# STANDARDS/MANUALS/ GUIDE LINES FOR SMALL HYDRO DEVELOPMENT

## 3.10
## Electro-Mechanical–
## Power evacuation and interconnections with grid

Sponsor:

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# 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

| | |
|---|---|
| **General** | |
| 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 |
| **Civil works** | |
| 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 |
| **Electro Mechanical works** | |
| 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 |

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# CONTENTS



# LIST OF FIGURES



# LIST OF TABLES

## LIST OF ANNEXURE

# GUIDELINES FOR POWER EVACUATION AND INTERCONNECTIONS WITH GRID

## 1.0 GENERAL

### 1.1 Scope

Small hydroelectric power plants are mostly located far away from load centers. For transfer of generated power economically it becomes necessary to step up generation voltage through step up transformers in switchyard located near power plant and connect the same to nearest grid substation through transmission lines.

Provisions of Grid Standard for Operation and Maintenance of Transmission Lines as per Central Electricity Authority (Grid Standard) Regulation –2010 (Annexure-I) are to be taken into consideration where ever necessary.

The intent of this guideline is to provide guidance for selecting voltage level for power evacuation, bus bar arrangement in the switchyard, interconnection with isolated load or grid, selection of necessary protection scheme for the selected grid interconnection.

### 1.2 References and Codes

| | | | |
|---|---|---|---|
| R1. | CEB- Guide | : | Guide for grid connection of embedded generators-2000. |
| R2. | CBIP:250-1996 | : | Modern trends and practices in power sub transmission and distribution line |
| R3. | IEEE Standard C 37.101-2006 | : | IEEE Guide for generator grounding |
| R4. | IEEE 37.95 – 2007 | : | IEEE guide for protective reclosing |
| R5. | IEEE Standard 242, 1996 | : | IEEE recommended practice for protection |
| R6. | REC Spec. 30-1984 | : | Specifications for resin cast dry outdoor type transformers |
| R7 | REC Spec.43-1987 | : | Specifications for11 kV Air Break Switches |
| R8 | REC standards-1994 | : | Specification and construction standard |
| R9. | CEA- Grid Regulation | : | Central Electricity Authority (Grid Standard) Regulation- 2010 |
| R10. | IS:3043-1998 | : | Installation of Grounding/Earthing of Power Line. |
| R11. | IS:2551-1963 | : | Installation of Danger Board |
| R12. | IS:398 (Part II) 1996 | : | Stringing of Conductor |
| R13. | IS:2486 (Part II) 1989 | : | Stringing of Conductor |
| R14. | IS:209 -1992 | : | Installation of Insulators |
| R15. | IS:2713 (Part I to III (1980) | : | Installation of Steel Tubular Pole |
| R16. | IS:2062-1992 | : | Structural Steel (fusion welding quality) |
| R17. | IS:398-1994 | : | Aluminium Conductor for overhead Transmission Purposes (ACSR/AAAC) |
| R18. | IS 2121-1981 | : | Conductor and earth wire accessories for overhead power line |
| R19. | IS:4091-1979 | : | Design and construction of foundation for transmission line poles |

| | | | |
|---|---|---|---|
| R20. | IS:4826-1976 | : | Hot-dip galvanizing coatings on round steel ires |
| R21. | IS:4759-1979 | : | Hot-dip galvanizing coatings on structural steel & allied products |
| R22. | IS:731-1971 | : | Porcelain insulators for overhead power lines with a nominal voltage greater than 1000 V |
| R23. | IS:2544-1973 | : | Porcelain Post Insulators for systems with normal Voltage greater than1000V |
| R24. | IS:5350-1970 | : | Dimensions of Indoor and Outdoor Porcelain Post Insulators and Post Insulator Units for Systems with nominal Voltage greater than 1000 V |
| R25. | IS:13134-1992 | : | Guide for the selection of insulators in respect of polluted conditions |
| R26. | IS:5561-1970 | : | Electric power connectors |
| R27. | IS:2633-1986 | : | Method of testing weights, thickness & uniformity on H.D.G. articles |
| R28. | IS:2629-1985 | : | Recommended practices for hot dip galvanizing of iron & steel |
| R29. | IS:2486-1993 | : | Insulator fitting for overhead power lines with a normal voltage greater than 1000 V |
| R30. | IS:802-1995 | : | Use of structural steel in overhead transmission Lines |
| R31. | IS:808-1989 | : | Rolled steel beams, channels and Angle sections |
| R32. | IS:1367-1980 | : | Nuts & threaded fasteners |
| R33. | IS:961-1975 | : | High tension structural steel |
| R34. | IS:6639-1972 | : | Hexagonal bolts & steel structure |
| R35. | IS:5561-1970 | : | Terminal connectors |
| R36 | IS:4722-2006 | : | Rotating Electrical Machines Specification |

**Abbreviations:**

CBIP : Central Board of Irrigation and Power
CEB : Ceylon Electricity Board
CEA : Central Electricity Authority
IEEE : Institute of Electrical & Electronic Engineers
IS : Indian Standards
REC : Rural electrification Corporation Ltd

## 2.0 ESSENTIAL ELEMENTS OF INTERCONNECTION OF A GENERATING STATION WITH GRID

### 2.1 Voltage levels

#### 2.1.1 Generation Voltages

Generation voltages are generally limited to levels as shown in Table 1:

**Table 1: Generation Voltage Levels**

| Generation | Voltage Level |
|---|---|
| Up to 750 kW | 415 Volt |
| 751 to 2500 kW | 3.3 kV |
| 2501 to 5000 kW | 6.6 kV |
| Above 5000 kW | 11.0 kV |

Generally terminal voltage for large generators is 11 kV in India.

Preferred voltage ratings of generators as per IEC 60034-1-2010 and IS: 4722-2006 is as follows:

Above 150 kW - 3.3 kV
Above 800 kW - 6.6 kV
Above 2500 kW - 11 kV

#### 2.1.2 Transmission Voltages

**Selection of System Voltage**

The selection of highest system voltage to be used at the generating step up substation depends upon the following main considerations.

(i) Length of transmission line from generating station to receiving substation.
(ii) Conductor required for voltage regulation prescribed in the law of land.
(iii) Voltage level (s) available at the receiving substation and suitability of connectivity.
(iv) Frequency at the generating station and receiving substation.
(v) Power System Network of the area for stability and future extension works in the vicinity of the generating station.
(vi) Economic consideration as cost of equipment increases with increase of voltage therefore, unit cost of power transmitted is subject to law of diminishing return. The transformers on either side of line also counter the gain, obtained from the higher voltage.
(vii) Provision of line capacitors to increase the economic limit even at lower voltage.

The voltages are therefore selected with complete study of all factors. The transmission voltage is selected from empirical formulae and standard practices in the area, after making a complete study regarding initial and operating cost at various voltages with different size of conductors.

The voltage is selected through following two empirical formulae.

$$\text{Economical Voltage} \quad V = 5.5\sqrt{\frac{L}{1.6}+\frac{kVA}{150}}$$

Where

| | | |
|---|---|---|
| L | = | Length of line in Km. |
| kVA | = | Power per phase required to be transmitted. |

$$\text{Economical Voltage } V = 5.5\sqrt{\frac{L}{1.6}+\frac{3P}{100}}$$

Where

| | | |
|---|---|---|
| L | = | Length of line in Km. |
| P | = | Power in kW per phase |

The above formulae give an idea of voltage, but final selection is made after detailed studies.

### 2.1.3 Grid Connection Criteria

The product of installed capacity in kW and distance in km of the substation at which the power line is to be terminated is the main criteria for selection of voltage level of power evacuation. For SHP normally following voltage levels are selected as per guide lines of REC.

| Voltage Level | Voltage Class |
|---|---|
| 415 V | 433 V |
| 11 kV | 12 kV |
| 33 kV | 36 kV |
| 66 kV | 72 kV |

Inter connecting lines are designed for 5 to 9 % voltage regulation for 11kV and 33kV lines. It is general practice to work out a constant in kW-km on the basis of 1% voltage drop at 60 deg. C at different voltages and conductor size. This helps in calculating the voltage regulation quickly. The constants are tabulated in Table 2 and Table 3 below:

**Table 2: kW-km for 1% Voltage Drop AT 60 Deg. C**

| S. No. | Conductor | 1.0 PF. | | | 0.9 PF | | | 0.8PF | | | 0.7 PF | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 33KV | 11KV | 415V | 33KV | 11KV | 415V | 33KV | 11KV | 415V | 33KV | 11KV | 415V |
| 1. | Dog (63 sq.mm) | 33405 | - | - | 21248 | - | - | 17714 | - | - | 15152 | - | - |
| 2. | Racoon (48 sq.mm) | 25150 | - | - | 17500 | - | - | 15000 | - | - | 13091 | - | - |
| 3. | Squirrel (13 sq.mm) | | 76 77 | 1.08 kVA | - | 674 | 0.98 | - | 640 | 0.93 | - | 605 | 0.88 |
| 4. | Weasel (20)sq.mm) | | 11 | 1.63 kVA | - | 970 | 1.41 | - | 900 | 1.31 | - | 840 | 1.25 |
| 5. | Rabbit (30sq.mm) | 16883 | 19 | 2.72 kVA | 12975 | 1490 | 2.18 | 11514 | 1330 | 1.96 | 10322 | 1200 | 1.78 |

**Table 3: kW-km for ACSR Conductors for 5% Regulation**
**(Source –Bhatia's Hand Book of Electrical Engineering)**

| Voltage-→ | | 11KV | | | 33KV | | | 66KV | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Power Factor-→ | | 0.8 | 0.9 | 1.0 | 0.8 | 0.9 | 1.0 | 0.8 | 0.9 | 1.0 |
| Conductor size | | | | | | | | | | |
| AWG Or cir. mils | Nearest Conductor mm | | | | | | | | | |
| 4 | 6/1/2.11 | 3040 | 3200 | 3840 | 27200 | 28800 | 35200 | 110400 | 114200 | 384000 |
| 8 | 6/1/2.59 | 4000 | 4480 | 5440 | 36000 | 40000 | 49600 | 144000 | 140800 | 352000 |
| 0 | 6/1/3.35 | 5280 | 6400 | 8800 | 48000 | 56000 | 80000 | 192000 | 160000 | 576000 |
| 2/0 | 6/1/3.66 | 6400 | 7040 | 10720 | 56000 | 64000 | 96000 | 224000 | 198400 | 460800 |
| 4/0 | 6/4.72-7/1.57 | 8000 | 9760 | 16000 | 72000 | 88000 | 144000 | 288000 | 224000 | 832000 |
| 266500 | 30/7/2.66 | 10720 | 12800 | 23040 | 96000 | 115200 | 208000 | 384000 | 320000 | 518400 |
| 336400 | 30/7/2.79 | 11520 | 14400 | 28800 | 104000 | 129600 | 256000 | 416000 | 256000 | 1024000 |

For 11KV and L.T. lines, the maximum kW-Km at permissible Voltage Regulation are given in Table 4.

**Table 4: Maximum kW-km at Permissible Voltage Regulation**

| S. No. | Conductor size | Voltage KV | Maximum kW-Km | % Permissible Voltage Reg. | Regulation Constant |
|---|---|---|---|---|---|
| 1. | 13 sq mm ACSR | 11 | 5760 | 9 | 6.40 |
| 2. | 20 sq mm ACSR | 11 | 8100 | 9 | 9.00 |
| 3. | 30 sq mm ACSR | 11 | 11970 | 9 | 13.30 |
| 4. | 13 sq mm ACSR | 0.415 | 5.58 | 6 | |
| 5. | 16 sq mm ACSR | 0.415 | 6.96 | 6 | |
| 6. | 20 sq mm ACSR | 0.415 | 7.86 | 6 | |
| 7. | 30 sq mm ACSR | 0.415 | 11.76 | 6 | |

However, some States follow regulation limit as detailed in Table 4:

**Table 5: Regulation limit**

| S. No. | Line Voltage | Conductor Size | Permissible Voltage Drop | Power which Can be Transmitted |
|---|---|---|---|---|
| 1. | 33 kV | Dog | 5% | 91.20 MW Km |
| 2. | 33 kV | Racoon | 5% | 75.20 MW Km |
| 3. | 11 kV | Rabbit | 8% | 16.57 MW Km |
| 4. | 11 kV | Weasel | 8% | 11.04 MW Km |
| 5. | 0.4 kV | Rabbit | 6% | 10.815MW Km |
| 6. | 0.4 kV | Weasel | 6% | 7.51 MW Km |

Fig. 1 with Table 6, Fig. 2 with Table 7 and Fig. 3 with Table 8 are taken from REC – Specification and Construction Stadards-1994 which also show the criteria for various voltages levels vis. a vis. type and size of conductor for various Power Factors:

**Table 6: kW – km for 33 kV 3 Phase Lines for 1% Voltage Drop**

| Conductor Size | kW – km for 1% Voltage Drop * | | | |
|---|---|---|---|---|
| | 1.0 p.f. | 0.9 p.f. | 0.8 p.f. | 0.7 p.f. |
| 50 $mm^2$ AAAC (7/3.15 mm) | 15329 | 12140 | 10896 | 9868 |
| 80 $mm^2$ AAAC (7/3.81 mm) | 22398 | 16326 | 14213 | 12560 |
| 100 $mm^2$ AAAC (7/4.26 mm) | 28081 | 19268 | 16439 | 14302 |

**REC CONSTRUCTION STANDARD**

**M – 12**

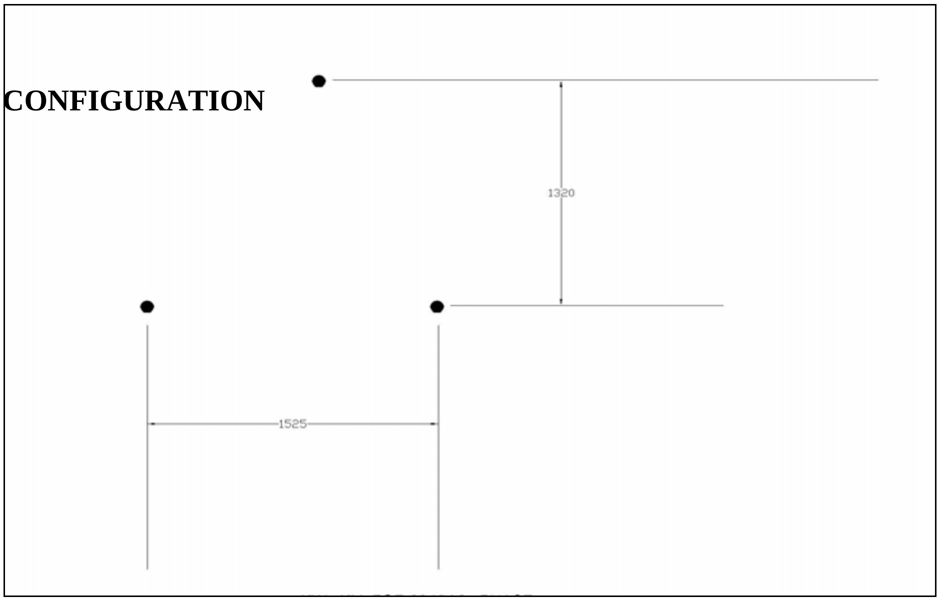


**Fig 1 : kW – km for 33 kV 3 Phase Lines for 1% Voltage Drop**

**REC CONSTRUCTION STANDARD**

**A – 9**

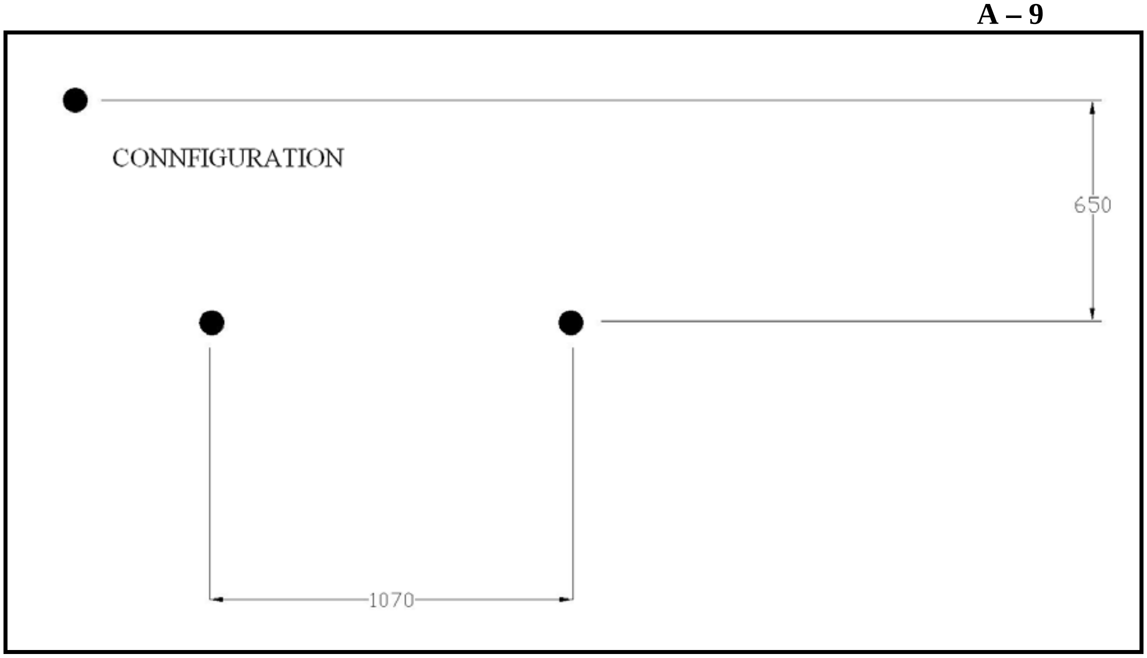


**Fig 2 : kW – km for 11 kV 3 Phase Lines for 1% Voltage Drop**

**Table 7 : kW – km for 11 kV 3 Phase Lines for 1% Voltage Drop**

| Conductor | kW – Km for 1% VOLTAGE DROP * | | | |
|---|---|---|---|---|
| | 1.0 p.f. | 0.9 p.f. | 0.8 p.f. | 0.7 p.f. |
| 7/2.11 mm ACSR | 727 | 652 | 617 | 585 |
| 7/2.59 mm ACSR | 1048 | 902 | 838 | 782 |
| 7/3.35 mm ACSR | 1703 | 1356 | 1219 | 1106 |

