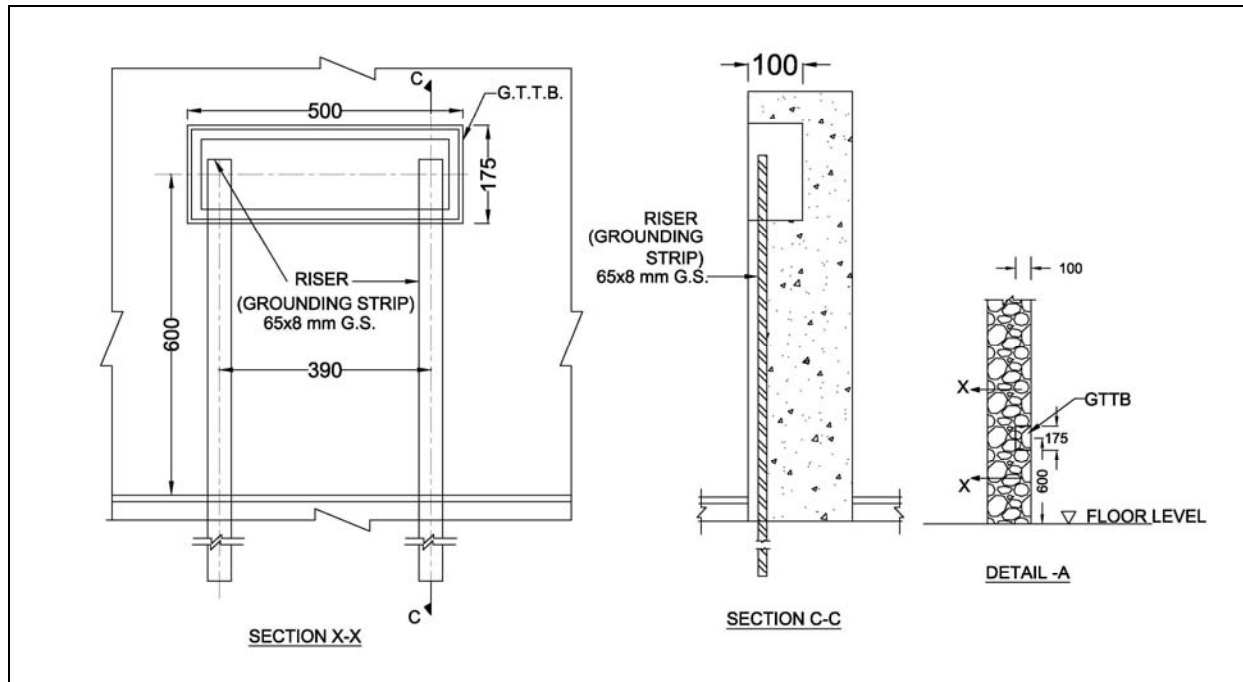
Exposed surface of all electrical equipment must be grounded and non-electrical items like mat hand-rails, hatch cover frames. Cable rack support etc., should be grounding. In reinforced concrete structure most structural elements such as windows, frames, grills and louvers need not be grounded. Economy does not permit grounding of metal parts.

- (i) The frame of every generator, motor, circuit breaker and the metallic parts (not intended as conductors) of all transformers, and regulating or control apparatus connected with the supply are grounded by two separate and distinct connections.
- (ii) The metal conduits, armour and/or sheath of a cable may be used as ground conductor and should be earthed at one point only (preferably at the source end) in the following cases: -
- (iii) Conduit, armour and/or lead sheath of single phase cable.

