

**GOVERNMENT OF INDIA
CENTRAL ELECTRICITY AUTHORITY
(MINISTRY OF POWER)
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PUBLIC NOTICE

In accordance with the Section 177 of the Electricity Act, 2003 (No. 36 of 2003), the Central Electricity Authority (CEA) had notified the Regulations *namely* **“Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010”** on 20.08.2010

It is now proposed to amend few clauses in the above Regulations. The proposed draft amendments in the above Regulations are available on the CEA website www.cea.nic.in. The Regulations can also be seen in the office of Chief Engineer (Legal), Room No. 622(N), Sewa Bhawan, R.K.Puram, New Delhi-110066 on any working day from 10th April, 2017 to 26th May, 2017 between 1100 hrs to 1600 hrs. Members of the public are requested to send their comments on the draft Regulations to Chief Engineer (Legal), Room No. 622(N), Sewa Bhawan, R.K.Puram, New Delhi-110066 by post or through e-mail latest by **26th May, 2017**.

**(P.D.Siwal)
Secretary, CEA**

भारत सरकार
केंद्रीय विद्युत प्राधिकरण
(विद्युत मंत्रालय)

छठवां तल (उत्तरी खंड), सेवा भवन, आर.के.पुरम, नई दिल्ली-110066
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सार्वजनिक सूचना

विद्युत अधिनियम, 2003 (2003 का 36) की धारा 177 के अनुसरण में, केंद्रीय विद्युत प्राधिकरण (के.वि.प्रा.) द्वारा केंद्रीय विद्युत प्राधिकरण (विद्युत संयंत्रों और विद्युत लाइनों के निर्माण के लिए तकनीकी मानक) विनियम, 2010 दिनांक 20.08.2010 को अधिसूचित किये गये थे। अब उपर्युक्त विनियमों में विशिष्ट खंडों को संशोधित किए जाने का प्रस्ताव किया गया है। उक्त विनियमों में प्रस्तावित प्रारूप संशोधन के.वि.प्रा. की वेबसाइट www.cea.nic.in पर उपलब्ध हैं। विनियमों को 10 अप्रैल, 2017 से 26 मई, 2017 तक 11:00 बजे से 16:00 बजे तक किसी भी कार्य दिवस को मुख्य अभियंता (विधि), कमरा नं. 622(एन), सेवा भवन (उत्तरी खंड), छठवां तल, आर.के.पुरम, नई दिल्ली-110066 के कार्यालय में भी देखा जा सकता है। जनता से प्रारूप विनियमों पर अपनी टिप्पणियां डाक अथवा ई-मेल के जरिए मुख्य अभियंता (विधि), कमरा नं. 622(एन), सेवा भवन (पश्चिमी खंड), छठवां तल, आर.के.पुरम, नई दिल्ली-110066 को 26 मई, 2017 तक भेजने का अनुरोध किया जाता है।

(पी.डी.सिवाल)
सचिव, के.वि.प्रा.

(To be published in the Gazette of India, Part III Section 4)
Government of India
Ministry of Power
Central Electricity Authority

New Delhi, dated the 2016

Notification

No. CEA/TETD/MP/R/01/2010 -In exercise of the power conferred by sub section (2) of Section 177 of the Electricity Act, 2003 (No.36 of 2003), the Central Electricity Authority, hereby makes the following Regulations to amend the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations,2010, namely:-

1. Short title and commencement. (1) These Regulations may be called the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Amendment Regulations,2016.

(2) These Regulation shall come into force on the date of their publication in the Official Gazette.

2. In the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 (herein after referred to as the said Regulations) after the Regulation 2(1)(b), the following Regulation shall be inserted, namely:-

(b)(i) "Automatic Voltage Regulator (AVR)" means a continuously acting automatic excitation control system to regulate a generating unit terminal Voltage;

3. In the said Regulations, after the Regulation 2(1)(k), the following Regulation shall be inserted, namely:-

(k)(i) "Generator Transformer" means power transformer required to step up generator voltage to connected bus (grid) voltage.

4. In the said Regulations, after the Regulation 2(1)(zb), the following Regulation shall be inserted, namely:-

(zb)(i) "Motor Control Centre (MCC)" means the switchgear which contains modules for electric supply to motor and its control.

5. In the said Regulations, after the Regulation 2(1)(ze), the following Regulation shall be inserted, namely:-

(ze)(i) "Power System Stabilizer (PSS)" means controlling equipment which receives input signals of speed, frequency and power to control the

excitation via the voltage regulator for damping power oscillations of a synchronous machine.

6. In the said Regulations, after the Regulation 2(1)(zl), the following Regulation shall be inserted, namely:-

(zl)(i) "Station Transformer" means power transformer required to step down the grid voltage to cater to the starting and shut down of generating unit load and station load during running.

7. In the said Regulations, after the Regulation 2(1)(zv), the following Regulation shall be inserted, namely:-

(zv)(i) "Unit Auxiliary Transformer" means the transformer meant for catering the loads connected to unit buses corresponding to auxiliaries required for respective Boiler, Turbine and Generator.

8. In the said Regulations, after the Regulation 2(1)(zw), the following Regulation shall be inserted, namely:-

(zw1) "Ultra super-critical Unit" in relation to coal or lignite based thermal generating unit means a Supercritical unit designed for steam temperature of 600/600°C or higher at turbine inlet.