**REC CONSTRUCTION STANDARD**

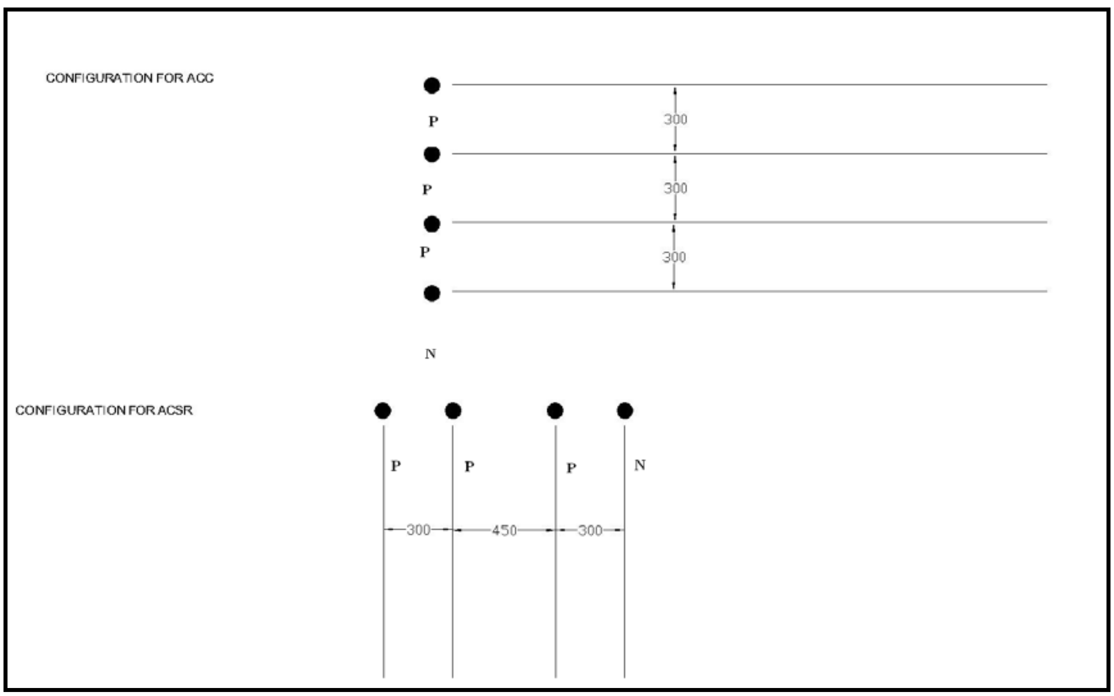


**Fig 3 : kW – km for 415 V 3 Phase Lines for 1% Voltage Drop**

**Table 8 : kW – km for 415 V 3 Phase Lines for 1% Voltage Drop**

| Conductor | P kW – Km for 1% VOLTAGE DROP * | | | |
|---|---|---|---|---|
| | 1.0 p.f. | 0.9 p.f. | 0.8 p.f. | 0.7 p.f. |
| 7/2.21 mm AAC | 1.37 | 1.21 | 1.14 | 1.08 |
| 7/3.10 mm AAC | 2.69 | 2.18 | 1.98 | 1.81 |
| 7/2.11 mm ACSR | 1.04 | 0.94 | 0.90 | 0.85 |
| 7/2.59 mm ACSR | 1.49 | 1.31 | 1.22 | 1.15 |
| 7/3.35 mm ACSR | 2.42 | 1.98 | 1.80 | 1.65 |

***For a conductor temperature of $60^0$c

**Note:** For a conductor temperature of $50^0$c, the above figures would be about 5% higher and for a temperature of $70^0$c, about 5% lower.

## 2.2 General consideration for switching arrangements in switchyards

Main considerations for selecting a suitable and economical switching arrangement are as follows:

(i) Inter connected transmission system
(ii) Voltage level
(iii) Site limitations
(iv) General & special considerations

### 2.2.1 Inter Connected Transmission System

The switching should fit in the planning criteria used to design transmission system. System should remain stable, if a fault occurs on line. However, impact of switching in/off of SHP in grid is insignificant as such studies for system stability are not recommended.

### 2.2.2 Voltage Level

Following points must be considered at the time of selection of voltage level for step up.

(i) Power carrying capability of transmission line increases roughly as the square of the voltage. Accordingly disconnection of higher voltage class equipment from bus bars get increasingly less desirable with increase in voltage level.

(ii) High structures are not desirable in earth quake prone areas. Therefore in order to keep lower structure height and facilitate maintenance, it is important to design such switchyards preferably with not more than two levels of bus bars.

### 2.2.3 Site Limitations

Practical site consideration at a particular location e.g. lack of adequate flat area of layout of equipment in the switchyard may also influence the choice in such locations. Pollution caused by location near to sea or some other contaminated atmosphere may also effect layouts.

### 2.2.4 General and Special Considerations

Other considerations in the selection of suitable arrangement and layout are given below:

- (i) Repair and maintenance of equipment should be possible without interruption of power supply
- (ii) Future expansion of switchyard should be easily possible
- (iii) In seismic prone zones, height of structures should be as low as possible.
- (iv) The outgoing transmission line should not cross each other.

## 2.3 Switching schemes for switchyard

Following schemes are considered for planning and design of different types of switchyards

- (i) Single bus
- (ii) Sectionalized single bus
- (iii) Double bus with bus coupler for higher capacity power stations

## 2.4 Power evacuation and interconnection with grid

### 2.4.1 Power Evacuation Modes

(i) Micro hydropower stations up to 100 kW unit size with electronic load controller

- (a) Isolated operation
- (b) Grid / mini grid connected operation (provision of manual flow control if required)

(ii) Small hydropower plant (unit size 0.1 to 5 MW) with integrated governor and plant control with conventional manual facility/ SCADA

- (a) Isolated operation
- (b) Grid / mini grid connection

(iii) Small hydropower plant unit size 5 MW to 25 MW size having PLC based unit governor and plant control with SCADA

- Grid connected operation only

### 2.4.2 Requirements of Power Evacuation

- (i) Step up voltage at generating station is to be fixed in accordance with para 3 above.

(ii) Interconnected transmission and switching scheme to be designed in accordance with para 5 above.

(iii) Transmission line protection to be provided in accordance with prevalent schemes for different voltage levels. The high voltage transmission lines i.e. 66 KV and above, must be disconnected at receiving end as well as sending end by suitable communication signals.

(iv) Provision of no voltage closing for receiving end breakers It is normal practice to provide synchronizing facilities at power house end generator breaker or transmission line.

### 2.4.3 Provision in Generating Equipment

(i) Isolated and islanding operation will require adequate flywheel for stable operation for commercial load changes. This may be checked by full load rejection. The speed rise should not be more than 35-45% or even lower in case of special (large motor) load characteristics.

(ii) In case isolated operation is not required, flywheel effect could be reduced and the criteria of speed rise on full load rejection can be increased upto 55% - 60%.

(iii) Excitation system for generator should have a provision for power factor control in grid connected mode. Voltage control is required for isolated mode operation as well grid connected mode operation. Before synchronizing machine with the grid voltage control mode is required and after synchronizing change over from voltage control mode to power factor control mode is required. In case of micro-hydro manual excitation control with excitation limit could be provided.

(iv) The transformers for micro hydro for interconnection with the grid should be resin cast dry outdoor type as per REC specifications-30-1984 which corresponds to IEC 60726-1986. The transformers are suitable for harsh conditions and require less rigid maintenance schedule.

(v) Electronic load controller or Induction Generator controller can be used for load variations.

(vi) The transformers should be connected with grounded star on low voltage side and delta on high voltage side, so that grounded neutral is provided for local load in case the SHP is shut down.

(vii) The generator breaker and bus bar at generator voltage be provided for islanding operation.

(viii) Generator breakers HV line side circuit breakers should be electrically operated.

(ix) Reclosing on receiving end grid breaker should be prevented/ blocked.

### 2.4.4 Isolated Operation Mode

(i) Isolated power supply systems using renewable technologies are emerging as technically reliable and economical option for power supply to remote and secluded places.

(ii) For electrification of remote and secluded rural areas there are two general m

- Grid extension
- Diesel generators

In remote areas both options are extremely costly as such renewable resource such as river based or stream based micro, mini or small hydropower plant with isolated operation mode provide low cost alternative.

Fig 4 and Fig 5 shows standard connection for isolated operation.

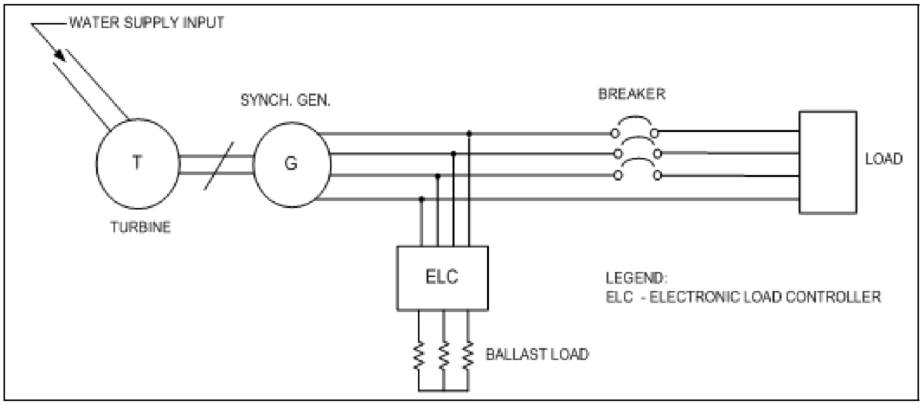


**Fig 4: Standard inter-connection of synchronous generator**

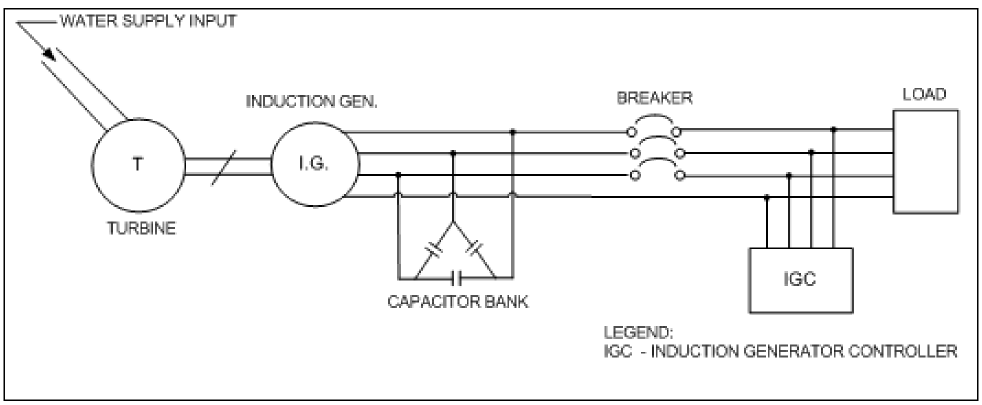


**Fig 5: Standard inter-connection of induction generator**

### 2.4.5 Mini Grid Operation (Decentralized distributed generation facilities with local area network)

Micro hydro for electrification of remote rural areas should conform to following.

### 2.4.5.1 Government of India policy 2005 (extract reproduced below).

### 2.4.5.1.1 Rural Electrification by Small & Micro Hydro Projects

The development objective of the power sector in the country is supply of electricity to all areas including rural areas as per Indian Electricity Act.

Reliable rural electrification systems with small and micro hydro projects especially in Northern States which aim at creating the following are required.

(i) Rural Electrification Ditribution Backbone (REDB) with at least one 33/11 kV (or 66/11 kV) substation in every block and more if required as per load, networked and connected appropriately to the state transmission system.
(ii) Emanating from REDB would be supply feeders and one distribution transformer at least in every village settlement.
(iii) Household Electrification from distribution transformer to connect every household on demand.

**2.4.5.1.2 Accordingly it is suggested:**

(i) That 11 kV substation be provided for electrifying each village.
(ii) That mini grid for micro hydro should be at 11 kV. The mini grid may be connected to REDB 33/11 kV (or 66/11 kV) substation which is if not existing may be identified for the block and the grid should be with reference to the proposed REDB.
(iii) Adequate protection for successful mini grid operation be provided.
(iv) In view of Govt. of India , following provisions should also be incorporated

(a) All micro hydros be provided with 415V/11kV transformer so that village electrification by 11 kV substations is feasible.
(b) A 11 kV mini grid interconnecting the micro hydro should be formed so that spare capacities are reduced and reliability of power supply is increased.
(c) The 11 kV mini grid could be connected REDB in every block envisaged in the Government policy. If the REDB does not exist it could be identified and mini grid form with reference to the REDB.
(d) Provision be made for grid/mini grid operation in generators, excitation system and electronic load controller for successful grid/ mini grid operation of the projects.

**2.4.5.1.2.1 Special requirements**

Technical specifications of Micro Hydro Projects have been grouped in 3 different sizes

Category A – 10kW;
Category B – above 10 to 50kW
Category C – above 50 to 100 kW

Micro hydro for power generation category B & C should have the following provisions:-

- Parallel operation in local grids whenever available.
- Parallel operation with main grid whenever extended.

Micro hydropower generating station category B & C having more than 1 unit shall have following additional provisions:-

- Parallel operation between units at the station
- The Governor/Load Controller, AVR should have adequate provision for adjusting the Speed Droop and
- Droop for facilitating the Parallel Operation of the Units.

#### 2.4.5.1.2.2 Micro hydro mini grid

(i) 11 kV substations be provided for electrifying each village.

(ii) Mini grid for micro hydro should be at 11 kV. The mini grid may be connected to REDB 33/11 kV (or 66/11 kV) substation which is if not existing may be identified for the block and the grid should be with reference to the proposed REDB.

(iii) Adequate protection for successful mini grid operation be provided.

#### 2.4.5.1.2.3 11 kV equipment

11 kV equipment should meet Rural Electrification Corporation (REC) standards as follows:

(i) 11 kV Air Break Switches as REC spec. 43/1987; IS: 9920-2002.

(ii) Sectionalizing switches be 200A/400A capacity with HRC fuses as per REC Standard F-9.

Fig 6a shows a typical metering, relaying and interconnection with mini grid and Fig 6b shows a micro hydro mini grid single line diagram.

### 2.4.5.2 Synchronization with ELC (with provision of adjustment of reference frequency)

#### 2.4.5.2.1 Procedure

(i) Run up turbine.

(ii) ELC regulates speed/ frequency.

(iii) Mini grid and generator side protections are set.

(iv) Auto synchronizer than matches generator speed regulated by ELC and mini grid frequency and brings them in synchronism.

(v) On synchronization main contactor/ breaker is closed and system is connected to grid.

#### 2.4.5.2.2 Advantages of synchronization with ELC

(i) Provides smooth synchronization

(ii) No need of fine control of water flow to turbine

(iii) It is possible to synchronize at low power output in order to use small ELC e.g. 1 MW system can be synchronized at 50 to 100 kW output only.

## 2.4.6 Grid Interconnections

### 2.4.6.1 Types of Grid Inter Connections

There are mainly following type of grid connections of SHP.