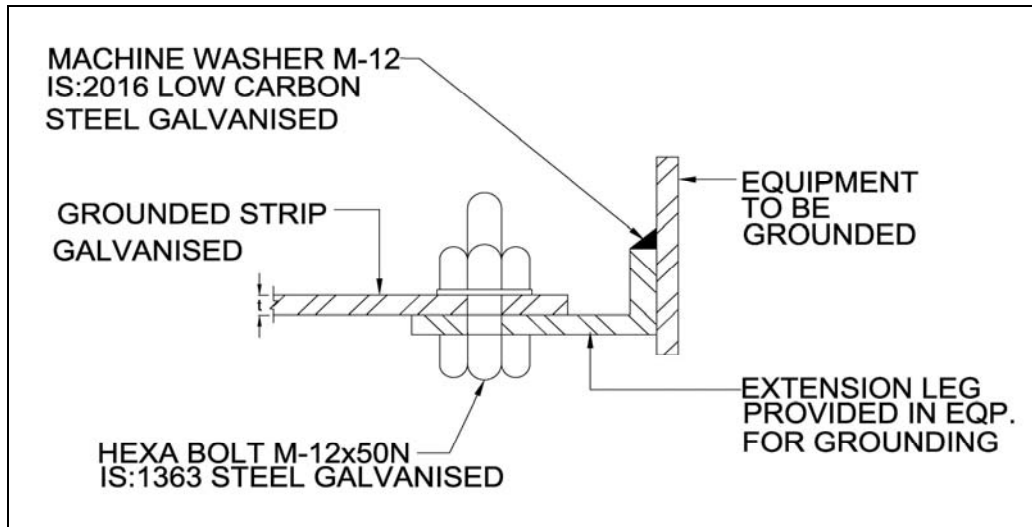
- (iv) In long runs, insulating sleeves are occasionally installed in the lead sheath, thus breaking up long sections and reducing sheath potentials. Each section of the lead sheath is grounded. Grounding the same lead sheath of a single phase cable at both ends intentionally or accidentally may over heat the cable and are avoided.
- (v) Three phase cables should have the lead sheaths grounded at both ends in all cases. Metallic junction or pull boxes not containing protective equipment, and in which conduits are installed with a socket and metallic bush are not considered a break, when the voltage is below 240 volts to ground, but is so considered for higher voltages.
- (vi) All junction and pull boxes in the runs of non-metallic conduits as well as these containing overload protective devices are individually grounded.
- (vii) All paint, enamel, and scale is removed from the point of contact on metal surfaces before making ground connections.
- (viii) In switchyard any items of equipment not covered by grounding system layout drawings and which are so located that there is some chance of a high-tension conductor flashing to or coming in contact with them must also be grounded with individual connections.
- (ix) Where some arrangement for grounding is already provided on the equipment by manufacturers, that arrangement should be used for grounding if suitable for the size of grounding strips specified in the net-work drawing concerned. The mode of connection may not be the same as shown in typical equipment connections.
- (x) The bases of lightning arrestors are directly connected to the grounding test terminal box (G.T.T.B.) of system (Fig 15) by grounding strips as short and straight as practicable to ensure minimum impedance.
- (xi) For lightning arrestors mounted near the transformers, grounding strips are located clear of the cable and coolers in order to avoid possible leakage caused by arcing.
- (xii) Typical grounding strips connections to various equipment are shown in Fig 16 and Fig 17.
- (xiii) Main grounding strips ring inside the power plant building should be laid surface embedded on the wall as shown in Fig 18. So that these can be tapped easily later on for connection to individual equipments, which may or may not have been covered in the network drawing.
- (xiv) The frame of every generator, motor, control panels and the metallic parts of all transformer connected with the supply should be grounded by two separate and distinct connections.
- (xv) Any tapping for grounding purpose shall be taken only from grounding ring surface embedded on the walls.



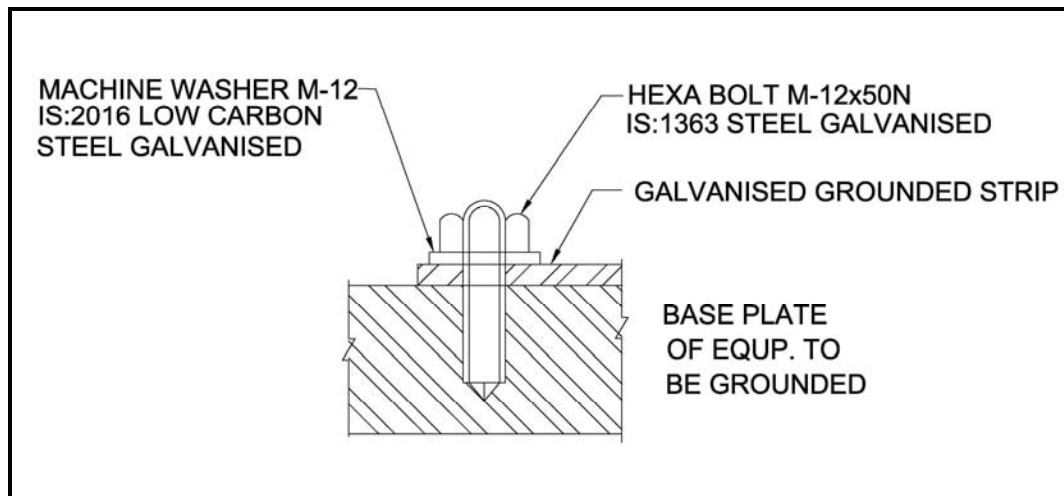
**Fig 15: Details GTTB**



**Fig 16: Grounding strip ring**



**Fig 17: Bolted Connection to Extension Leg**



**Fig 18: Bolted Connection to Base Plate**

## 6. Precautions

- (i) Grounding strips should never be run through a steel conduit or through an opening in the floor or walls of magnetic material. It may be run in either fiber conduit or conduit of non-magnetic material.
- (ii) Grounding strips should never be laid close to or parallel to generator single-phase main-leads or single core power leads and the distance or separation should not be less than 300 mm. This will be shown on the drawings concerned.
- (iii) Current transformer secondary circuit should never be grounded at more than one point.

## 7. Ground Mat Resistance

After the grounding system is laid, actual measurement shall be taken and remedial measures if any required will be devised by the field to bring down the resultant grounding resistance within safe limits.