CHAPTER – I

GENERAL REQUIREMENTS

9. In the said Regulations, for Regulation 3(4),3(4)(e),3(4)(f),3(4)(g) the following Regulation shall be substituted, namely:-

(4) The Electrical Plants and Electric Lines shall be designed to comply with the requirements stipulated in the following Regulations /Codes (as amended from time to time):

(e) Central Electricity Authority (Measures relating to Safety and Electric Supply), Regulations, 2010

(f) Central Electricity Authority (Safety Requirements for Construction, Operation and Maintenance of Electrical Plants and Electric Lines) Regulations, 2011

(g) Central Electricity Authority (Grid Standards) Regulations, 2010

10. In the said Regulations, for Regulation 3(8)(c), the following Regulation shall be substituted, namely:-

(c) Copies of the results of all tests performed including Performance Guarantee Test reports;

11.In the said Regulations, for Regulation 3(8)(d), the following Regulation shall be substituted, namely:-

(d) Technical documents relating to the design, engineering and construction of the electrical plant and/or electric line. Technical specifications for Main Plant and major Balance of Plant systems;

12.In the said Regulations, for Regulation 3(8)(e), the following Regulation shall be substituted, namely:-

(e) Indian Boiler Regulation (IBR)/ Chief Controller of Explosive (CCOE) approved documents, Statutory clearances, Safety procedures.

13.In the said Regulations, after the Regulation 3(9), the following Regulation 3(10) shall be inserted, namely:-

(10) Cyber Security : Due attention and importance shall be given to Cyber Security for automation and control systems in the Electric Sector. The firewall and Virtual Private Network (VPN) technology or any other state-of art technology shall be built up for security of the system. The access to systems and devices shall be further protected by using user authentication and authorization. The standards like NERC-CIP, IEEE and IEC addressing Cyber Security for control system and Guidelines of National Critical Information Infrastructure Protection Centre (NCIIPC), Government of India, shall be followed.

CHAPTER – II

TECHNICAL STANDARD FOR CONSTRUCTION OF THERMAL GENERATING STATIONS

PART – A

COMMON TO ALL TYPES OF THERMAL GENERATING STATIONS

14.In the said Regulations, for Regulation 5(1), the following Regulation shall be substituted, namely:-

(1) The coal/ lignite and gas based thermal generating stations shall be designed to give life of not less than twenty five (25) years. IC engine based Stations shall be designed for life not less than fifteen (15) years.

15.In the said Regulations, for Regulation 5(3), the following Regulation shall be substituted, namely:-

(b) Noise level for the continuously operating equipment shall not be more than 85 dBA at a distance of 1 metre and at a height of 1.5 metre from any equipment except for the following:

- i) Turbine- Generator and Pulverizers - 90 dBA
- ii) Safety valves and associated vent pipes, Soot blowers/ Wall blowers, Regulating drain valves _ 115 dBA
- iii) IC engine based generating sets of capacity upto 1 MVA. They shall meet the stipulations of MOE&F on “Noise limit for generator sets run with diesel”.

(b₁) For short term exposure, noise levels shall not exceed the limits as stipulated in the Occupational Safety & Health Administration (OSHA) Standard.

16.In the said Regulations, for Regulation 5(5), the following Regulation shall be substituted, namely:-

(5) All the equipment and surfaces (excluding coal or lignite mills, pulverized fuel pipes, lube oil piping and electrical equipment) having skin temperature more than 60°C shall be provided with required insulation along with cladding. The insulating materials, accessories and protective covering shall be non-sulphurous, incombustible, low chloride content, chemically rot proof, non-hygroscopic and shall withstand continuously and without deterioration the maximum temperature to which they will be subjected as per duty conditions. Insulation or finishing materials containing asbestos in any form shall not be used.

17.In the said Regulations, for Regulation 6(2)(d), the following Regulation shall be substituted, namely:-

(d) Adequate space shall be provided for unloading and maintenance purposes in Turbine - Generator (TG) area. Requisite lay down area shall be provided for each unit on TG floor and same shall be approachable with electric overhead travelling (EOT) crane. In case of coal or lignite based generating stations, two transverse bays shall be provided in TG area at ground level depending upon lifting method to be used for generator stator and also functional requirement for unloading and maintenance purposes. For Stations with multiple units, adequate space shall be provided to meet the requirement for simultaneous maintenance of two units. One number maintenance/ unloading bay shall be provided at ground level at the start of the first unit.

18.In the said Regulations, for Regulation 6(2)(j), it shall be deleted:-

(j) Deleted

PART – B

COAL OR LIGNITE BASED THERMAL GENERATING STATIONS

19.In the said Regulations, for Regulation 7(1)(c), the following Regulation shall be substituted, namely:-

(c) Operating grid frequency variation of -5% to +3% (47.5 Hz to 51.5 Hz).

20.In the said Regulations, for Regulation 7(3), the following Regulation shall be substituted, namely:-

- (3) The sub-critical unit shall be designed for constant pressure and sliding pressure operation. The supercritical unit shall be designed for sliding pressure operation / modified sliding pressure condition where, at any operating load, the throttle reserve shall be sufficient so as to achieve an instantaneous increase in turbine output by 5% of the corresponding load, by opening turbine control valves wide open. However, the output after instantaneous increase shall be limited to 105% of TMCR load. In case overload valve (HP stage bypass) is provided to meet the above specified VWO requirement as per proven practice of the turbine manufacturer, sufficient margin in the main turbine control valves shall be ensured so as to generate at least 102% of MCR output at rated parameters. Load requirement beyond 102% of MCR output can be met with overload valve.

21.In the said Regulations, for Regulation 7(4), the following Regulation shall be substituted, namely:-

- (4) The design shall cover adequate provision for quick start up and loading of the unit to full load at a fast rate. The unit shall have minimum rate of loading or unloading of 3% per minute above the control load (i.e. 50% MCR). For supercritical and ultra super-critical units, minimum rate of loading or unloading shall be 5% per minute above the control load (i.e. 50% MCR).