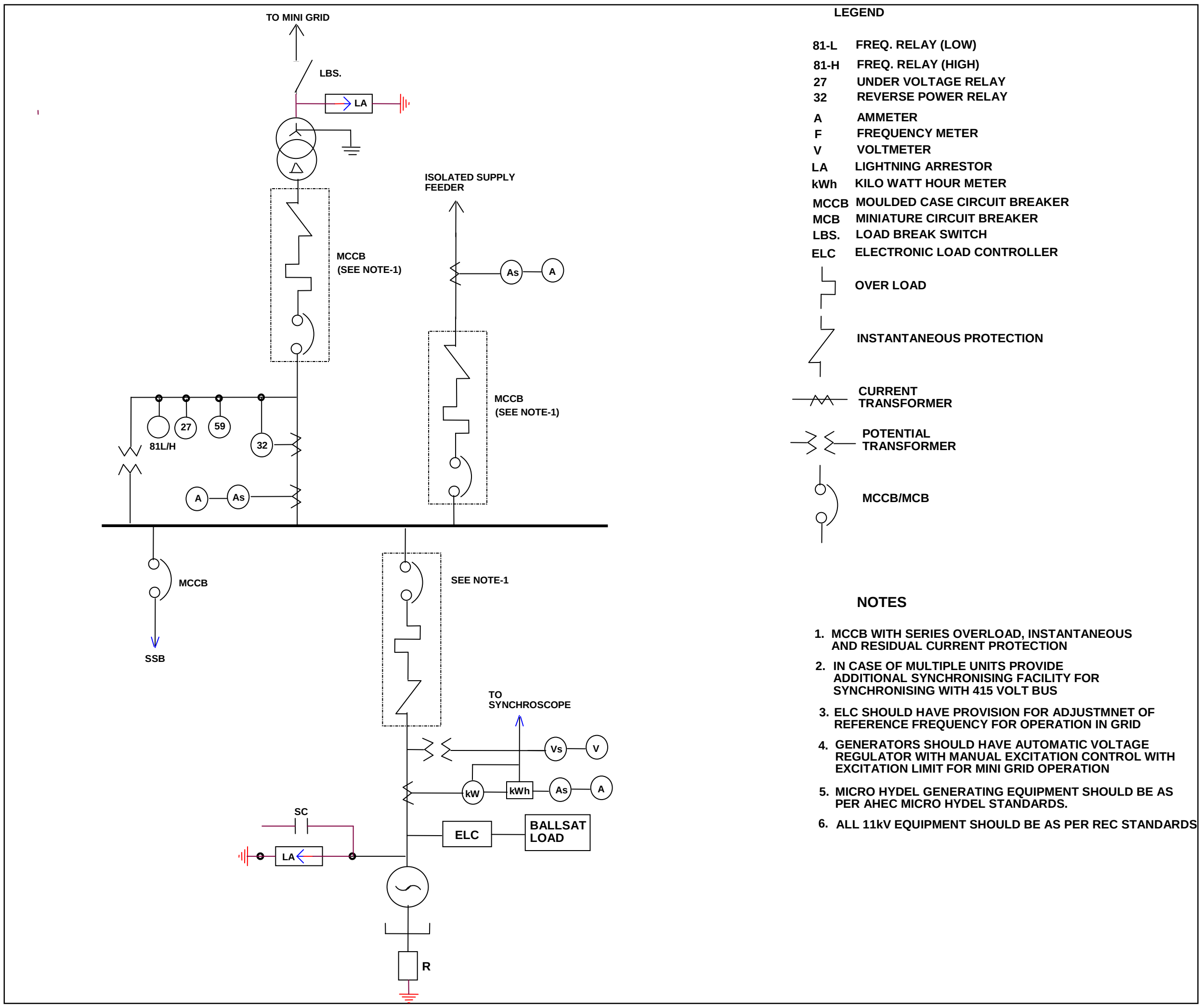


**Fig 6(a) : A Typical Metering, Relaying and Interconnection with Mini Grid**

### 2.4.6.1.1 Power plants with substantial local load

These power plants will regularly operate in parallel with connected grid, but supply the requirements of localized industrial or other facility. The power plant and load when considered together may either be a net importer or net exporter of electrical energy from grid.

### 2.4.6.1.2 Power plants with minimal local loads

These power plants are built to harness a source of energy. These power plants are typically connected to grid through a dedicated line. Typically there will be no other consumer load between the grid substation and power plant. The generators of these power plants will always operate in parallel with the grid.

There are several plants presently in operation with minimal local load which supplies the requirement of generating plant and associated residential colonies and drinking water system.

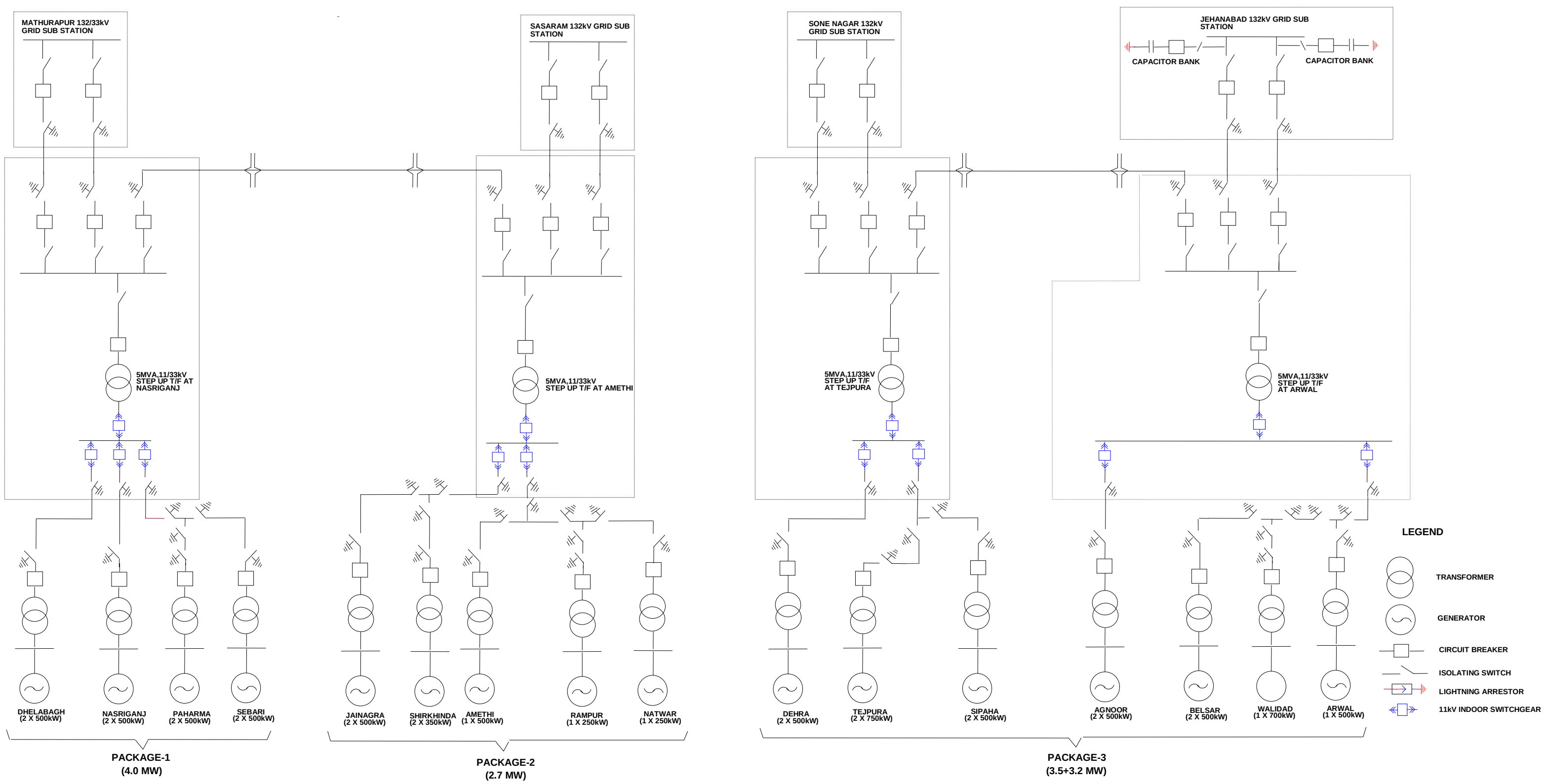


**Fig 6(b) : Typical Stable Mini Grid Single Line Diagram**

### 2.4.6.2 Special Scheme of Interconnection as per IEEE 37.9-2007

A simple scheme of interconnection of an SHP with 33 kV Grid and 415 volts local feeder is shown in the Fig. 7.

For islanding operations synchronizing arrangement is made from generator breaker as well as from interconnecting LV/HV grid breaker

The transformer is connected grounded star on low voltage side so that grounded neutral system is provided for local load in case SHP is shut down. HV (33 kV) side is grounded from sending end side. HV side is protected by HV breaker installed at receiving end transformer grid sub-station for ground fault.

Minimum protection relays to ensure adequate protection of both generator as well as interconnection are shown in the Fig. 7.

**(i) Transformer Protection**

Fig 11 shows transformer protected by transformer differential (87T), Buccholz relay (63) and high voltage side over current (50/51) and ground fault (51G) relays. In case of smaller Hydro electric plants bus differential relays (87B) could be replaced by33 KV side fuses and over current relays (50/51) on the LV side.

**(ii) Transformer low voltage side bus and feeder protection**

Bus differential (87B) provided can be removed and common bus & transformer differential can be provided if the local feeder load is beyond the capacity of local generation.

Back up protection for both the transformer and the feeders is provided by transformer over current relays(50/51) and (51G).The setting of these back up relays should be coordinated with the over current relay which protects the feeder(50/51)and (50N/51N)

**(iii) Protection of inter connecting line**

Reverse power relay (32) which can detect when SHP is not able to supply power to the grid and will operate the grid supply HV side breaker. In normal cases over voltage (59), under voltage (27) and under/over frequency (81) relay will isolate the grid from SHP in case of line outage.

Ground fault protection on the HV line should be provided by over voltage relay (59G) in open delta. A time delay can be provided to clear temporary faults.

**(iv) Synchronising**

Suitable inter locks, check relay, and operating procedure should be designed for following conditions.

Planned or inadvertent outage of the plant, Grid failure or disturbances

For example refer Fig 7:

Breakers 52-3 and 52-4should have facility to synchronise the SHP to system Dead line and synchronise check in relay should be used on breaker 52-1& 52-2 Provision of these will permit following operating procedure.

Breaker 52-1 &52-2 tripped for any fault on inter connecting line.

Breaker 52-1 should close only when it is confirmed that inter connecting line is energized.

Breaker 52-2 should close breaker only when 52-3 is open. If SHP is in operation and bus 1 is energized then 52-3 may be synchronized and closed. If bus 1 is de-energised and breaker 52-4 is open, breaker 52-3 may be closed

### 2.4.6.3 Voltage Levels for Interconnection

The voltage at the point of supply from the small hydropower plant shall be determined as follows:

**2.4.6.3.1** Micro HPs with installed generation capacity up to and including 250 kW shall be inter connected at LV distribution voltage level, if the nominal voltage of generator is 415 V line to line, three phase or 240 V line to neutral, single phase.

**2.4.6.3.2** For installed capacities between 251 kW to 1000 kW, it can be decided on case by case basis, depending on the capacity of transformer at the sub-station normally it is either 415 V or 11 kV.

**2.4.6.6.3 SHPs with an installed generating capacity exceeding 1000 kW shall be interconnected at 11 kV or 33 kV.**

**2.4.6.3.4** SHPs with an installed capacity exceeding 5000 kW shall be interconnected at 33 kV or higher depending on voltage level of nearest grid sub-station.

### 2.4.6.4 Other Miscellaneous Considerations

#### 2.4.6.4.1 Voltage rise

The voltage rise due to generation at grid sub-station bus bar must be within operational limits. Generator voltage variation as per IS, IEC should be within +/-5%.

#### 2.4.6.4.2 Earthing of lines

For earthing provisions of Indian Standards IS: 2309-1989, IS: 3043-1987, IEEE: 80-2000/IEEE: 665-1995, Indian Electricity Rules-1956 and Indian Electricity (supply) Act-2003 are to be followed.

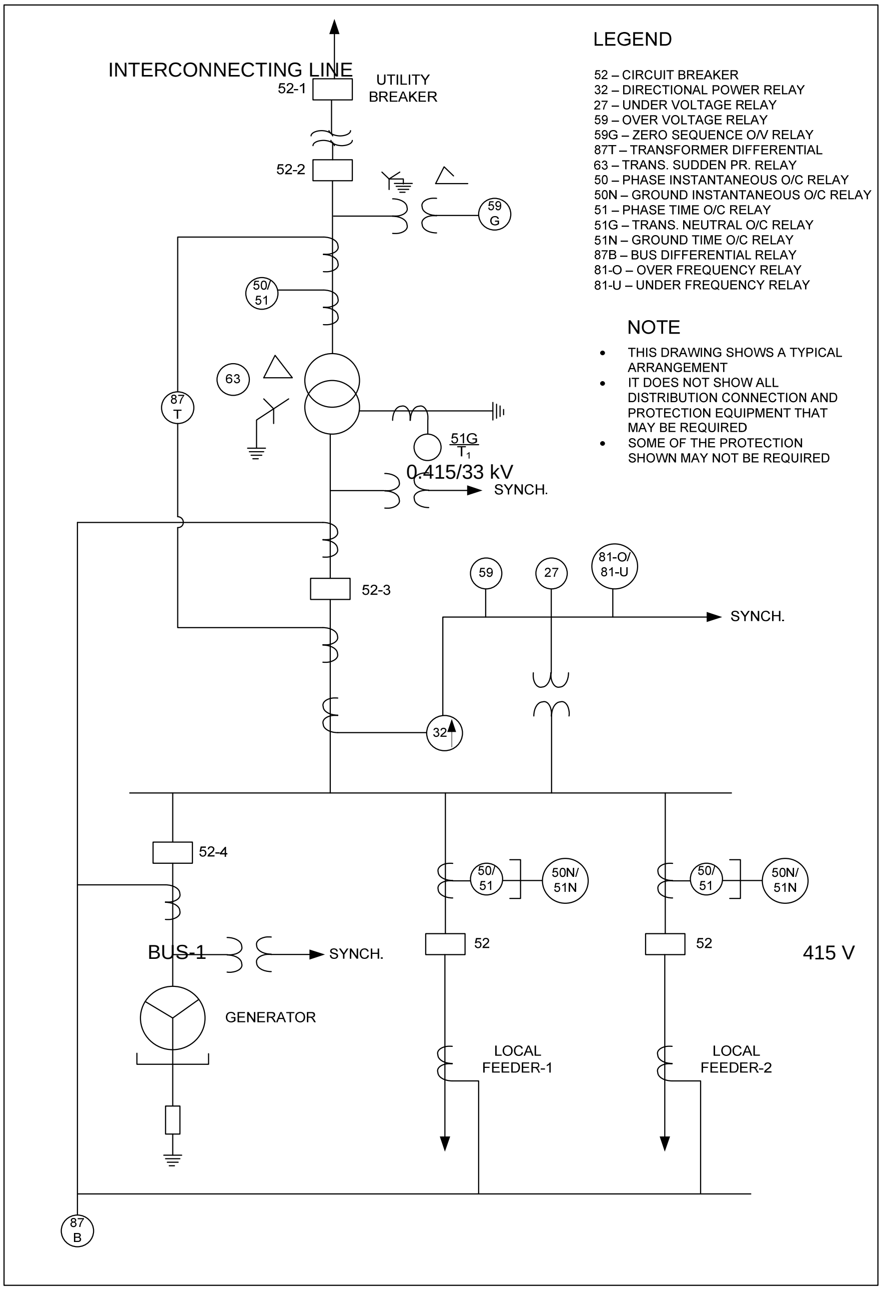


**Fig 7 : Interconnection of SHP with 33 kV grid and local 415 V feeders (Source: IEEE 37.95-2007)**

## 3.0 SPECIFICATION OF POWER LINES (EXAMPLE 33 kV POWER LINE)

### 3.1 Design consideration

#### 3.1.1 General

(i) All electrical installation shall conform to the Indian Electricity Act-2003, IE Rules-1956 and Regulation in force, in the state, by electrical inspectorate.

(ii) Before charging the line/equipment, contractor shall submit the completion report for each part/equipment indicating rectifications/modifications carried out during erection, site test certificates with observations and rectifications carried out. Contractor shall also indicate the correctness of operational and safety interlocks. Site test certificates shall also indicate the corresponding values obtained in the factory test.

(iii) The conductor/jumpers shall be correctly and effectively connected to the terminals of equipment. The connection shall be flexible to withstand stresses during switching operation.

**3.1.2 Relevant IS**: References R17 to R35

#### 3.1.3 Poles

Following types of poles can be used:

(i) Steel Tubular Poles
(i) Pre-stressed concrete poles
(ii) Latticed steel poles

##### 3.1.3.1 Steel Tubular Poles

The Swaged Type Steel Tubular Poles shall conform to IS: 2713 Part-I to Part-III (1980) including subsequent amendments thereof in every respect. Poles shall be made of steel tubes having minimum tensile strength as 42 kg/mm$^2$ and minimum percentage elongation as specified in IS: 1161 (1979). Table 9 shows technical parameters of Swaged Type Steel Tubular Poles

##### 3.1.3.2 Prestressed Concrete Poles

**3.1.3.2.1 Scope**

This specification covers solid rectangular type PCC poles with factor of safety 2.0 of overall length of 9.0 and 9.5M suitable for use in overhead 33 KV power lines.

**3.1.3.2.2 Terminology**

For the purpose of specification, the following definitions shall apply.

**(i) Average Permanent Load**

That fraction of the working load which may be considered of long duration over a period of one year.

**Table 9: Technical Parameters Steel Tubular Poles**

| S. No. | Description | Type of Pole | | | | |
|---|---|---|---|---|---|---|
| | | SP-21 | SP-23 | SP-33 | SP-45 | SP-55 |
| (1). | Total length in Met. | 8.5 | 8.5 | 9.0 | 10.0 | 11.0 |
| (2). | Outside Diameter & Thickness of section in mm | | | | | |
| | (a)Bottom | 139.7 x 5.4 | 165.1 x 4.85 | 165.1 x 5.4 | 165.1 x 5.4 | 193.7 x 4.85 |
| | (b)Middle | 114.3 x 4.5 | 139.7 x 4.5 | 139.7 x 4.5 | 139.7 x 4.5 | 165.1 x 4.5 |
| | (c)Top | 88.9 x 3.25 | 114.3 x 3.65 | 114.3 x 3.65 | 114.3 x 3.65 | 139.7 x 4.5 |
| (3). | Min. weight of Pole in kg | 129.0 | 148.0 | 164.0 | 178.0 | 227.0 |
| (4). | Breaking load in kgf | 462.0 | 596.0 | ≥612.0 | ≥580.0 | 650.0 |
| (5). | Crippling load kgf | 328.0 | 423.0 | ≥435.0 | ≥412.0 | 462.0 |
| (6). | Max. permissible working load F.O.S. of 1.5 m crippling load with point of application of load at 0.3 M from top of the Poles in kgf | 218.0 | 282.0 | ≥290.0 | >275.0 | 308.0 |

**(ii) Load Factor**

The ratio of ultimate transverse load to the transverse load at first crack.

**(iii) Transverse**

The direction of the line bisecting the angle contained by the conductor at the pole. In the case of a straight run, this will be normal to the run of the line.

**(iv) Transverse Load at First Crack**

For design, the transverse load at first crack shall be taken as not less than the value of the working load.

**(v) Working Load**

The maximum load in the transverse direction, that is ever likely to occur, including the wind pressure on the pole. This load is assumed to act at a point 600mm below the top with the butt end of the pole planted to the required depth as intended in the design.

**(vi) Ultimate Failure**

The condition existing when the pole ceases to sustain a load increment owing to either crushing of concrete, or snapping of the prestressing tendon or permanent stretching of the steel in any part of the pole.

**(vii) Ultimate Transverse Load**

The load at which failure occurs, when it is applied at a point 600 mm below the top and perpendicular to the axis of the pole along the transverse direction with the butt end of the pole planted to the required depth as intended in the design.

**3.1.3.2.3 Application**

**(i) 9.0 M Poles**

These poles shall be used at tangent locations of 33,11,0.415 kV lines using conductor formation and clearances as per REC Construction Standard M-3. The requirement of working loads of the poles in different wind pressure zones would be as per REC Construction Standard M-2, which is reproduced below:

| Working load of Pole | Wind Pressure Zone |
|---|---|
| 200 kg | 50 $kg/M^2$ |
| 300 kg | 75 $kg/M^2$ |
| 400 kg | 100 $kg/M^2$ |

Assuming 100 $kg/m^2$ wind pressure in the area, 400 kg poles shall be used for this line.

The maximum permissible spans shall be as per REC Construction Standard M-2.

**(ii) 9.5 M Poles**

These poles shall be used for special locations of lines such as road crossings etc. in the same wind pressure zones as above.

**3.1.3.2.4 Material**

**(i) Cement**

The cement used in the manufacture of prestressed concrete poles shall be as per IS: 269-1976 Specification for ordinary and low heat Portland cement, IS : 8041 E-1978 Specification for rapid hardening portland cement and IS : 8112-1976 Specification for high strength ordinary portland cement.

**(ii) Aggregates**

Aggregates used for the manufacture of prestressed concrete poles shall confirm to IS: 383-1970 (Specification for coarse and fine aggregates from natural sources for concrete). The nominal maximum size of aggregates shall in no case exceed 10 mm.

**(iii) Water**

Water should be free from chlorides, sulphates, other salts and organic matter. Potable water will be generally suitable.

**(iv) Admixture**

Admixtures should not contain Calcium Chloride or other chlorides and salts which are likely to promote corrosion of prestressing steel.

**(v) Pre-stressing steel**

The pre-stressing steel wires shall be conforming to IS: 1785 (Part-I)-1983 Specification for plain hard-drawn steel wire for prestressed concrete, Part-I cold drawn stress relieved wire and IS: 6003-1983: Specification for indented wire for prestressed concrete

**(vi)** The concrete mix shall be designed to the requirements laid down for controlled concrete (also called design mix concrete) in IS: 1343-1980 (Code of practice for prestressed concrete) and IS : 456-1978 (Code of practice for plain and reinforced concrete), subject to the following special conditions:

(a) Maximum works cube strength at 28 days should be at least 400 $kg/cm^2$.

(b) The concrete strength at transfer should be at least 200 $kg/cm^2$.

(c) The mix should contain at least 380 kg of cement per cubic meter of concrete.

(d) The mix should contain as low water content as is consistent with adequate workability. If it becomes necessary to add water to increase the workability, the cement content also should be raised in such a way that the original value of water cement ratio is maintained.

**3.1.3.2.5 Design requirements**

The poles shall be designed for the following requirements:

(i) The poles shall be planted directly in the ground with a planting depth as per IS: 1678-1978.

(ii) The working load on the poles should correspond to those that are likely to come on the pole during their service life.

(iii) The factor of safety for all these poles shall not be less than 2.0.

(iv) The average permanent load shall be 40% of the working load.

(v) The F.O.S. against first crack load shall be 1.0.

(vi) At average permanent load, permissible tensile stress in concrete shall be 30 kg/cm .

(vii) At the design value of first crack load, the modulus of rupture shall not exceed 53.0 kg/cm for M-400 concrete.

(viii) The ultimate moment capacity in the logitudinal direction should be at least one fourth of that in the transverse direction.

(ix) The maximum compressive stress in concrete at the time of transfer of prestress should not exceed 0.8 times the cube strength.

(x) The concrete strength at transfer shall not be less than half the 28 days strength ensured in the design, i.e. 400 x 0.5 = 200 kg/cm.

### 3.1.3.2.6 Dimensions and Reinforcements

The cross-sectional dimensions and the details of prestressing wires should conform to REC standards.

The provisions of holes for fixing cross-arms and other fixtures should conform to the REC standards and in accordance with the construction practices adopted by the State Electricity Boards.

### 3.1.3.2.7 Manufacture

(i) All prestressing wires and reinforcements shall be accurately fixed as shown in drawings and maintained in position during manufacture. The untensioned reinforcement, as indicated in the drawings, should be held in position by the use of stirrups which should go round all the wires.

(ii) All wires shall be accurately stretched with uniform pre-stress in each wire. Each wire or a group of wires shall be anchored positively during casing. Care should be taken to see that the anchorages do not yield before the concrete attains the necessary strength.

(iii) Cover

The cover of concrete measured from the outside of pre-stressing tendon shall be normally 20 mm.

(iv) Welding and Lapping of Steel

The high tensile steel wire shall be continuous over the entire length of the tendon. Welding shall not be allowed in any case. However, jointing or coupling may be permitted provided the strength of the joint or coupling is not less than the strength of each individual wire\

(v) Compacting

Concrete shall be compacted by spinning, vibrating, shocking or other suitable mechanical means. Hand compaction shall not be permitted.

(vi) Curing

The concrete shall be covered with a layer of sacking, canvass, hessian or similar absorbent'material and kept constantly wet up to the time when the strength of concrete is at least equal to the minimum strength of concrete at transfer of pre-stress. Thereafter, the pole may be removed from the mould and watered at intervals to prevent surface cracking of the unit, the interval should depend on the atmospheric humidity and temperature.

(vii) The prestressing wires shall be detensioned only after the concrete has attained the specified strength at transfer (i.e. 200 kg/cm). The cubes cast for the purpose of determining the strength at transfer should be cured, as far as possible, under conditions similar to those under which the poise are cured. The transfer stage shall be determined based on the daily tests carried out on concrete cubes till the specified strength indicated above is reached. Thereafter the test on concrete shall be carried out as detailed in IS : 1343-1980 (Code of practice for prestressed concrete). The manufacturer shall supply, when required by the purchaser or his representative, result of compressive test conducted in accordance with IS: 456-1978 (Code of practice for plain and reinforced concrete) on concrete cubes made from the concrete used for the poles. If the purchaser so desires, the manufacturer shall supply cubes for test purposes and such cubes shall be tested in accordance with IS: 456-1978 (Code of practice for plain and reinforced concrete).

(a) The detensioning shall be done by slowly releasing the wires, without imparting shock or sudden load to the poles. The rate of detensioning may be controlled by any suitable means either mechanical (screw type) or hydraulic.
(b) The poles shall not be detensioned or released by cutting the prqstressing wires using flames or bar croppers while the wires are still under tension.

(viii) Separate eye-hooks or holes shall be provided for handling the transport, one each at a distance of 0.15 times the overall length, from either end of the pole. Eye-hooks, if provided, should be properly anchored and should be on the face that has the shorter dimension of the cross-section. Holes, if provided for lifting purposes, should be perpendicular to the broad face of the pole.
(a) Stacking should be done in such a manner that the broad side of the pole is vertical. Each tier in the stack should be supported on timber sleepers located as 0.15 times the overall length, measured from the end. The timber supported in the stack should be aligned in a vertical line.
(b) Poles should be transported with their broad faces placed vertically and in such a manner that shocks are avoided. Supports should be so arranged that they are located approximately at a distance equal to 0.15 times the overall length from the ends. The erection of the pole should be carried out in such a way that the erection loads are applied so as to cause moment with respect to the major axis, i.e. the rope used for hoisting the pole should be parallel to the broader face of the pole.

(ix) Earthing

(a) Earthing shall be provided by having length of 8 SWG GI wire embedded in concrete during manufacture and the ends of the wires left projecting from the pole to a length of 100mm at 250 mm from top and 150 mm below ground level.
(b) Earth wire shall not be allowed to come in contact with the prestressing wires.

**3.1.3.2.8 Tests**

**(i) Transverse Strength Test**

(a) Poles made from ordinary Portland cement shall be tested only on the completion of 28 days and poles made from rapid hardening cement only on the completion of 14 days, after the day of manufacture.
(b) The poles may be tested in either horizontal or vertical position. If tested in horizontal position, provisions shall be made to compensate for the overhanging weight of the pole, for this purpose, the overhanging portion of the pole may be supported on a movable trolley or similar device.

(c) The pole shall be rigidly supported at the butt end for a distance equal to the agreed depth of planting.

(d) Load shall be applied at a point 600 mm from the top of the pole and shall be steadily and gradually increased to the design value of the transverse load at first crack. The deflection at this load shall be measured.

A prestressed concrete pole shall be deemed not to have passed the test if visible cracks appear at a stage prior to the application of the design transverse load for the first crack.

The load shall then be reduced to zero and increased gradually to a load equal to the first crack load plus 10% of the minimum ultimate transverse load, and held up for 2 minutes. This procedure shall be repeated until the load reaches the value of 80 per cent of the minimum ultimate transverse load and thereafter increased by 5 per cent of the minimum ultimate transverse load until failure occurs. Each time the load is applied, it shall be held for 2 minutes. The load applied to prestressed concrete pole at the point of failure shall be measured to the nearest five Kilograms.

The pole shall be deemed not to have passed the test if the observed ultimate transverse load is less than the design ultimate transverse load.

**(ii) Measurement of Cover**

After completion of the transverse strength test, the sample pole shall be taken and checked for cover. The cover of the pole shall be measured at 3 points, one within 1.8 meter from the butt end of the pole, the second within 0.6 meters from the top and the third at an intermediate point and the mean value compared with the specified value.

The mean value of the measured cover should not differ by more than ± 1mm from the specified cover. The individual values should not differ by more than ±3mm from the specified value.

If these requirements are not met, the workmanship with reference to aligning of the end plates and prestressing wires and assembly of moulds should be improved and inspection at pre-production stage tightened suitably.

**3.1.3.2.9 Sampling and Inspection**

**(i) Scale of Sampling**

(a) Lot: In any batch, all poles of the same class and same dimensions shall be grouped together to constitute a lot.

(b) Sub-lot: If the number of poles in a lot exceeds 500, the lot shall be divided into a suitable number of sub lots such that the number of poles in any sub-lot shall not exceed 500. The acceptance or otherwise of sub-lot shall be determined on the basis of performance of samples selected from it.

The number of poles to be selected from a lot or a sub-lot shall depend upon its size and shall be as shown in the following Table 10:

**Table 10 : Number of poles to be selected from a lot or a sub-lot**

| Sample size and criterion for conformity | | | |
|---|---|---|---|
| **Size of lot or sub-lot** | **Dimensional requirement** | | **No. of poles for transverse strength test *** |
| | **Sample size** | **Permissible No. of defective samples** | |
| Upto 100 | 10 | 1 | 3 |
| 101 to 200 | 15 | 1 | 3 |
| 201 to 300 | 20 | 2 | 4 |
| 301 to 500 | 30 | 3 | 5 |

*The number of poles to be tested shall be subject to the agreement between the purchaser and supplier.

(c) These poles shall be selected at random. In order to ensure randomness, all the poles in the lot or the sub-lot may be arranged in a serial order and starting from any random pole, every rth pole may be included in the sample, r being the integral part of N/n where N is size of the lot or the sub-lot and n is the sample size. These poles may be selected out of those which have already been tested.

**(ii) Number of Tests**

(a) All the poles as selected shall be tested for overall length, cross-section and uprightness. The tolerance shall be (+) (-) 3 mm on cross sectional dimensions and 0.5 per cent on uprightness.

(b) The number of poles to be tested for transverse strength test shall be in accordance with Col. 4 of the above Table.

**(iii) Criteria for Conformity**

(a) A lot or sub-lot shall be considered as conforming to this specification if the above conditions are satisfied.

(b) The number of poles which does not satisfy the requirements of overall length, cross-section and uprightness shall not exceed the corresponding number given in Col. 3 of above Table. If the number of such poles exceeds the corresponding number, all poles in the lot or sub-lot shall be tested for these requirements and those not satisfying the requirements shall be rejected.

(c) All the poles tested for transverse strength test shall satisfy the requirements of the test. If, one or more poles fail, twice the number of poles originally tested shall be selected from those already selected and subjected to the test. If there is no failure among these poles, the lot or the sub-lot shall be considered to have satisfied the requirements of this test.

**3.1.3.2.10 Marking**

The pole shall be clearly and indelibly marked with the following particulars either during or after manufacture but before testing at a position so as to be easily read after erection in position:

(i) Month and year of manufacture
(ii) Transverse strength of pole in Kg.
(iii) Maker's serial No. and mark.

Table 11 shows Economical design for a solid rectangular type prestressed concrete pole for 33 kV line.

**Table 11 : Economical Designs for Solid Rectangular Type Prestressed Concrete Poles For 33 kV Lines**

Factor of Safety: 2.0 Concrete Grade - M-400

| S. No | Overall Lengths of pole | Working Load | Overall Dimensions | | | Reinforcement Details | | Concrete Quantity Per pole | Steel Qty. per Pole | Weight Per Pole |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bottom Depth | Top Depth | Breadth Prestres Sing | Diameter of Wires | No. of Tensioned Wires | | | |
| | m | kg | cm | cm | cm | Mm | | Cub.-m | kg | kg |
| 1 | 9.0 | 200 | 31.5 | 14.5 | 8.5 | 4 | 12 | 0.176 | 10.65 | 425 |
| 2 | 9.0 | 300 | 35.5 | 18.5 | 10.0 | 4 | 16 | 0.243 | 14.20 | 585 |
| 3 | 9.0 | 400 | 39.5 | 22.5 | 10.0 | 4 | 20 | 0.279 | 17.76 | 670 |
| 4 | 9.5 | 200 | 31.5 | 14.5 | 10.0 | 4 | 12 | 0.218 | 11.25 | 525 |
| 5 | 9.5 | 300 | 36.5 | 18.5 | 10.0 | 4 | 16 | 0.261 | 14.99 | 625 |
| 6 | 9.5 | 400 | 40.5 | 22.5 | 10.0 | 4 | 20 | 0.299 | 18.74 | 720 |

**3.1.3.3 Latticed Steel Poles**

**3.1.3.3.1 Scope of supply**

Usually tubular steel poles are used but the latticed steel poles may be used in hill regions having narrow and winding roads where transportation of steel tubular poles or pre stressed concrete poles become extremely difficult.

The relevant IS or equivalent international standards are to be considered in the design, manufacture and testing of the above mentioned materials. Specifications and quantities are stated in the following items.

**3.1.3.3.2 General requirements**

The materials shall be of first class quality and suitable for the climatic conditions of the site where these are to be used.

**3.1.3.3.3 Technical requirement**

Table 12 shows require system data

#### 3.1.3.3.4 Materials and process

The poles shall be made from hot rolled RS- joists and angle-steel sections with steel plates specified in IS: 2062-1992 or in accordance with any international equivalent standard having mechanical properties as shown in Table 13.