22.In the said Regulations, after the Regulation 7(5), the following Regulation 7(6) shall be inserted, namely:-

- (6) All coal fired units to be ordered after 31-03-2021 OR getting commissioned after 31-03-2027 shall be ultra supercritical units only

23.In the said Regulations, for Regulation 8(4), the following Regulation shall be substituted, namely:-

- (4) Boiler Maximum Continuous Rating (BMCR) shall correspond to at least 102% of the steam flow at turbine inlet under VWO (valves wide open) condition (including overload valves (HP stage by pass) if provided) plus continuous steam requirement for auxiliary systems of the unit (e.g. fuel oil heating, etc.) when unit is operating above control load. The steam generator shall be capable to give BMCR output for the worst fuel quality stipulated.

24.In the said Regulations, for Regulation 8(11), the following Regulation shall be substituted, namely:-

- (11) Pulverised fuel combustion based steam generator shall not require oil support above 40% unit MCR load. However, FBC based steam-generator shall be designed such that oil support is not needed beyond 25% MCR load.

25. In the said Regulations, for Regulation 8(12)(c), the following Regulation shall be substituted, namely:-

(c) Coal supply to the mills shall be from the individual coal bunkers having storage capacity of about 10 hours for the unit operation at MCR;

26. In the said Regulations, for Regulation 9, Table 1, the following Regulation, Table 1 shall be substituted, namely:-

Table 1

Unit rating (MW)	Heat rate* (kcal / kWh) at 100% MCR with motor driven BFP	Heat rate* (kcal / kWh) at 100% MCR with turbine driven BFP
50 MW to less than 100 MW**	2280	
100 MW to less than 200 MW**	2000	-
200 MW to less than 250 MW**	1970	-
250 MW to less than 500 MW**	1955	-
500 MW and above**	1895	1935
Supercritical units	1790	1830
Ultra Supercritical Units	1750	1790

*corresponding to reference conditions of 33^o C cooling water temperature and 0% de-mineralised water make up.

** sub-critical units.

27. In the said Regulations, for Regulation 9(4), the following Regulation shall be substituted, namely:-

(4) The steam flow through steam turbine under valves wide open (VWO) condition shall correspond to 105% of steam flow corresponding to MCR output. In case overload valve (HP stage bypass) is provided to meet the above specified VWO requirement as per proven practice of the Turbine manufacturer, VWO shall mean wide open condition of both the turbine main control valves and the overload valves. However, in such case sufficient margin in the main turbine control valves shall be ensured so as to generate at least 102% of MCR output at rated parameters. Load requirement beyond 102% of MCR output can be met with overload valve.

28. In the said Regulations, for Regulation 9(6), the following Regulation shall be substituted, namely:-

(6) Suitable mechanism shall be provided to ensure lubrication and prevent damage to bearings of steam turbine-generator during starting or turning gear operation. Jacking oil system if provided, to supply high pressure oil to bearings of steam turbine-generator to lift the rotor during starting or turning gear operation shall be with 2x100% jacking oil pumps (one AC driven and one DC driven). Hand barring gear shall be provided for manually rotating the turbine in an emergency.

29.In the said Regulations, for Regulation 9(7), the following Regulation shall be substituted, namely:-

(7) The oil used for turbine governing (control) shall be supplied either from the lubricating oil system or from a separate control oil system. In case of separate control oil system, the pumps provided shall be of 2x100% capacity. Fire resistant fluid for control fluid system for all hydraulically operated valves/ servo motor for turbine stop and control valves shall be used.

30.In the said Regulations, for Regulation 9(18)(d), the following Regulation shall be substituted, namely:-

(d) Vacuum pumps or steam ejectors shall be provided as per Heat Exchange Institute (HEI) Standards or equivalent for evacuating air steam mixture and non-condensable gases from the condenser.

31.In the said Regulations, for Regulation 9(19), the following Regulation shall be substituted, namely:-

(19) 3x50% or 2x100% condensate extraction pumps shall be provided for each unit. The design shall meet the requirements of Hydraulic Institute Standard (HIS) or equivalent.

32.In the said Regulations, for Regulation 9(20)(a), the following Regulation shall be substituted, namely:-

(a) Large Size Units (500 MW & above)

2x50% or 1x100% turbine driven BFP(s) plus one (1) number motor driven BFP of adequate capacity for start up of the unit.

or

2X50% motor driven BFPs.

33.In the said Regulations, for Regulation 9(20)(b), the following Regulation shall be substituted, namely:-

(b) Small Size Units (< 500 MW)

3x 50% motor driven BFPs

or

2x100% motor driven BFPs.

34. In the said Regulations, for Regulation 10(2)(d), the following Regulation shall be substituted, namely:-

- (d) For hydrogen cooled generators, hydrogen gas system shall be provided. In case, driers are provided, the same shall be of 2x100% duty to maintain dryness of hydrogen inside the machine. Suitable system shall be provided to prevent condensation during long shut down. The system shall have the provision of on-line dew point measurement as well as gas analyser.

35. In the said Regulations, for Regulation 10(2)(f), the following Regulation shall be substituted, namely:-

- (f) In case of hydrogen cooled machines, the seal oil system provided shall be equipped with 2x100% AC motor driven pumps and 1x 100% DC motor driven pump or any other proven system as per OEM practices/ recommendations. The system shall be provided with coolers (if applicable) and filters having 2x100% duty.