**Table 12 : System Data**

| **a. 11 KV System** | |
|---|---|
| Nominal voltage | 11000 V |
| Highest system voltage | 12000 V |
| System | 3-phase, 3wire neutral earthed through resistance of 21.1 Ohm limiting the earth fault current to 300A |
| Short circuit breaking current | 16 kA rms at 11000 Volts |
| **b. 0.415 kV System** | |
| Nominal voltage | 415 V |
| System | 3phases, 4 wires with neutral solidly grounded. |
| Frequency | 50 Hz |

**Table 13: Mechanical properties of steel sections used for fabrication of latticed poles**

| **Characteristics** | **Unit** | **Steel type** |
|---|---|---|
| | | **Steel 52 (to IS 2062-1992)** |
| Tensile strength | kg f /mm$^2$ (min) | 52 |
| Yield strength | kg f /mm$^2$ (min) | 36 |
| Design bending stress | kg f /mm$^2$ (min) | 20.8 |

Materials for clamps and cross-arms shall be made of hot rolled structural carbon steel in accordance with the same specifications as that of the poles.

#### 3.1.3.3.5 Lattice-steel poles

Each low voltage lattice steel pole shall be made out of two Nos. I-steel joists which are to be welded together and cross-braced with angle iron size (30×30×3) of steel forming the shape of latter (A) as shown at Fig 8.

I-steel sizes (120×58×5.1×7.7) for low voltage (140×66×5.7x8.60) for medium voltage lattice steel pole are to be used

(i) Low-Voltage Lattice Poles

The lattice pole which is shown in Fig 8 should be capable of withstanding a working load of (700 Kgf) acting vertical to its plan in the transverse and longitudinal directions at the poles top. Planting depth shall be (1.5 m) for (9 m) poles. The rest of dimensions and parameters as per Fig 8 attached and also for locations of holes. The whole pole shall be hot-dip galvanized according to the relevant IS.

(ii) Medium Voltage Lattice Poles

Referring to Fig 8 this pole has to withstand the max. working loads 1400 kgf. Planting depth shall be (2m) for (11 m) poles. The rest of dimension, parameters, locations of hole shall be as per Fig 8 attached. (A clamp) as per Fig 9 shall be welded to the top of each pole. The whole pole shall be hot-dip galvanized according to relevant IS.

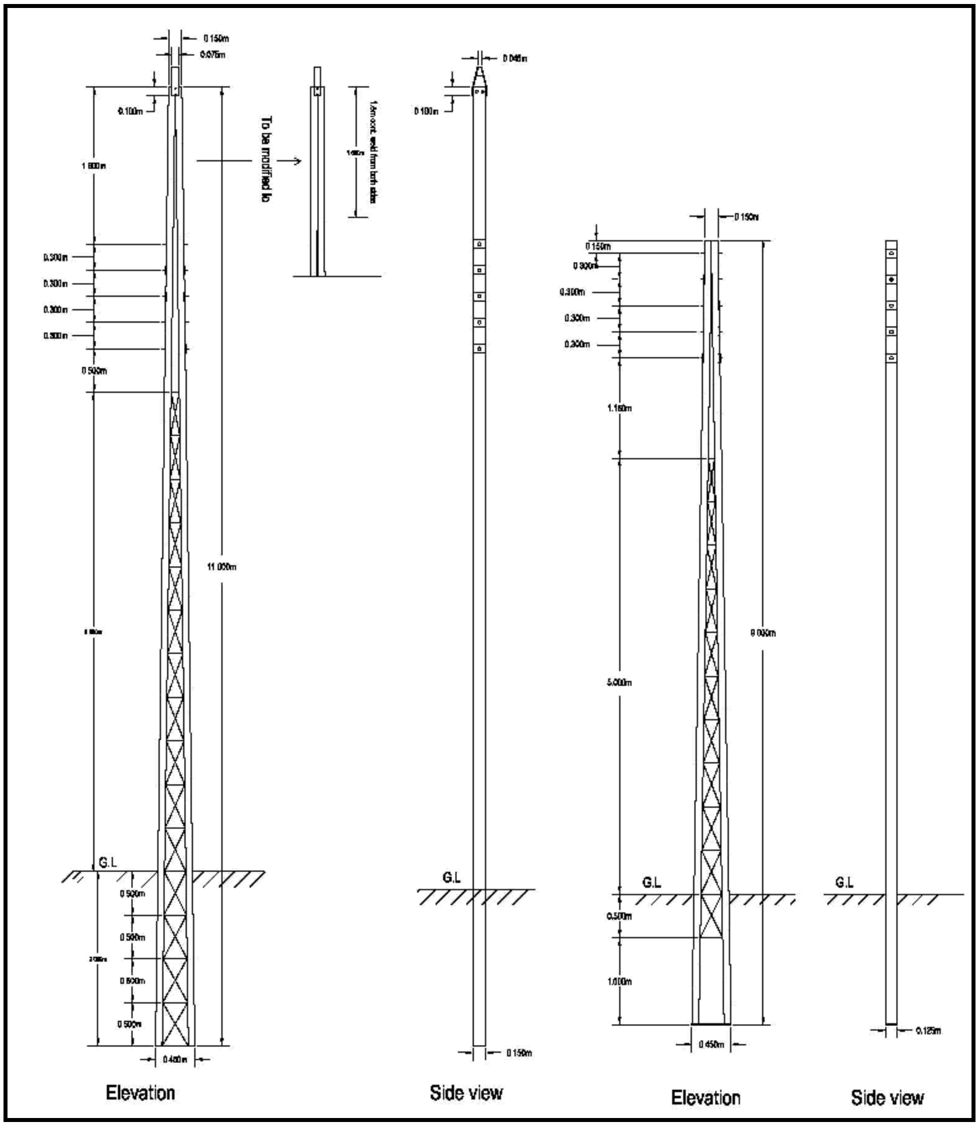


**Fig 8 : 11m and 9m latticed Poles**

(iii) Common Remarks for Lattice Poles:

a. Each of the (9&11 m) lattice steel poles shall have an earthing hole (18 mm dia.) located at the center of the lower plate for earthing purposes.
b. Every steel lattice pole shall be electrically galvanized, high stress, hexagonal – headed (M-16) fully threaded bolt (35 mm) length of screw with nut, plain washer & spring washer as required.

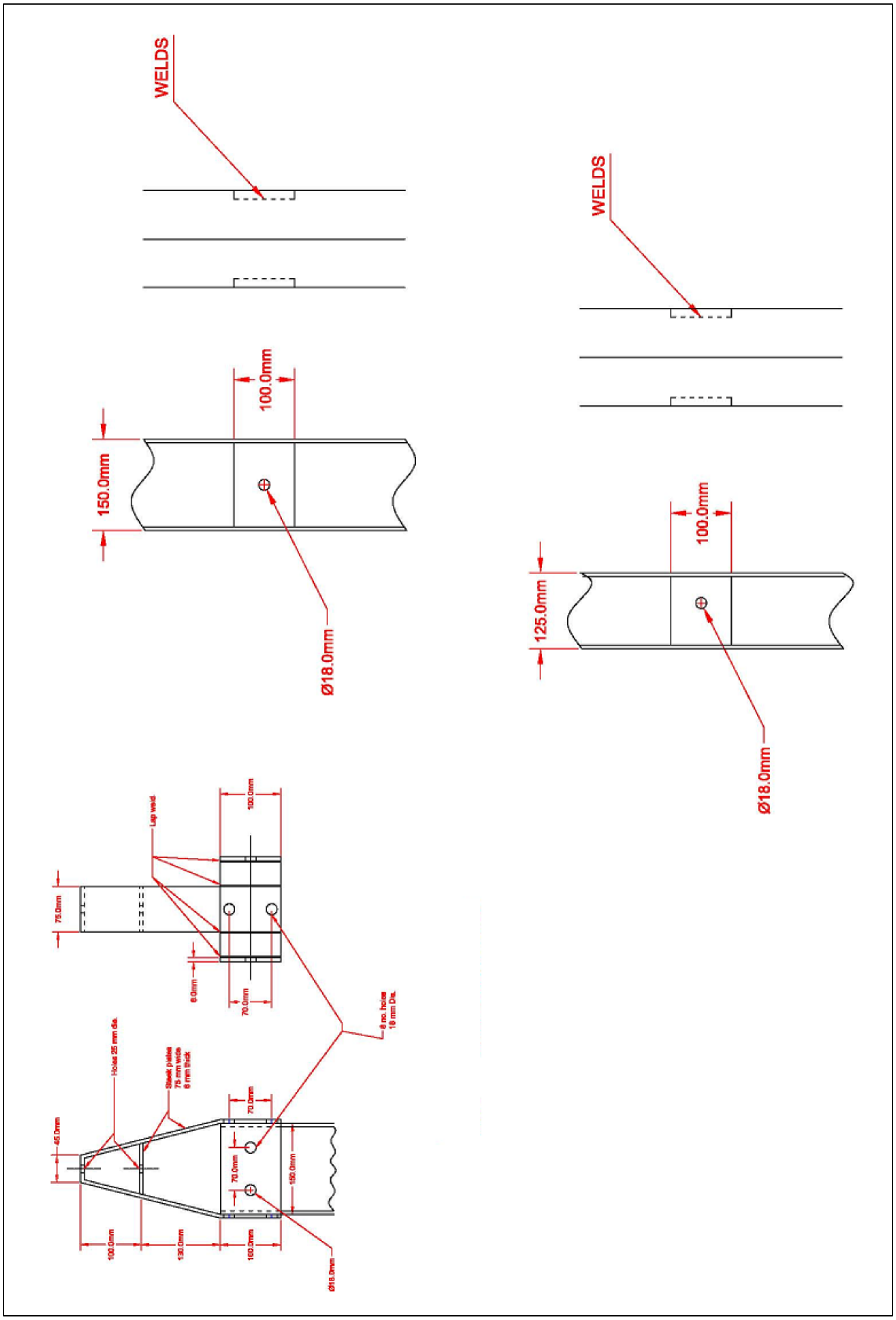


**Fig 9 : Details of a clamp to be welded at top of Poles**

**3.1.3.3.6 Testing**

All materials under contract shall be tested at the manufacturing works to verify compliance to our specifications. The Purchaser shall appoint an inspector for this purpose, but the manufacturer shall supply all equipment and facilities to inspector necessary for conducting all such tests without extra charge, the tests shall include the followings: -

(i) Certificate furnished by the manufacturer for the materials like I-joist, angle-steel, steel plates, channel steel, bolts & nuts…etc. These should be in accordance with provisions of relevant IS.
(ii) Dimensional tests in quantities not less than (5%) of the quantity of each batch, taking into consideration that eccentricity between top and bottom part of the pole shall not exceed 1/1000.
(iii) Welding tests by x-ray at the rate of two tests per each 100 Nos. of lattice poles.
(iv) Loading Tests (type test)

The design of each pole shall have the acceptance criteria as shown in Table 14 when conducting loading tests.

**Table 14 : Acceptance Criteria**

| Load | Measuring item | Acceptance criteria |
|---|---|---|
| Ps | Specified working load | Any defect should not be produced |
| O | | |
| Pp | Ps × 1.5 load | Any defect should not be produced |
| O | | Permanent set shall not exceed (13 mm) from zero position |
| Pb | Ps × 2.5 load | Destruction |

Where

Ps = Specified working load.

Pp = Load for permanent set not exceeding (13 mm).

Pb = Breaking load.

The loading test shall be carried out at rate of one test per each batch of 500 Nos. of lattice poles manufactured.

(v) Galvanizing
Test shall be carried out on samples of the materials under contract as per relevant IS

**3.1.3.3.7 Packing**

The manufacturer shall state clearly in his offer the proposed packing of the materials under contract mainly for the lattice poles and how many poles in each bundle. The cross arms and accessories shall be supplied in suitable bundles as well.

**3.1.3.3.8 Alternative design**

The tenderer may offer an alternative design for the lattice poles, but the new design shall take the following points into consideration.

a. Same applied working load.
b. Same total lengths of pole.
c. Same locations of the medium voltage and low voltage conductor.
d. Suitability of the cross-arms to the (11 m) lattice poles.

#### 3.1.3.3.9 Specification for the Cross-Arms

The cross-arm shall be used to support insulators carrying bare almunium conductors on the medium voltage poles (11 m) they are to be made of channel steel section. Flat steel, bolts, nuts and washers as per Fig 10 attached. All steel work shall be hot dip galvanized but bolts nuts; washers shall be electrically galvanized.

<u>Note:</u>

a. All drawings of the pole and its accessories subjected to Purchaser's approval before start of manufacturing.
b. The type of poles (galvanized or painted) will be fixed by the tenderer.

#### 3.1.3.3.10 Schedule of materials

Schedule of materials shall be prepared in the following tabular form as shown in Table 15.

**Table 15 : Schedule of Materials**

| S. No. | Item | Qty. | Total Price |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

### 3.1.4 ACSR Conductor

**Construction**

Conforming to IS 398 (Part-II), 1996.

(i) Aluminium wire made from at least 99.5% pure electrolytic aluminium rods of EC grade with copper content less than 0.04%.
(ii) Steel wires uniformly coated with electrolytic high grade, 99.95% pure zinc.
(iii) Steel strand hot dip galvanized with minimum coating of 250 gm/sq.m. after standing.
(iv) No joints permitted in the individual aluminium wires and steel core of the conductor.

Standard length of conductor shall be as specified in relevant IS.

The materials in common use for conductor and connections are ACSR conductors. However, All Aluminium Conductors of equivalent size may also be used. Details of various type of ACSR conductors are given in Annexure-2.

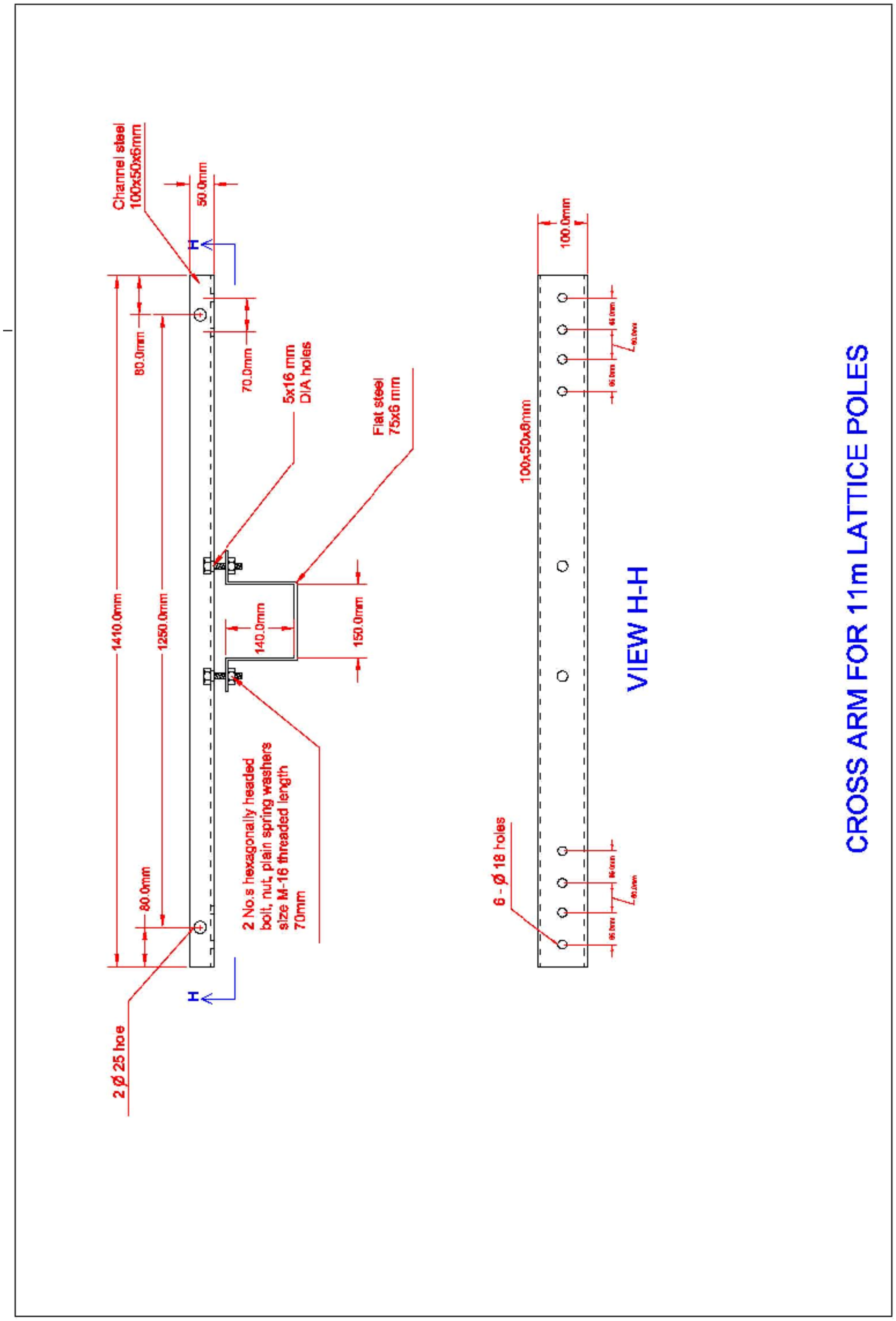


**Fig 10 : Cross arm for 11 m latticed pole**

### 3.1.5 Connectors

Bi-metallic connectors shall be used for connecting equipment terminals made of copper or brass, bolts, nuts and washers for connector shall be made of mild steel and shall be electro-galvanized and passivated to make them corrosion resistant conforming to requirements of BS 1706:1990 – "Method for specifying electroplated coatings of zinc and cadmium on iron and steel".

### 3.1.6 H.T. Insulators

String insulators (Constructional Features)

Suspension and tension insulators shall be wet process porcelain with ball and socket connections. Insulators shall be interchangeable and shall be suitable for forming either suspension or strain strings.

The insulator shall be such that stresses due to expansion and contraction in any part of the insulator shall not lead to deterioration. All ferrous parts shall be hot dip galvanized, the zinc used for galvanizing shall be of grade Zinc 99.5% as per IS: 209. The zinc coating shall be uniform, adherent, smooth, reasonably bright, continuous and free from imperfections such as rust stains, bulky white deposits and blisters.

Rated strength of each insulator shall be printed on the porcelain before firing. Polymeric insulators may be used as per the guidelines of the Engineer in charge

### 3.1.7 String Insulator Hardware (Constructional Features)

Insulator hardware shall be of forged steel. The surface of hardware must be clean, smooth, without cuts, abrasion or projections. No part shall be subjected to excessive localized pressure. The metal parts shall not produce any noise generating corona under operating condition.

Insulator tension string hardware assembly shall be designed with electromechanical strength of 11500 kg.

Tension string assembly shall be supplied along with suitable turn buckle (one turn buckle per string).

All hardware shall be bolted type. The tension/suspension clamp shall be of Aluminium alloy.

Each Insulator string shall comprise of 4 nos. disc insulator for 33kV to meet the required creepage / dry arc distance requirements.

### 3.1.8 Hot Dip Galvanized MS Stranded Wire

The hot dip galvanized MS stranded wire of sizes 7/8, 7/10 and 7/16 mm etc. SWG shall conform to the following specifications:

(i) Material

- (a) MS Wire: Used for each strands shall have the chemical composition maximum Sulphur & Phosphor – 0.055%, Carbon-0.25%.
- (b) Zinc shall conform to grade Zn 98 specified as per IS: 209-1966 and IS: 4926-1979 with up-to-date amendments.

(ii) Zinc Coating: Shall be in accordance with IS: 4826-1979 (heavily coated hard quality grade 4 as per Table 1).
(iii) Galvanizing: Shall be as per IS: 2629-1966, IS: 4826-1979 with up-to-date amendments.
(iv) Uniformity of Zinc Coating: Shall be as per IS: 2633-1972 (Col. 4.2.1 to 4.2.3) with up-to-date amendments.
(v) Tensile Properties: Of each strand ensuring MS wire, mechanical properties as per IS: 280-1972 Cl. 8.1 to 8.3 and after galvanizing each wire shall be of tensile strength minimum 700 $N/mm^2$ (71 $kg/mm^2$).
(vi) Tensile strength breaking load and elongation of each wire and full stand shall conform to IS: 2141-1968, IS: 2141-1979 in the tensile grade given above.
(vii) Construction: Shall be as per IS: 2141-1968.
(viii) Test on Wire before manufacture: As per IS: 2141-1979 (Cl. 7.1 to 7.2.2).
(ix) Test on Complete Strand: Test shall be conducted in accordance to IS: 2141-1979.
(x) Packing: Each coil shall be between 50-100 kg packed as per IS: 2141-1968 (Cl. 9.10 6594-1979) and 2141-1979 (Cl. 11).
(xi) Marking: As per IS: 2141-1968 (Col. 8.1 and 8.1.1), IS: 2141-1979 Cl. 10 and 10.1).

### 3.1.9 MS Stay Sets

#### 3.1.9.1 GS Stay Sets For HT Lines

**(i) Anchor Rod with one washer and nuts**

Overall length of galvanized rod should be 1800 mm to be made out of 20mm dia MS Rod end threaded upon 40 mm length with a pitch of 5 threads per cm and provided with one square MS washer of size 40 x 40 x 1.6mm and one MS hexagonal nut conforming to IS: 1367 - 1967 and IS: 1363:1967, and as per latest version. Both washer and nut to suit threaded rod of 20mm dia. The other end of the rod shall be made into a round eye having an inner dia of 40mm with best quality welding.

**(ii) Anchor Plate**

To be made out of MS plate of 6mm thickness. The anchor plate of size 200x200x6 mm shall have at its centre 18mm dia hole.

**(iii) Turn Buckle**

(a) Eye bolt with 2 nuts:

To be made of 20mm dia MS rod having overall length 450mm, one end of the rod to be threaded up to 300mm length with a pitch of 5 threads per cm and provided with two MS Hexagonal nuts of suitable size conforming to IS : 1363 - 1967 and IS : 1367 - 1967. The other end of rod shall be rounded into a circular eye of 40mm inner dia.

(b) Bow with welded angle:

To be made out of 20mm dia rod. The finished bow shall have an overall length of 995mm and height of 450mm. The apex or top of the bow shall be bent at an angle of 10R. The other end shall be welded with proper and good quality welding to a MS angle 180mm long having a dimension of 50 x 50 x 6mm. The angle shall have 3 holes of 22mm dia each.

**(iv) Thimble**

To be made of 1.5mm thick MS sheet into a size of 75 x 22 x 40mm shape.

**(v)** Entire stay set shall be hot dip galvanized as per relevant IS.

**(vi)** Use stay wire of 7/10 SWG GS grade.

### 3.1.10 Structural Work

Design and fabrication of structural parts shall conform to the applicable provisions of the DIN standards, including DIN 19704, Hydraulic steel structures: criteria for design and calculations and DIN 4114, Stability of steel structures, unless otherwise prescribed elsewhere in these Specifications. All embedded metal shall be at least 12 mm thick and all other metal shall be at least 10 mm thick. Dimensions without tolerances shall be according to DIN 7168

### 3.1.11 Welding

The welding shall be conforming to relevant IS: 823/1964 or its latest amendment.

### 3.1.12 Clamps and Connectors

The clamps and connectors shall be made of materials shown in Table 16:

**Table 16: Materials for Clamps and Connectors**

| | |
|---|---|
| For connecting ACSR Conductors destination | Aluminium alloy casting conforming to A6 of IS: 617-1994 and shall be tested for all test as per IS: 617-1994. |
| For connecting equipment terminals made of copper with ACSR conductors | Bimetallic connectors made from aluminium conforming to A6 of IS: 617-1994. |
| For connecting G.I. Shield wire | Galvanized mild steel. |
| Bolts, nuts and plain washers | Hot dipped galvanized mild steel except for sizes below M12 for which electro-galvanized ones shall be used. |
| Spring washers | Electro galvanized mild steel as per service conditions at least 3 of IS: 1573-1986. |

All casting shall be free from blow holes, surface blisters, cracks and cavities. All sharp edges and corners shall be blurred and rounded off. No current carrying part of a clamp or connector shall be less than 12 mm thick.

All ferrous parts shall be hot dip galvanized conforming to IS: 2629-1966.

For bimetallic clamps and connectors, bimetallic strip shall be used.

Flexible connectors, braids or laminated straps shall be made from tinned copper sheets or aluminium laminates depending on the clamp. The terminal clamps for bus posts shall be suitable for both expansion as well as fixed / sliding connection as required. Fixed sliding feature shall be possible just by reversing the top gripper without the necessity of any additional components.

Code number for the clamp / connector shall be indelibly marked on each component of the clamp / connector, except on the hardware.

Clamp shall be designed to carry the same current as the conductor and the temperature rise shall be equal or less than that of the conductor at the specified ambient temperature. The rated current for which the clamp / connector is designed with respect to the specified reference ambient temperature, shall also be indelibly marked on each component of the clamp / connector, except on the hardware.

All current carrying parts shall be designed and manufactured to have minimum contact resistance.

Clamps and connectors shall be designed for corona controlled.

The welding sleeve for the aluminium tube shall match with that of the aluminium tube to avoid unnecessary work at site after the dispatch. The length of the sleeve shall be minimum seven times the outdoor diameter of the main aluminium tube.

Sleeves along with distancing pins (4 nos. per sleeve) shall be supplied

## 3.2 INSTALLATION GUIDELINES

### 3.2.1 General

The Power Line work includes Survey, Profiling, Alignment each including preparation of schedule of material, check survey profiling etc., manufacture/ procurement of electrical equipment, shop testing, packing, transportation, loading & unloading, delivery, storage at site, handling, erection, Laying, Stringing & Sagging of 3 phase conductor with GI earth wire including the hosting of Disc insulator, Disc Fitting & jumpering of line by fixing of PG clamps, pre-commissioning test and commissioning of all equipment/ system including preliminary acceptance test, performance guarantee and post commissioning services.

### 3.2.2 Relevant Standard

References R8 to R14

### 3.2.3 Installation Works

#### 3.2.3.1 Excavating pits for erection of poles

(i) After the pit locations are finalized and peg marked on the ground, the pole pit of size 750 x 750 x 1500/1850 mm be dug (9/11 M. pole). The base padding of 200mm thick with 1:4:8cement concrete shall be done before erection of pole. The earthing coil shall also be grounded 800mm below ground level by digging a separate pit minimum 4 mtr away from pole and filling the pit with soil. The pole in the pole pit shall be erected in truly vertical position and the pit is filled with 1:3:6 cement concrete mixture for size 600 x 600 x 1500/1850 mm and muffing be provided on pole upto 400 x 400 x 400mm above ground level of 1:2:4 cement concrete mixture.

(ii) The poles shall be erected normally with a span of 80 to 90 meters or as per standard design.

(iii) Painting of pole with one coat of red oxide and two coats of approved aluminium paints on portion above ground level shall be applied.

(iv) For the portion buried under ground, additional two coats of Bitumen paints shall be applied.

(v) Each pole shall be earthed with MS earth rod 2500x20mm below the 800mm below ground level including fixing of 6 SWG Gl wire between rod and pole. At 600 mm height above ground level by putting hole in pole and bolting with 16mm size nuts and bolts. The earth coil shall be grounded 800mm below ground level by digging separate pit and filling the pit with soil. All materials are included in tenderer's scope, as part of erection works.

### 3.2.3.2 Fixing cross arm, top clamps, channels etc. on the poles

The fitting such as V cross arm, top clamps, channel etc. shall be fixed on poles as per standard practice. The fabrication of above fittings shall also be done as per approved standard drawing submitted by tenderer. The general specifications of steel sections are given below:

(i) V cross arm shall be made of MS angle of size 125 x 65 mm.\

(ii) Top clamp shall be made of MS flat of size 50 x 8, mm.

(iii) Double Cross arm shall be made out of the MS channel of size 100 x 50 x 6mm.

(iv) Other special fittings if required may be got fabricated as per the standard drawings of utility. The clamps for holdings the fittings shall be fabricated out of MS flat 65 x 8msize.

All nuts and bolts used shall be of MS with combination of plain and spring washer and machine made.

### 3.2.3.3 Fixing of insulators and Connected Hardware

(i). Insulator shall be handled carefully in all stages of loading and individually checked for cracks, damages, loss of glaze etc. before assembling and erection at site.

(ii). The 33kV galvanized steel pins made by process of forging suitable for 33kV pin insulators having maximum failing load of 10KN with small steel head as per Fig. IB of IS: 2486 -1974 shall be used. The pin shall be provided with nut (hot-dip galvanized) one plain washer and one spring washer (electro galvanized).

(iii). The disc insulators shall be fitted with 33kV Hardware for tensioning the conductor 33kV hardware should be fixed in the disc insulators as per the standard practice and in the correct position to bear the tension of conductor. The 33kV strain hardware fitted of aluminium alloy suitable for required conductor (ACSR) shall be used conforming to IS: 2486 (Part-II) 1989. Polymer insulators can also be used.

(iv). The pit 0.4 x 0.6 x 1.6 meter shall be excavated and anchor plate with stay rod shall be suitably aligned in such a manner that the stay wire when bonded with - anchor rod and stay clamp at pole, the same shall make on angle of 30o to 45o from the pole. Cement concrete mix of 1:3:6/1:2:4/1:1½:2 shall be poured in the pit, rammed adequately and cured properly.

#### 3.2.3.4 Stringing of Conductor

Conductor shall be laid out from rotating wheel supported on jacks for easy unwinding of the conductor. Snatch blocks shall be used for stringing the conductor and shall have grooves of a shape and size to allow early flow of conductor and ensure damage free operation. Clamps shall be used to grip the conductor at the time of stringing.

#### 3.2.3.5 Sagging of conductor

All conductors sagging shall be in accordance with the sag and tension tables as per relevant Indian Standards. After the conductors have been pulled to the required sag, inter mediate spans shall be checked to determine the correct sag. The conductor shall be installed on insulators secured to it by means of 6 SWG aluminium binding wire. The jumpers at the tension locations shall also be bound by 6 SWG aluminium binding wire. Before fixing the conductor on insulator and strain hardware, aluminium tape shall be wrapped on the conductor.

#### 3.2.3.6 Guarding

The 33kV cross arm fitted on the pole guarding line with 6SWG GI wire guard wire and 8 SWG G I wire for lacing. Guarding cross made of 75 x 75 x 6mm angle, 8 feet long shall be claimed at 300mm below the bottom arm of V cross arm.

#### 3.2.3.7 Anti Climbing Devices

Barbed wire shall be wrapped at a height of 3000mm above ground level stretching in 900mm length. Both ends of barbed wire shall be clamped suitably to avoid coming down from its location.

#### 3.2.3.8 Danger Board

Danger board for 33kV voltage and danger mark conforming to IS: 2551 - 1963 shall be fixed on each location.

#### 3.2.3.9 Survey and Markings for Construction of Overhead lines

(i). The preliminary survey of the line shall be done and plotted on the map.

(ii). During preliminary survey, crossings / proximity to buildings and to all categories of power lines as well as telecom lines under P&T Department shall be clearly indicated in the route map.

(iii). The detailed survey shall be undertaken only after finalizing the route alignment

(iv). The pit marking shall then be done at the locations. Any likely discrepancy in respect of ground / building clearance shall be sorted out first, and then the work shall be started.

(v). Some sites may be in forest area. Safety of forest property shall be ensured and forest clearance from Government, shall be obtained.

#### 3.2.3.10 Construction

**(i) ACSR Conductor**

Conforming to IS 398 (Part-II), 1956.

a. No joints permitted in the individual aluminium wires and steel core of the conductor.
b. Standard length of conductor as given in relevant IS shall be used.

**(ii) Clearances**

The net clearance in air for conductor, bus bars, Jumpers etc. shall not be less than provisions made in Indian Electricity Act /Rules as shown in Table 17, Table 18 and Table 19 detailed below.

**Table 17 : Clearance above Ground of the Lowest Conductor Across Street**

| Clearance above ground of the lowest conductor across street | Clearance in meters |
|---|---|
| For low and medium voltage | 5.791 m(19 ft) |
| For high voltage | 6.096 m(20 ft) |

**Table 18 : Clearance above Ground of the Lowest Conductor Along Street**

| Clearance above ground of the lowest conductor along street | Clearance in meters |
|---|---|
| For low and medium voltage | 5.486 m(18 ft) |
| For high voltage | 5.791 m(19 ft) |

**Table 19 : Clearance above Ground of the Lowest Conductor Else Where**

| Clearance above ground of the lowest conductor else where | Clearance in meters |
|---|---|
| For low , medium and high voltage up to 11000 voltage if bare | 4.572 (15 ft) |
| For low , medium and high voltage up to 11000 voltage if insulated | 3.963(13 ft) |
| For high voltage lines above 11000 V | 5.182(17 ft) |

For extra –high voltage lines the clearance above ground shall not be less than 5.182 meters (17 ft) plus 0.305 meters (1ft) for every 33,000 volts or part thereof by which the voltage of the line exceeds 33,000 volts. Provided that the minimum clearance along or across any street shall not be less than 6.0965 meters (20 ft).

**(a) Clearance from buildings of low and medium voltage lines and service lines**

Where a low or medium voltage overhead line passes above or adjacent to or terminates on any building the following minimum clearances from any accessible point on the basis of maximum sag shall be observed:

For any flat roof, open balcony verandah, roof and lean to roof.

- When the line passes above the building a vertical clearance of 2.439 meters (8 ft) from the highest point and
- When the line passes adjacent to the building a horizontal clearance of 1.219 meters (4ft) from the nearest point and

For pitched roof

- When the line passes above the building a vertical clearance of 2.439 meters (8 ft) immediately under the lines and
- When the line passes adjacent to the building a horizontal clearance of 1.219 meters (4 ft).
- Any conductor so situated as to have a clearance less than specified in sub-rule (1) shall be adequately insulated and shall be at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 350 kg. (700 lbs).
- The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressure

**(b) Clearance from buildings of high and extra –high voltage line**

Where a high or extra –high voltage overhead line passes above or adjacent to any building or part of a building it shall have on the basis of maximum sag a vertical clearance above the highest part of the building immediately under such lines of not less than

(a) For high voltage lines up to and including 33,000 volts 3.58 metres (12 ft.)