36. In the said Regulations, for Regulation 10(2)(g)(iii), the following Regulation shall be substituted, namely:-

- (iii) Automatic voltage regulator shall have 2x100% auto channels and automatic changeover. In the event of failure of auto channels, manual control shall be possible. In case of Static Excitation System Power thyristor converter shall be fully controlled three phase, full wave bridge type with fast and high ceiling performance. The converter shall have 'N+2' redundancy where N is the number of bridges required to deliver rated excitation current and 'N+1' number of bridges shall deliver the ceiling voltage/current. In case of brushless excitation system, rectifier assembly shall be provided with either complete bridge as redundant or at least one redundant parallel branch in each of the six arms of the bridge.

37. In the said Regulations, for Regulation 10(3)(b)(ii), the following Regulation shall be substituted, namely:-

- (ii) filled with mineral oil and cooling shall be of oil forced air forced (OFAF) / oil directed air forced (ODAF) type. Alternate cooling arrangement viz. oil natural air forced (ONAF), or oil natural air natural (ONAN) may also be adopted depending upon unit size. It shall be provided with two or more cooling radiator banks. Suitable number of standby fans and oil pumps shall be provided. Total capacity of coolers for each transformer shall be minimum 120% of actual requirements.

38. In the said Regulations, for Regulation 10(3)(b)(iii), it shall be deleted:-

- (iii) Deleted

39. In the said Regulations, for Regulation 10(3)(c)(ii), the following Regulation shall be substituted, namely:-

(ii) filled with mineral oil and cooling shall be of oil natural air forced (ONAF) or oil natural air natural (ONAN) type. However, oil forced air forced (OFAF) / oil directed air forced (ODAF) cooling may also be adopted depending upon transformer size. It shall be provided with two or more cooling radiator banks. Suitable number of standby fans and oil pumps shall be provided. Total capacity of coolers for each transformer shall be minimum 120% of actual requirements.

40. In the said Regulations, for Regulation 10(3)(c)(iii), it shall be deleted:-

(iii) Deleted

41. In the said Regulations, for Regulation 10(3)(d), 10(3)(d)(i), 10(3)(d)(ii) the following Regulation shall be substituted, namely:-

(d) In case of Non-GCB Scheme, the station transformer(s) shall be- (i) used to cater the start-up power requirement, station auxiliary load requirement during normal operation of the unit(s) and unit load in case of outage of UAT.

(ii) filled with mineral oil and cooling shall be of oil forced air forced (OFAF) / oil directed air forced (ODAF) type. Alternate cooling arrangement viz. oil natural air forced (ONAF), or oil natural air natural (ONAN) may also be adopted depending upon unit size. It shall be provided with two or more cooling radiator banks. Suitable number of standby fans and oil pumps shall be provided. Total capacity of coolers for each transformer shall be minimum 120% of actual requirements.

42. In the said Regulations, for Regulation 10(3)(d)(iii), it shall be deleted:-

(iii) Deleted

43. In the said Regulations, for Regulation 10(3)(g), the following Regulation shall be substituted, namely:-

(g) Short circuit withstand test shall be conducted on one of each type and rating of power transformers to validate the design and quality unless such test has been conducted on transformer of same design within last five years (from the date of placement of order). In case there is a change in design before five years, the new transformer design shall be validated by carrying out short circuit withstand test

44. In the said Regulations, for Regulation 10(4), the following Regulation shall be substituted, namely:-

(4) High tension (HT) switchgear- Sulphur hexa fluoride (SF₆) or vacuum type of circuit breakers shall be provided for HT switchgear (11/6.6/3.3 kV) which shall be of draw out type, re-strike free, trip free, stored energy operated and with electrical anti-pumping features. The same shall be applicable for 33kV voltage level also in case used. The protective relays shall be of numerical type with self-

monitoring, diagnostic features and communication facility. The switchgear shall be designed for suitable fault withstanding capability.

45. In the said Regulations, for Regulation 10(5), the following Regulation shall be substituted, namely:-

(5) Low tension (LT) switchgear- Air break type of circuit breakers shall be provided for LT switchgear (415 V) which shall be of draw out type, trip free, stored energy operated and with electrical anti-pumping features. The protective relays shall be of numerical type with self monitoring and diagnostic features. The switchgear shall be designed for suitable fault withstanding capability.

46. In the said Regulations, for Regulation 10(6)(d), the following Regulation shall be substituted, namely:-

(d) The HT busduct (11/6.6/3.3 kV) shall be segregated phase/ sandwich type and LT busduct (415V) shall be non-segregated phase type.

47. In the said Regulations, for Regulation 10(7)(c), the following Regulation shall be substituted, namely:-

(c) Power supplies, buses, switchgears, interlocks and standby supply systems for station and unit auxiliaries shall be designed in such a way that the equipments connected are not endangered under all operating conditions. Transformer voltage ratios, type of tap changers and tap ranges, impedances and tolerances thereon shall be so optimized that the auxiliary system voltages under various grid and loading conditions are always within permissible limits and equipment are not subjected to unacceptable voltages during operation and starting of motors. The vector groups of the generator transformers, unit auxiliary transformers and station transformers shall be so selected that the paralleling at 11/ 6.6/ 3.3kV buses shall be possible. Further, the vector group of other auxiliary transformers shall have identical vector groups.

48. In the said Regulations, for Regulation 10(13), the following Regulation shall be substituted, namely:-

(13) Diesel generator set- Automatic mains failure (AMF) diesel generators (DG) shall be installed for feeding emergency loads in the event of failure of Station supply. One DG set shall be provided for each unit of 200 MW and above. In addition, there shall be one common standby DG set of same rating to serve a block of two units. For unit sizes less than 200 MW, one DG set may be provided for every two units. However, a Station with a single unit of 200 MW or higher rating shall be provided with two(2) numbers DG sets of full designed capacity.

49. In the said Regulations, for Regulation 10(14), the following Regulation shall be substituted, namely:-

(14) DC system- Standard voltage levels of the DC system shall be 220 volts, 48 volts and 24 volts for control and protection of various equipment. However, 110V DC may be provided for off-site areas and for Gas Turbines only. Two sets of batteries, each catering to 100% load, shall be provided for each DC system. One float -cum- boost charger shall be provided for each battery.

50.In the said Regulations, for Regulation 10(15), the following Regulation shall be substituted, namely:-

(15) Illumination system- Adequate illumination shall be provided in accordance with relevant IS. Emergency AC and DC illumination shall also be provided at important places. Energy conservation measures shall be adopted while designing the lighting system. Illumination system shall be Energy Efficient/ LED based as far as practicable/ feasible. For battery backed emergency lighting, only Energy Efficient/ LED fixtures shall be used.

51.In the said Regulations, after the Regulation 10(16)(C), the following Regulation 10(16)(d) shall be inserted, namely:-

(d) All LT motors shall be of premium efficiency (IE3) class as per relevant IS.

52.In the said Regulations, for Regulation 11(2)(b)(iii), the following Regulation shall be substituted, namely:-

(iii) Control systems integral to turbine- generator shall include turbine protection system, electro-hydraulic governing (EHG) system, turbine stress control system, turbine supervisory system, automatic turbine run up system (ATRS) and automatic on load turbine testing system (ATT). Turbine protection system shall comply with relevant VDE code.

53.In the said Regulations, for Regulation 12(9)(a), the following Regulation shall be substituted, namely:-

(a) The EOT cranes shall be provided for maintenance of TG cycle equipment and CW pumps. These shall comply with the requirements of latest versions of relevant IS. The crane capacity shall be taken as 10% more than the single heaviest equipment to be lifted by the crane.

CHAPTER – III

TECHNICAL STANDARD FOR CONSTRUCTION OF HYDRO ELECTRIC GENERATING STATIONS

54.In the said Regulations, for Regulation 29, the following Regulation shall be substituted, namely:-

“29. Preliminary –

This Chapter stipulates the minimum technical requirements for construction of Hydro-Electric Generating Stations for various types of schemes i.e. Run- of-river scheme, Storage scheme, pumped storage scheme (fixed speed), Canal head scheme etc. with installed capacity of 25MW and above. For hydro-electric generating stations having installed capacity less than 25 MW, the stipulations as appropriate, shall apply.

55. In the said Regulations, for Regulation 30(1), the following Regulation shall be substituted, namely:-

“30. General Requirements –

(1) While designing hydro-electric projects, the life of the civil works shall not be less than one hundred (100) years with regular inspection and required maintenance, while that of main electric-mechanical generating equipment i.e. turbine, generator, transformers, auxiliaries, etc. installed shall not be less than thirty-five (35) years.

56. In the said Regulations, for Regulation 30(2), the following Regulation shall be substituted, namely:-

“30. General Requirements –

(2) The station shall be designed for unconstrained operation within the range of maximum net head and minimum net head, specified silt conditions wherever applicable and full range of ambient and other environmental conditions.

57. In the said Regulations, for Regulation 30(4), the following Regulation shall be substituted, namely:-

“30. General Requirements –

(4) The chemical analysis of water and silt data including the petrographic and petrofabric analysis shall be taken into consideration while designing the turbine, main inlet valve and other auxiliary equipment susceptible to abrasive effects of silt. Suitable materials, protective coatings and painting shall be provided to resist silt abrasion wherever required as per the site conditions.

58. In the said Regulations, for Regulation 30(5), the following Regulation shall be substituted, namely:-

“30. General Requirements –

(5) The operation of the unit shall be smooth and quiet. The noise level shall not be more than 90 dBA at a distance of 1 metre from any equipment when operating near rated head and rated output.

59. In the said Regulations, for Regulation 31(1), the following Regulation shall be substituted, namely:-

“31. Layout Considerations –

(1) General layout of the station shall be developed considering the proper utilization of space, functional requirements, future extensions and considering requirements of space during construction stage.

60. In the said Regulations, for Regulation 32(8), the following Regulation shall be substituted, namely:-

“32. Operating Capability of the Generating Unit –

(8) The station shall be equipped with facilities for black start of one generating unit at a time in the event of grid black-out conditions.

61. In the said Regulations, for Regulation 33(5), the following Regulation shall be substituted, namely:-

“33. Hydraulic Turbines and Auxiliaries -

(5) Before the manufacturing of the prototype turbine is taken up, homologous scale model of the prototype turbine shall be made if not already available and tested to demonstrate that the prototype turbine will meet the guaranteed performance in respect of efficiency, output, smooth operation, pressure pulsations and other guarantees as stipulated in the technical specifications. For power station size up to 100 MW and unit size of 50 MW, Computational Fluid Dynamics can be used to demonstrate that the prototype turbine will meet the guaranteed performance in respect of efficiency, output, smooth operation, pressure pulsations and other guarantees.

62. In the said Regulations, for Regulation 33(6), the following Regulation shall be substituted, namely:-

“33. Hydraulic Turbines and Auxiliaries –

(6) The weighted average efficiency shall be computed based on the efficiencies at various outputs. The weightage factors shall be selected corresponding to the average duration or period (in percentage) in a year, for which the units are expected to be operated at different outputs. The weighted average efficiency obtainable shall not be less than 93% for Francis, 92% for Kaplan and Bulb turbines and 91% for Pelton and Deriaz turbines. The peak efficiency at rated conditions shall be higher than 94% for Francis, 93% for Kaplan & Bulb and 91.5% for Pelton, Deriaz & Propeller turbines. The weighted average efficiency of the turbine shall be determined after the installation and commissioning of the generating units on the basis of field acceptance tests on one of the units as per relevant IS/IEC standards.