(b) For extra high voltage line 3.58 meters (12 ft.) plus 0.305 meter (1 ft) for every additional 33,000 volts or part thereof.

The horizontal clearance between the nearest conductor and any part of such building shall on the basis of maximum deflection due to wind be not less than

(a) For high voltage lines up to and including 11,000 volts 1.219 meters (4ft.)

(b) For high voltage lines above 11000 volts up to and including 33000 volts 1.829 meters (6 ft) plus

(c) For extra high voltage line 1.829 meters (6 ft.) plus 0.305 meter (1 ft) for every additional 33,000 volts or part thereof.

### 3.2.3.11 Earthing of line

Earthing at every fourth support of the line shall be provided as per practice and in accordance with relevant standard. Necessary earthing wire shall be fixed properly and earthing GI pipe of appropriate size shall be provided nearest to the pole structure. The pins of insulators and cross arms shall be bonded with 8 SWG G.I. wire and connected with G.I. pipe 3 meter long driven into the ground as per REC standards.

## ANNEXURE 1

# GRID STANDARD FOR OPERATION AND MAINTENANCE OF TRANSMISSION LINES AS PER CENTRAL ELECTRICITY AUTHORITY (GRID STANDARD) REGULATION –2010

THE GAZETTE OF INDIA, JUNE, 26, 2010 (ASADHA, 1936)

No.12/X/STD (GRID)/GM/CEA-Whereas the draft of Central Electricity Authority(Grid Standards) Regulation 2006 was published, as required by Sub-section (3)of section177 of the Electricity Act, 2003, read with rule3 of the Electricity (Procedure for Previous Publication)Rule,2005:

Now, therefore, in exercise of the powers coffered by sub-section (2) of Section 177 read with Section 34 and clause (d) of the Electricity Act 2003, the CentralElectricity Authority hereby makes the following regulations, namely:-

**1. Short Title, Commencement and Application**

(1) These regulations may be called the Central Electricity Authority (Grid Standards) Regulation, 2010.

(2) Save as otherwise provided in these regulations, they shall come into force onthe date of their publication in the Official Gazette.

(3) These regulations shall apply to the Entities, Appropriate Load Despatch Centres, and, Regional Power Committees.

**2. Definitions. -** In these regulations, unless the context otherwise requires,-

(a) "Act" means Electricity Act 2003;

(b) "Appropriate load Despatch Centre" means the National Load Despatch Centre, Regional Load Despatch Centre or Area Load Despatch Centre as the case may be;

(c) "Area Load Despatch Centre" means the centre as established by State Tranmission Utility or licensee for load dispatch and control in a particular area of the State;

(d) "Bulk Consumer" means a consumer who avails supply at a voltage of 33 kV or above;

(e) "condition based maintenance" means a set of maintenance actions based on continuous or frequent assessment of equipment condition, which is obtained from either of or a combination of embedded sensors, external tests and measurements;

(f) "disaster management" means the mitigation of the impact of a major breakdown on the system and bringing about restoration in the shortest possible time;

(g) "Emergency Restoration System" means a system comprising of transmission towers or structures of modular construction, complete with associated components such as insulators, hardware fittings, accessories, foundation plates, guys, anchors or installation tools and they like to facilitate quick restoration of damaged or failed transmission line towers or sections;

(h) “Entity” means a Generating Company including captive generating plant or a transmission licensee including Central Transmission Utility and State Transmission Utility or a distribution licensee or a Bulk Consumer whose electrical plant is connected to the Grid at voltage level 33 kV and above;

(i) “grid disturbance” means tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, resulting in total failure of supply at a sub-station or loss of integrity of the grid, at the level of transmission system at 220 kV and above (132 kV and above in the case of North-Eastern Region);

(j) “grid incident” means tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires re-scheduling of generation or load, without total loss of supply at a sub-station or loss of integrity of the grid at 220 kV and above (132 kV and above in the case of North-Eastern Region);

(k) ‘Schedule’ means schedule appended to these regulations;

(l) “time based maintenance” means inspection, cleaning and replacement of parts of the equipment based on a predetermined time schedule.

(m) “transient stability” means the ability of the power system to maintain synchronism when subjected to a severe disturbance such as a short circuit on a transmission line;

(n) “voltage unbalance” means the ratio of the maximum voltage deviation of the phase voltage from the average phase voltage to the average phase voltage of the three phases;

(2) Words and expressions used and not defined in these regulations but defined in the Act shall have the meaning assigned to them in the Act.

## 3. Standards for Operation and Maintenance of Transmission Lines

(1) All Entities, Appropriate Load Despatch Centres and Regional Power Committees, for the purpose of maintaining the Grid Standards for operation and maintenance of transmission lines, shall,

(a) make all efforts to operate at a frequency close to 50 Hz and shall not allow it to go beyond the range 49.2 to 50.3 Hz or a narrower frequency band specified in the Grid Code, except during the transient period following tripping.

(b) maintain the steady state voltage within the limits specified below in Table 1:

**Table 1:**

| S. No. | Nominal System Voltage (kV rms) | Maximum (kV rms) | Minimum (kV rms) |
|---|---|---|---|
| 1 | 765 | 800 | 728 |
| 2 | 400 | 420 | 380 |
| 3 | 220 | 245 | 198 |
| 4 | 132 | 145 | 122 |
| 5 | 110 | 121 | 99 |
| 6 | 66 | 72 | 60 |
| 7 | 33 | 36 | 30 |

(c) ensure that the temporary over voltage due to sudden load rejection remains within the limits specified in Table 2

**Table 2 :**

| S. No. | Nominal System Voltage (kV rms) | Phase to Neutral Voltage (kV peak) |
|---|---|---|
| 1 | 765 | 914 |
| 2 | 400 | 514 |
| 3 | 220 | 283 |
| 4 | 132 | 170 |

Provided that for the voltage level below 132 kV, the temporary over voltage limits as given in Table 2 shall be decided by the State Commission in the respective State Grid Code.

(d) ensure that the maximum permissible values of voltage unbalance shall be as specified in Table 3 below:

**Table 3 :**

| S. No. | Nominal System Voltage (kV rms) | Voltage Unbalance (%) |
|---|---|---|
| 1 | 765 and 400 | 1.5% |
| 2 | 220 | 2% |
| 3 | 33 to132 | 3% |

Provided that Bulk consumers shall avoid unbalanced load during operation: Provided further that the distribution licensees shall ensure that their loads are not unbalanced.

(e) provide standard protection systems having the reliability, selectivity, speed and sensitivity to isolate the faulty equipment and protect all components from any type of faults, within the specified fault clearance time and shall provide protection coordination as specified by the Regional Power Committee.

*Explanation.*-For the purpose of this regulation "fault clearance time" means the maximum fault clearance times are as specified in the Table 4 below

**Table 4 :**

| S. No. | Nominal System Voltage (kV rms) | Maximum Time ( in milliseconds) |
|---|---|---|
| 1 | 765 and 400 | 100 |
| 2 | 220 and 132 | 160 |

Provided that in the event of non clearance of the fault by a circuit breaker within the time limit specified in Table 4, the breaker fail protection shall initiate tripping of all other breakers in the concerned bus-section to clear the fault in the next 200 milliseconds.

(f) operate the system in a such a way that the Grid System is capable of withstanding one of the following contingencies without experiencing loss of stability:

(g) operate the system in a such a way that under any one of the following contingencies, the system remains stable and sustains integrity so that no generator loses synchronism and no part gets isolated from the rest of the

(h) observe the following permissible limits of voltage fluctuation :

(i) the permissible limit of voltage fluctuation for step changes which may occur repetitively is 1.5 percent:
(ii) for occasional fluctuations other than step changes the maximum permissible limit is 3 percent:

(1) outage of one single largest generating unit of the system or
(2) outage of a 132 kV Double circuit line or
(3) outage of a 220 kV Double circuit line or
(4) outage of a 400 kV Single circuit line or
(5) outage of a 400 kV Single circuit line with series compensation or
(6) outage of 765 kV Single circuit line without series compensation or
(7) outage of one pole of HVDC Bipolar line or
(8) outage of an Interconnecting Transformer

**System:**

(1) tripping of a single largest generating unit; or
(2) transient ground fault in one phase of a 765 kV Single Circuit Line close to the bus; or
(3) a permanent single phase to ground fault in 400 kV single circuit line followed by 3 pole opening of the faulted line; or
(4) a permanent fault in one circuit of a 400 kV Double Circuit Line when both circuits were in service in the pre-contingency period; or
(5) a transient single phase to ground fault in one circuit of a 400 kV Double Circuit Line when the second circuit is already under outage; or
(6) a three-phase permanent fault in a 220 kV or 132 kV line; or
(7) a permanent fault in one pole of HVDC bipolar in a HVDC Converter

Provided that the standard on voltage fluctuations shall come into force concurrently with clause 4 of Part IV of the Schedule to the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

**(2)** The transmission licensee shall ensure that the voltage wave-form quality is maintained at all points in the Grid by observing the limits given in Table 5 below

**Table 5:**

| S. No. | System Voltage (kV rms) | Total Harmonic Distortion (%) | Individual Harmonic of any particular Frequency (%) |
|---|---|---|---|
| 1 | 765 | 1.5 | 1.0 |
| 2 | 400 | 2.0 | 1.5 |
| 3 | 220 | 2.5 | 2.0 |
| 4 | 33 to 132 | 5.0 | 3.0 |

Provided that the standard on Harmonic Distortion shall come into force concurrently with clause 3 of Part IV of the Schedule to the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

*Explanation*: For the purpose of this regulation, Total Harmonic Distortion (VTHD) expressed as percentage, shall be calculated as under,

$$V_{THD} = \sqrt{\sum_{n=2}^{n=40} \frac{V_n^2}{V_1^2}} X100$$

'1' refers to fundamental frequency (50 Hz)
'n' refers to the harmonic of $n^{th}$ order (corresponding frequency is 50 x n Hz)

## 4. Operation Planning

The Regional Power Committee shall periodically review the performance of the grid for the past period and plan stable operation of the grid for the future, considering various parameters and occurrences such as frequency profile, voltage profile, line loading, grid incident, grid disturbance, performance of system protection schemes and protection coordination.

## 5. Maintenance Planning

(1) The Regional Power Committees shall, before the commencement of the financial year, prepare an annual maintenance plan for the generating stations and the inter-State transmission system in their respective regions keeping in view the demand pattern and maintenance schedule of the generating units and diversity in demand of the States.

(2) The Regional Power Committees shall co-ordinate the annual maintenance plan for Inter-Regional transmission system.

(3) The Regional Power Committees shall review and revise the coordinated generation and transmission system maintenance plan in their monthly operating Committee meetings.

(4) The State Load Despatch Centre shall in consultation with the concerned transmission licensee, coordinate the annual maintenance plan of Intra-State transmission system taking into account the annual maintenance plan of generating units and inter-state transmission system decided by the Regional Power Committee.

(5) The State Load Despatch Centre shall also review and coordinate the maintenance plan of intra-state transmission system for the next month, taking into account the monthly maintenance plan of generating units and inter-state transmission system prepared by the Regional Power Committee for the next month.

(6) The generating company or transmission licensee shall, before actual shut down, obtain the approval of the Appropriate Load Despatch Centre.

**6. Coordination in Operations**

(1) No Entity shall introduce or take out the element of the grid without the concurrence of the Appropriate Load Despatch Centre except in case of imminent risk of safety of plant and personnel in which case it must intimate Appropriate Load Despatch Centre giving reasons therefore.

(2) The Appropriate Load Despatch Centre shall inform all affected parties of the outage.

**7. Operating Instructions**

(1) Every generating company and transmission licensee shall provide written operating instructions for each equipment and operating procedure for sequence of operations of power system equipment in their control room.

(2) The operating instructions followed shall not be inconsistent with the manufacturer's instructions.

(3) The operating instructions and procedures may be revised by the generating company or transmission licensee, as the case may be.

**8. Instructions by Regional Load Despatch Centres and State Load Despatch Centres to be recorded**

(1) All operational instructions given by Regional Load Despatch Centres and State Load Despatch Centres through telephone, Fax, e-mail, etc shall be given a unique operating code number and every Regional Load Despatch Centre and State Load Despatch Centre shall maintain a voice recorder for recording and reproduction of conversation with time tag or stamp.

(2) The record of instructions referred to in sub-regulation (1) shall be kept for at least six months.

**9. Automatic under frequency Relay**

(1) All Entities shall set their under-frequency (UF) Relays and rate of change of frequency with time Relays in their respective systems, in accordance with the plan made by the Regional Power Committee, to provide adequate load relief for grid security and ensure the operation of these relays at the set frequencies.

(2) All constituents shall submit a detailed report of operation of these Relays at different frequencies to Regional Load Despatch Centre and Regional Power Committee on daily basis and the Regional Power Committees shall carry out inspection of these Relays as and when required.

**10. Islanding Schemes**

(1) The Regional Power Committees shall prepare Islanding schemes for separation of systems with a view to save healthy system from total collapse in case of grid disturbance.

(2) The Entities shall ensure proper implementation of the Schemes referred to in sub-regulation (1).

*Explanation*.-For the purposes of this regulation 'Islanding Scheme' means a scheme for the separation of the Grid into two or more independent systems as a last resort, with a view to save healthy portion of the Grid at the time of grid disturbance.

## 11. Categorisation of grid incidents and grid disturbance based on severity of trippings

The categorisation of grid incidents and grid disturbances shall be as follows:

(1) Categorisation of grid incidents in increasing order of severity,

**Category GI-1 -** Tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires re-scheduling of generation or load, without total loss of supply at a sub-station or loss of integrity of the grid at 220 kV (132 kV in the case of North-Eastern Region);

**Category GI-2 -** Tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires re-scheduling of generation or load, without total loss of supply at a sub-station or loss of integrity of the grid at 400 kV and above (220 kV and above in the case of North-Eastern Region).

(2) Categorisation of grid disturbance in increasing order of severity, *Explanation*: For the purpose of categorisation of grid disturbances, percentage loss of generation or load, whichever is higher shall be considered.

| | |
|---|---|
| **Category GD-1** | When less than ten percent of the antecedent generation or load in a regional grid is lost; |
| **Category GD-2** | When ten per cent. to less than twenty percent of the antecedent generation or load in a regional grid is lost. |
| **Category GD-3** | When twenty per cent. to less than thirty per cent. of the antecedent generation or load in a regional grid is lost; |
| **Category GD-4** | When thirty per cent. to less than forty per cent. of the antecedent generation or load in a regional grid is lost |
| **Category GD-5** | When forty percent or more of the antecedent generation or load in a regional grid is lost. |

## 12. Reporting of events affecting grid operation

(1) Any tripping of generating unit or transmission element, along with relay indications, shall be promptly reported by the respective Entity to the Appropriate Load Despatch Centre in the reporting formats as devised by the Appropriate Load Despatch Centre.

(2) The Appropriate Load Despatch Centre shall promptly intimate the event to the Regional Load Despatch Centres and State Load Despatch Centres of the affected regions and States respectively which shall, in turn, take steps to disseminate this information further to all concerned.

## 13. Reporting of grid disturbance

(1) The Regional Load Despatch Centre shall inform occurrence of the grid disturbance to the constituents immediately and to the concerned Regional Power Committee at the earliest.

(2) The grid disturbance resulting in failure of power supply to large areas in a State shall also be reported by the Regional Load Despatch Centre to the Authority within twenty four hours of the occurrence of the grid disturbance.

(3) The Regional Load Despatch Centre shall also post on its website a brief preliminary grid disturbance report, indicating the affected area or system, extent of outage and the likely cause of initiation for the benefit of the constituents of the region.

## 14. Restoration of grid following grid incident and grid disturbance

(1) The Regional Load Despatch Centre, in consultation with Regional Power Committee, shall develop procedures for enabling restoration and normalisation of the Grid for inter-State system at the earliest, following grid incident and grid disturbance of the categories specified in regulation 11.

(2) The State Load Despatch Centre shall also develop procedures accordingly for restoration of intra-State system.

(3) The restoration procedures shall be reviewed following any addition of generating station or transmission line or at least once in two years, and revised, if considered necessary by the Regional Load Despatch Centre and State Load Despatch Centre, as the case may be.

(4) The procedures specified in sub-regulations (1), (2) and (3) shall be made available to, and be followed by all concerned Entities, Regional Load Despatch Centres and State Load Despatch Centres.

## 15. Operational Data during normal operation and during grid incidents and grid disturbances

(1) All real time operational data as required by the Appropriate Load Despatch Center shall be furnished by the Entities.

(2) All data required by Regional Power Committee, in discharge of the responsibilities assigned to it, shall be furnished by Regional Load Despatch Centre (RLDC).

(3) All operational data, including disturbance recorder and event logger reports, for analysing the grid incidents and grid disturbance and any other data which in its view can be of help for analysing grid incident or grid disturbance shall be furnished by all the Entities within twenty four hours to the Regional Load Despatch Centre and concerned Regional Power Committee.

(4) All equipment such as disturbance recorders and event loggers shall be kept in healthy condition, so that under no condition such important data is lost.

(5) A real time operation display of the grid position shall also be made available to the Regional Power Committee by Regional Load Dispatch Centre.

(6) Regional Load Dispatch Centre shall classify the grid incidents and grid disturbances according to regulation 11, analyse them and furnish periodic reports of grid incidents and grid disturbances to the Regional Power Committee which shall recommend remedial measures to be taken on the Report of Regional Load Despatch Centre to prevent recurrences of such grid incidents and grid disturbances.

## 16. Operational Data Records

(1) Operational data including equipment and system parameters logged manually and electronically shall be preserved for at least three years.

(2) Logbooks shall be maintained by every manned switchyard and sub-station or at the control centre responsible for operation of the unmanned switchyard and substation.

(3) All operations conducted shall be recorded in chronological order and the time of each operation and occurrence of each event shall be recorded in such a manner that there shall be no over-writing and any mistake shall be neatly cut by a line and new words written thereafter.

(4) The observations made during inspection including important parameters and deviation of parameters outside permissible tolerances shall also be recorded in the logbook and all entries must be made in the logbooks immediately.

(5) A record shall be kept of the number of grid incidents and grid disturbances of various categories by the respective Regional Power Committees for each financial year.

(6) A compendium of grid disturbances, indicating details such as the date and time of the disturbance, the sequence of tripping, the cause, and the sequence of restoration, remedial measures taken to avert recurrence of such incidents and disturbances shall be maintained by the respective Regional Power Committee.

## 17. Communication Facilities

The communication facilities installed by the transmission licensees shall be in accordance with Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and shall be maintained in good operating condition.

## 18. Safety Procedure

(1) The Entity shall prepare contingency procedures for use of operators at each sub-station and switchyard and these shall be regularly updated.

(2) All operating personnel shall be trained in contingency procedures at regular intervals and the entities shall require their personnel to follow the contingency procedures during operation and maintenance.

(3) The firefighting equipment shall be made available at all sub-stations, switchyards and converter stations and shall be checked periodically for its upkeep and mock exercises in fire fighting shall be carried out at least once in a year and record maintained.

## 19. Maintenance of Tools and Equipment

The maintenance staff shall be made aware of the list of tools, devices and equipment for various maintenance and rectification works on transmission lines, sub-stations, switchyards and converter stations and the tools shall be made readily available and certified for usage.

## 20. Maintenance Procedures

The Entity shall prepare maintenance procedures for each equipment in line with the manufacturer’s recommendations and prudent utility practices.

## 21. Hot Line Methods

(1) The hot line techniques for maintenance of critical transmission lines and sub-stations shall be adopted wherever possible.

(2) Only trained staff shall be used for the hot line techniques and the tools employed in such techniques shall have necessary certification from a national or international accredited laboratory before usage.

## 22. Emergency Restoration System

Each transmission licensee shall have an arrangement for restoration of transmission lines of 400 kV and above and strategic 220 kV lines through the use of Emergency Restoration System in order to minimise the outage time of the transmission lines in case of tower failures.

## 23. Inspection and Patrolling

(1) All essential parameters, which indicate the healthiness of the equipment in a sub-station, shall be inspected by the shift engineer once in each shift and periodically by the officer-in-charge.

(2) Overhead lines shall be patrolled at periodicity decided by the transmission licensee and different patrolling schedules shall be implemented by the transmission licensees for normal terrain, vulnerable terrain and most vulnerable terrain.

(3) The patrolling schedules for ground inspection of live lines and tower top inspection of de-energised lines shall be separately issued by the licensees.

(4) The important lines shall be inspected by senior engineers after patrolling by junior staff and maintenance works such as tree cutting and replacement of damaged insulators shall be carried out immediately after patrolling, wherever required.

## 24. Maintenance Schedules

(1) Entities shall identify critical equipment and as far as possible, practice condition based maintenance for such equipment in place of traditional time based maintenance.

(2) In case of time based maintenance, the periodicity of maintenance of lines shall be fixed based on whether they are passing through normal area or polluted area or coastal area and the transmission lines and sub-stations in polluted or coastal areas shall be maintained more frequently.

(3) The maintenance of lines passing through and sub-stations located in such areas should be completed once before onset of winter so as to minimise tripping under conditions of fog or due to salt deposit on insulator discs in coastal areas and once before onset of summer.

(4) Maintenance and cleaning of various equipment fittings, accessories, primary instruments and sensors shall be carried out when they are de-energised during the shut-down of main equipment so as to minimise shutdown time.

(5) Where defects are observed through condition monitoring or during patrolling and inspection, the maintenance work on various items of equipment may be advanced depending on the condition of the equipment.

**25. Use of diagnostic techniques for condition monitoring of equipment.**

The diagnostic methods of maintenance shall be preferred over traditional time based maintenance. For purpose of this regulation, devices or methods specified in the Schedule shall be used.

**26. Thermo – vision scanning**

The Thermo-vision scanning for hot spots on all overhead lines and sub-station equipment at voltage level of 220 kV and above shall be carried out at least once a year and necessary remedial measures shall be taken where hot spots are detected.

**27. Failure Analysis**

(1) All failures of equipment and tower collapse shall be analysed by the Entity to avoid recurrence and a copy of the report shall be submitted to the Regional Power Committee and the Authority.
(2) The Authority may appoint a group of experts for investigation and analysis and the representatives of manufacturers may be invited to participate in such analysis.
(3) All relevant data which may help the group of experts in analysing the failures shall be furnished by the respective Entities.
(4) The recommendations of the group of experts shall be submitted to the Authority and the recommendations accepted by the Authority shall be implemented and circulated to all within the organisation and to other concerned organisations to prevent recurrence of similar failures.

**28. Inventory Control and Spare Part Management**

(1) The required spare parts shall be kept in stock, to ensure speedy the maintenance of the equipment.
(2) Computerised materials management system shall be developed by the Entities to optimise inventory.

**29. Maintenance Audit**

(1) An internal committee may be established by the Entities to verify whether actual maintenance works are carried out at site in compliance of the procedures and the policy of the transmission company.
(2) The observations of the Committee shall be put up to the management of the Entity for perusal and taking corrective action, if any.

**30. Residual life Assessment**

The residual life assessment shall be carried out for all major equipments including transformers, reactors, breakers, as envisaged by the relevant standards specified by the Bureau of Indian Standards, manufacturer’s instruction or industry best practices and suitable remedial action for breach of the same shall be taken by the management of the Entity.

**31. Disaster Management**

(1) The maintenance staff shall be trained in disaster management and a detailed procedure for the same shall be developed by the Entity and displayed prominently.

(2) This detailed procedure shall be reviewed periodically and also based on mock exercises carried out by the Entity.

(3) The maintenance staff shall be trained in emergency restoration procedures for managing major failures and breakdowns.

(4) The equipment including vehicles, diesel generating sets and firefighting equipment and Emergency Restoration System for transmission lines shall be kept available at sub-station or at appropriate location for disaster management.

## 32. Maintenance Records

The records of all maintenance carried out for each equipment shall be kept in the table and formats in electronic form and hard copy and the next due date for maintenance of each item of work shall be clearly marked in such tables and formats.

## 33. Training

(1) Every person involved in operation and maintenance of transmission lines shall be trained at the induction level and at least once in a year.

(2) The shift staff shall be trained to make them thorough in carrying out operations at each sub-station and every person concerned with real time operation shall be trained.

(3) Every grid operator shall undergo training in real time digital simulator and a refresher course at least once in two years.

(4) The maintenance personnel of every entity shall also be trained in preventive and breakdown maintenance of various equipment and the personnel shall be trained in various detailed maintenance procedures.

**Secretary**
**Central Electricity Authority**

**SCHEDULE**
(See regulation 25)

**The Devises and Methods for Condition Based Monitoring of Equipment**

(1) Hot line puncture detection of insulators
(2) Vibration measurement of the line
(3) Pollution measurement of the equipment
(4) Dissolved Gas Analysis of Transformer oil
(5) Frequency response analysis of transformers/reactors
(6) Tan δ and capacitance measurement
(7) Circuit breaker operational analyzer
(8) Dynamic contact resistance measurements of breakers
(9) Third harmonic resistive current measurements of surge arresters
(10) Recovery voltage measurements of transformers/reactors
(11) Vibration measurements of the reactors
(12) Steady state and Dynamic testing of protective relays
(13) Signature Analysis
(14) Partial Discharge measurement for transformers/Gas insulated Switchgear
(15) Static resistance meter for circuit breakers, isolators, bus bar joint, earth switches etc.
(16) Ground tester for measurement of resistivity of soil and ground resistance
(17) Battery impedance test equipment
(18) Insulator tester
(19) SF6 gas leakage detector and dew point
(20) Power quality Analyzer
(21) Fibre optic cable testing devices

## ANNEXURE 2

**ALUMINIUM CONDUCTORS STEEL REINFORCED (ACSR)-BARE**

**BRITISH STANDARD SIZES (METRIC) CONFORMING TO BS 215 : 1956**

| Code Name | Equivalent to nearest copper | | Standard Nominal copper area (sq. in) | ACSR Stranding No. and wire dia. Mm. | | | | Dia of complete cable | Gross area of aluminium | Gross area of complete cable mm2 | Approx-imate ultimate strength kg. | Approxi-mate resistance at 20°C ohms per km. | Approximate weight in kg. per km. | | | Standard length of cable metres | Approx. wt. of standard length of cable kg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Aluminium | | Steel | | | | | | | | | | | |
| | SWG OR CM | Area mm² | | No. | Dia | No. | Dia | mm. | mm² | | | | Aluminium | Steel | Complete cable | | |
| Mole | 12 | 6.45 | 0.010 | 6 | 1.5 | 1 | 1.5 | 4.50 | 10.58 | 12.35 | 410 | 2.7050 | 29.0 | 13.8 | 42.8 | 2455 | 105 |
| Squirrel | 8 | 12.90 | 0.020 | 6 | 2.11 | 1 | 2.11 | 6.33 | 20.95 | 24.44 | 770 | 1.3660 | 57.5 | 27.2 | 84.7 | 2500 | 212 |
| Gopher | 7 | 16.13 | 0.025 | 6 | 2.36 | 1 | 2.36 | 7.08 | 26.30 | 30.68 | 955 | 1.0890 | 71.9 | 34.1 | 106.0 | 2000 | 212 |
| Weasel | 6 | 19.35 | 0.030 | 6 | 2.59 | 1 | 2.59 | 7.77 | 31.63 | 36.90 | 1135 | 0.9047 | 86.6 | 41.1 | 127.7 | 1650 | 211 |
| Fox | 6 | 22.58 | 0.035 | 6 | 2.79 | 1 | 2.79 | 8.38 | 36.79 | 42.92 | 1310 | 0.7780 | 100.6 | 47.9 | 147.5 | 1410 | 210 |
| Ferret | 5 | 25.81 | 0.040 | 6 | 3.00 | 1 | 3.00 | 9.00 | 42.35 | 49.41 | 1500 | 0.6760 | 116.2 | 55.1 | 171.3 | 1220 | 209 |
| Rabbit | 3 | 32.26 | 0.050 | 6 | 3.35 | 1 | 3.35 | 10.05 | 52.95 | 61.78 | 1860 | 0.5404 | 144.8 | 68.8 | 213.6 | 1960 | 419 |
| Mink | 2 | 38.71 | 0.060 | 6 | 3.66 | 1 | 3.66 | 10.98 | 63.06 | 73.57 | 2205 | 0.4540 | 172.9 | 82.1 | 255.0 | 1600 | 408 |
| Beaver | 1 | 45.16 | 0.070 | 6 | 3.99 | 1 | 3.99 | 11.97 | 74.97 | 87.42 | 2615 | 0.3820 | 205.5 | 97.5 | 303.0 | 1350 | 409 |
| Raccoon | 1 | 48.39 | 0.075 | 6 | 4.09 | 1 | 4.09 | 12.27 | 78.84 | 91.94 | 2745 | 0.3632 | 215.9 | 102.5 | 318.4 | 1280 | 408 |
| Otter | 1 | 51.61 | 0.080 | 6 | 4.22 | 1 | 4.22 | 12.66 | 83.74 | 97.74 | 2915 | 0.3418 | 229.9 | 109.1 | 339.0 | 1200 | 407 |
| Cat | 1/0 | 58.06 | 0.090 | 6 | 4.50 | 1 | 4.50 | 13.50 | 95.29 | 111.20 | 3315 | 0.3005 | 261.4 | 124.0 | 385.4 | 1060 | 409 |
| Hare | 2/0 | 64.52 | 0.100 | 6 | 4.72 | 1 | 4.72 | 14.16 | 105.20 | 122.70 | 3660 | 0.2722 | 287.6 | 136.7 | 424.3 | 960 | 408 |
| Dog | 2/0 | 64.52 | 0.100 | 6 | 4.72 | 7 | 1.57 | 14.15 | 105.20 | 118.80 | 3310 | 0.2722 | 287.6 | 106.4 | 394.0 | 1110 | 438 |
| Leopard | 3/0 | 80.65 | 0.125 | 6 | 5.28 | 7 | 1.75 | 15.81 | 131.60 | 148.50 | 4120 | 0.2177 | 359.8 | 133.8 | 493.6 | 885 | 437 |
| Coyote | 3/0 | 80.65 | 0.125 | 26 | 2.54 | 7 | 1.91 | 15.89 | 131.70 | 151.70 | 4645 | 0.2198 | 365.1 | 155.8 | 520.9 | 2020 | 1053 |
| Tiger | 3/0 | 80.65 | 0.125 | 30 | 2.36 | 7 | 2.36 | 16.52 | 131.50 | 162.10 | 5790 | 0.2203 | 363.4 | 240.4 | 603.8 | 1960 | 1184 |
| Wolf | 5/0 | 96.77 | 0.150 | 30 | 2.59 | 7 | 2.59 | 18.13 | 158.10 | 195.00 | 6875 | 0.1831 | 437.8 | 289.6 | 727.4 | 1640 | 1193 |
| Lynx | 6/0 | 112.99 | 0.175 | 30 | 2.79 | 7 | 2.79 | 19.53 | 183.90 | 226.80 | 7945 | 0.1575 | 508.1 | 336.1 | 844.2 | 1410 | 1191 |
| Panther | 252,000 | 129.00 | 0.200 | 30 | 3.00 | 7 | 3.00 | 21.00 | 211.70 | 261.20 | 9095 | 0.1368 | 587.4 | 388.6 | 976.0 | 1225 | 1196 |
| Lion | 283,000 | 145.20 | 0.225 | 30 | 3.18 | 7 | 3.18 | 22.26 | 237.50 | 292.90 | 10160 | 0.1219 | 660.0 | 436.6 | 1096.6 | 1090 | 1196 |
| Bear | 314,000 | 161.30 | 0.250 | 30 | 3.35 | 7 | 3.35 | 23.45 | 264.80 | 326.60 | 11320 | 0.1093 | 732.2 | 484.5 | 1216.7 | 975 | 1187 |
| Goat | 400,000 | 193.50 | 0.300 | 30 | 3.71 | 7 | 3.71 | 25.97 | 324.00 | 399.60 | 13765 | 0.08935 | 898.2 | 594.2 | 1492.4 | 1550 | 2314 |
| Sheep | 440,000 | 225.80 | 0.350 | 30 | 3.99 | 7 | 3.99 | 27.93 | 374.70 | 462.10 | 15900 | 0.07730 | 1039.0 | 687.3 | 1726.3 | 1335 | 2305 |
| Antelope | 440,000 | 225.80 | 0.350 | 54 | 2.97 | 7 | 2.97 | 26.73 | 374.50 | 423.10 | 11885 | 0.07606 | 1037.0 | 381.0 | 1418.0 | 1240 | 1759 |
| Deer | 503,000 | 258.10 | 0.400 | 30 | 4.27 | 7 | 4.27 | 29.89 | 429.10 | 529.20 | 18190 | 0.06748 | 1190.0 | 787.2 | 1977.2 | 1165 | 2304 |
| Zebra | 503,000 | 258.10 | 0.400 | 54 | 3.18 | 7 | 3.18 | 28.62 | 427.50 | 482.90 | 13245 | 0.06723 | 1184.0 | 435.0 | 1619.0 | 1090 | 1765 |
| Elk | 566,000 | 290.30 | 0.450 | 30 | 4.50 | 7 | 4.50 | 31.50 | 476.30 | 587.50 | 20185 | 0.06079 | 1321.5 | 874.2 | 2195.7 | 1050 | 2306 |
| Camel | 566,000 | 290.30 | 0.450 | 54 | 3.35 | 7 | 3.35 | 30.15 | 476.60 | 538.40 | 14740 | 0.06076 | 1320.0 | 485.0 | 1805.0 | 975 | 1760 |
| Moose | 629,000 | 322.60 | 0.500 | 54 | 3.53 | 7 | 3.53 | 31.77 | 528.50 | 597.00 | 16280 | 0.05480 | 1463.6 | 537.9 | 2001.5 | 880 | 1762 |