63. In the said Regulations, for Regulation 33(8), the following Regulation shall be substituted, namely:-

“33. Hydraulic Turbines and Auxiliaries –

(8) The pressure rise and speed rise of turbine shall be within the range specified by relevant Indian standards.

64. In the said Regulations, for Regulation 33(9), the following Regulation shall be substituted, namely:-

“33. Hydraulic Turbines and Auxiliaries –

(9) The turbine shall be designed to withstand runaway speed for 15 minutes with cooling water on & intact without causing any residual detrimental effect on future operation of the machine. However, critical speed of the machine shall be around 25% higher than maximum runaway speed.

65. In the said Regulations, for Regulation 33(12), the following Regulation shall be substituted, namely:-

“33. Hydraulic Turbines and Auxiliaries –

(12) Special care shall be taken to select the material of the underwater parts. The materials selected for runner, guide vanes, runner chamber, upper draft tube cone, etc. shall have high wear resistance, corrosion and cavitation resistance. Besides, the use of the material having good weldability shall be considered so that parts can be fabricated and the eroded parts can be repaired easily at site.

66. In the said Regulations, for Regulation 33(13), the following Regulation shall be substituted, namely:-

“33. Hydraulic Turbines and Auxiliaries –

(13) As most of the rivers in the Himalayan region carry high silt which erodes the runner and under water parts of a turbine at a comparatively faster rate, appropriate protective coatings shall be provided for these parts of a turbine in order to minimize silt erosion, wherever necessary and feasible.

67. In the said Regulations, for Regulation 33(15), the following Regulation shall be substituted, namely:-

“33. Hydraulic Turbines and Auxiliaries -

(15) The pump turbine shall be capable of giving output higher than the rated output while operating in the turbine mode. The pump turbine shall be hydraulically designed giving preference to its operation in “Pumping Mode” so that optimum efficiencies are obtained in both turbine and pump mode. However,

selection of machine should be made keeping in view predominant operating mode.

68. In the said Regulations, after the Regulation 33 (16), the following Regulation 33 (16)(a) shall be inserted, namely:-

“33. Hydraulic Turbines and Auxiliaries –

(16)(a) Each penstock / hydro turbine shall have online display of water flow measurement for unit size higher than 100 MW.

69. In the said Regulations, for Regulation 34 (2), the following Regulation shall be substituted, namely:-

“34. Governing System -

(2) High pressure oil system shall be provided for each turbine for the operation of wicket gates/ nozzle/ deflector servomotors through governors and for the control of main inlet valve (MIV). Piston/ Bladder type accumulator integrated with nitrogen bottles shall be used for pressures higher than 60 kg/cm².

70. In the said Regulations, for Regulation 34 (3), the following Regulation shall be substituted, namely:-

“34. Governing System –

(3) Separate oil pressure systems shall be used for the control of turbine and the control of MIV. However, common oil pressure system can also be considered, in case MIV is provided with closing weight for normal and emergency closing. Online filtration unit shall be used with servo valve based governing system.

71. In the said Regulations, for Regulation 34 (4), the following Regulation shall be substituted, namely:-

“34. Governing System –

(4) The sizes of various components of oil sump tank and pressure receiver shall be calculated as per the relevant IS/IEEE standards. The oil volume below its machine shutdown level shall be sufficient to perform 3 full operations of the servomotor viz. Close-Open-Close with oil pumps being out of operation for control of Turbine and open operation of MIV.

72. In the said Regulations, for Regulation 35 (6), the following Regulation shall be substituted, namely:-

“35. Main Inlet and Penstock Protection Valve –

(6) The penstock protection valve shall be provided after the surge shaft as a second line of defence in the projects having the length of Head Race Tunnel 5000 m or more. The valve shall be designed for penstock rupture condition.

73. In the said Regulations, after the Regulation 35(6), the following Regulation 35 (6)(a) shall be inserted, namely:-

“35. Main Inlet and Penstock Protection Valve –

(6)(a) The Penstock Protection Valve shall be provided with counter-weight for closing. Additional feature of oil assistance closing as back up shall also be provided for emergency closure.

74. In the said Regulations, after the Regulation 35(6)(a), the following Regulation 35(6)(b) shall be inserted, namely:-

“35. Main Inlet and Penstock Protection Valve –

(6)(b) In Dam Toe Power stations, where main inlet valve is not provided, the intake gates shall be quick closing type.

75. In the said Regulations, for Regulation 36 (1 b), the following Regulation shall be substituted, namely:-

“36. Mechanical Auxiliaries –

(1) Electric overhead travelling (EOT) cranes

(b) The crane capacity shall be kept as 10% more than the maximum weight to be lifted inclusive of the weight of the lifting beam. If the maximum weight to be lifted is more than 300 Tonnes, two cranes each of equal capacity shall be deployed to lift the heaviest package in tandem operation.

76. In the said Regulations, for Regulation 36 (1 e), the following Regulation shall be substituted, namely:-

“36. Mechanical Auxiliaries –

(1) Electric overhead travelling (EOT) cranes

(e) A monorail of adequate capacity can be provided for handling smaller packages, equipment and sub-assemblies and shall have larger reach than main crane.

77. In the said Regulations, for Regulation 36 (3) (a), the following Regulation shall be substituted, namely:-

“36. Mechanical Auxiliaries –

(3) Dewatering and drainage system

(a) Submersible type of dewatering pumps shall be provided to pump out the water trapped between the penstock gate/main inlet valve and draft tube gate in case of Francis and Kaplan turbines to the dewatering sump when maintenance on the turbine of any unit is required to be carried out. The capacity of the pump shall be chosen in such a way that a single unit can be dewatered within 6 hours operation without raising the level in the sump with the main pump(s) in operation. In addition, standby pump(s) of capacity 50 % of the main pump(s) shall also be provided.

78. In the said Regulations, for Regulation 36 (3) (b), the following Regulation shall be substituted, namely:-

“36. Mechanical Auxiliaries –

(3) Dewatering and drainage system

(b) All the drainage water within the power house shall be collected inside the drainage sump constructed near the dewatering sump. The drainage water shall be allowed to flow out to the tail race above the maximum flood water level using pumps, if required.

79. In the said Regulations, for Regulation 36 (5) (a), the following Regulation shall be substituted, namely:-

“36. Mechanical Auxiliaries –

(5) High pressure and low pressure compressed air system

(a) The Nitrogen (N₂) system having Piston/Bladder type accumulator shall be provided for pressure 60 kg/cm² and more for Turbine and MIV. However, if the high pressure compressed air is opted for lesser pressure requirement of turbine governing system and MIV, the pressure of HP air compressor shall be 1.1 times the working pressure.

80. In the said Regulations, for Regulation 36 (7) (a), the following Regulation shall be substituted, namely:-

“36. Mechanical Auxiliaries –

(7) Oil handling and purification system

(a) The insulating oil required in the generator transformers for the hydro station shall conform to relevant IS. The type of turbine oil used as a working fluid in speed regulation system and as a lubricant and a coolant for thrust and guide bearings shall be as per the recommendations of the equipment manufacturer. The oil type shall be same for bearing and governor.

81. In the said Regulations, for Regulation 36 (8) (c), the following Regulation shall be substituted, namely:-

“36. Mechanical Auxiliaries –

(8) Fire fighting system

(c) The provision shall be made for water sprinkler system for oil plant rooms, especially in an underground power house. In addition, provision shall also be made for fire hose cabinets/ hydrants inside the power house as well as for the transformer area. The water supply for the permanent fire protection installation should be based on the largest fixed fire suppression system demand plus the maximum hose stream demand of not less than 1890 L/min for a 2-hour duration. Two nos. of fire pumps, each capable of pumping water to fill the overhead water tank in 6 hours time shall be provided.

82. In the said Regulations, for Regulation 37(2) (a) (ii), the following Regulation shall be substituted, namely:-

“37. Electrical System

(2) Generator/ generator-motor

(a) *General*

(ii) Insulation shall be of thermal class F for the stator and the rotor windings with temperature rises at rated output, voltage and frequency limited to that of thermal class B as per relevant IS/IEC standards.

83. In the said Regulations, for Regulation 37(2)(a)(iv), the following Regulation shall be substituted, namely:-

“37. Electrical System

(2) Generator/ generator-motor

(a) *General*

(iv) The construction of the generator shall be such that the rotor poles and stator coils can be handled out or in without removal of the rotor and without disturbing the upper bearing bracket wherever feasible. The rotor poles shall be interchangeable with similar type of poles.

84. In the said Regulations, for regulation 37(2)(a)(vi), the following Regulation shall be substituted, namely:-

**“37. Electrical System
(2) Generator/ generator-motor**

(a) General

(vi) The generator rated speed shall match the rated speed of the turbine or the pump-turbine. A rated speed resulting in even number of pair of poles shall be preferred.

85. In the said Regulations, for Regulation 37(2)(a)(ix), the following Regulation shall be substituted, namely:-

**“37. Electrical System
(2) Generator/ generator-motor**

(a) General

(ix) Metal oxide surge arresters of suitable rating shall be provided for surge protection of generators.

86. In the said Regulations, for Regulation 37(2)(a)(xii), the following Regulation shall be substituted, namely:-

**“37. Electrical System
(2) Generator/ generator-motor**

(a) General

(xii) Weighted average efficiency based on the computed efficiencies at various outputs for which the generator is expected to operate shall be more than 98% for machine greater than 30 MVA.

87. In the said Regulations, for Regulation 37(2)(d)(i), the following Regulation shall be substituted, namely:-

**“37. Electrical System
(2) Generator/ generator-motor**

(d) Generator Busduct

(i) The generator busduct shall comply with the requirements of the latest versions of relevant IS/IEC standards. Generator busduct shall be segregated or isolated phase type. Busduct rated more than 3150 Amperes shall be isolated phase type. The isolated phase ducts shall be preferred over the segregated phase bus ducts. Generator Busduct rated more than 6000 Amperes shall be continuous isolated phase type. A hot air blowing system or air pressurization system can be provided to prevent

moisture deposition in case of isolated phase ducts while space heaters may be provided in case of other busducts.

88. In the said Regulations, for Regulation 37(3)(e), the following Regulation shall be substituted, namely:-

“37. Electrical System

(3) Excitation system

(e) All the performance requirements of the automatic voltage regulation (AVR), power system stabilizer (PSS) shall be in accordance with relevant IEEE standards/ Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations—and Central Electricity Authority (Grid Standards) Regulations as and when they come into force.

89. In the said Regulations, for Regulation 37(4)(c), the following Regulation shall be substituted, namely:-

“37. Electrical System

(4) Generator step-up transformers

(c) Selection of single phase or three phase transformers for hydro power stations shall be governed by the transportation limitations and shall be finalised considering the status of load carrying capacities of bridges, culverts etc. enroute. In case of single phase transformers, one no. transformer for three and more generating units shall be kept as spare.

90. In the said Regulations, for Regulation 37(4)(j), the following Regulation shall be substituted, namely:-

“37. Electrical System

(4) Generator step-up transformers

(j) The generator transformers having three phase rating of 120 MVA and above shall be provided with on line dissolved gas analyzer system.

91. In the said Regulations, for Regulation 37(4)(k), the following Regulation shall be substituted, namely:-

“37. Electrical System

(4) Generator step-up transformers

(k) Short circuit withstand test shall be conducted on one of each type and rating of generator transformers to validate the design and quality unless such test has been conducted within last five years on transformer of same design.

92. In the said Regulations, for Regulation 37(5)(b)(i), the following Regulation shall be substituted, namely:-

“37(5)(b). Station Auxiliary AC Supply System

(i) The station auxiliary AC supply system shall be designed to provide a high degree of reliability, continuity of service and primarily to supply uninterrupted AC supply to station auxiliaries during normal operation and unit auxiliaries during starting and stopping of the unit and during abnormal events.

93. In the said Regulations, for Regulation 37(5)(c), the following Regulation shall be substituted, namely:-

“37. Electrical System

(5) Unit auxiliary and station auxiliary AC supply systems

(c) The main/ critical switchgear, motor control centres (MCCs), Main Line Distribution Boards (MLDBs) shall be fed by 2x 100 % transformers/feeders and these shall be rated to carry the maximum load expected to be imposed.

94. In the said Regulations, for Regulation 37(6)(f), the following Regulation shall be substituted, namely:-

“37. Electrical System

(6) DC supply system

(f) The DC batteries, battery chargers, and DC distribution board shall be placed at a floor higher than of machine hall in underground power house and not below the machine hall floor in surface power house.

95. In the said Regulations, for Regulation 37(9)(b), the following Regulation shall be substituted, namely:-

“37. Electrical System

(9) Illumination

(b) Energy conservation measures shall be adopted, while designing the lighting system. LED based luminaires, Sodium vapour (high pressure) or other more efficient latest technology lighting fixtures shall be provided for outdoor lighting of areas such as switchyards, spillways and dams, parking areas etc. Automatic switching via photo electric cells can be adopted for outdoor lighting to optimize power consumption.

96. In the said Regulations, for Regulation 37(9)(d), the following Regulation shall be substituted, namely:-

“37. Electrical System

(9) Illumination

(d) LED lamps or more efficient lighting shall be used for battery powered emergency lights.

97. In the said Regulations, after the Regulation 37(9)(d), the following Regulation (37)(9)(e) shall be inserted, namely:-

**“37. Electrical System
(9) Illumination**

(e) LED based illumination system shall be designed and installed as far as practicable/ feasible at generating stations.

98. In the said Regulations, for Regulation 37(10), the following Regulation shall be substituted, namely:-

“37. Electrical System

(10) EHV/HV/LV power cables, busducts and control cables– Cables shall be flame retardant, low smoke, low halogen (FRLSH) type. Directly buried cables shall be essentially armoured type. Cables shall be derated for the site ambient and ground temperatures, grouping and soil resistivity as per relevant IS. Wherever feasible/ practicable, HV/LV busduct shall be used for interconnection.

99. In the said Regulations, after the Regulation 37(12)(g), the following Regulation 37(12)(h) shall be inserted, namely:-

“37(12). Electrical protection System

(h) Protection for 100% stator earth fault for generating unit shall be provided preferably through injection based principle for more than 200 MW generating units.

100. In the said Regulations, for Regulation 38(2)(c), the following Regulation shall be substituted, namely:-

**“38. Control, Protection and Instrumentation
(2) Control and protection system**

(c) The control system shall be divided in the following groups with independent controls:

- (i) Generating unit controls;
- (ii) Common controls (for control of common auxiliaries):
- (iii) Station controls (for station auxiliaries);
- (iv) Switchyard controls;
- (v) Dam gate controls (wherever applicable).

Controls in (ii) to (v) can be suitably integrated on case to case basis depending upon the extent of control required and the space availability.

The above groups shall be interconnected and also controlled from the control room through computerized control system (CCS). The type of interconnection with remote equipment shall be through a reliable communication mode.

101. In the said Regulations, for Regulation 39 (7), the following Regulation 39 (7) shall be deleted, namely:-

“39. Provisions Required for Protection of Power House against Flooding (7) -deleted-

CHAPTER – IV

TECHNICAL STANDARDS FOR CONSTRUCTION OF SUB_STATIONS AND SWITCHYARDS

PART-A

SUBSTATIONS AND SWITCHYARDS (66KV AND ABOVE)

102. In the said Regulations, for Regulation 41, the following Regulation shall be substituted, namely:-

41. **General-** (1) The rated rupturing capacity of the circuit breaker to be installed at any new sub-station or switchyard shall be at least 25% higher than the calculated maximum fault level at the bus to take care of the increase in short circuit levels as the system grows. The rated breaking current capability of switchgear ~~and breakers~~ to be installed at different voltage levels, ~~based on available capacities of the breakers~~, shall be considered as shown in Table 6 below.

Table 6

66 kV	31.5 kA (for 1 sec.)
110/ 132 kV	31.5 kA or 40kA(for 1 sec.)
220 /230kV	40 kA or 50 kA (for 1 sec.)
400 kV	40 or 50 kA or 63 kA (for 1 sec.)
765 kV	40 or 50 kA (for 1 sec.)
1150kV	40 or 50 kA (for 1 sec.)

(2) If the fault level at a sub-station exceeds or is likely to exceed the permissible fault level with the addition of more generators and termination of new transmission lines, adequate measures to limit the fault level like ~~sectionalization/splitting~~ of the sub-station bus or installation of series reactors on the line or bus ~~or installation of Fault Current Limiter (FCL) on Line or bus or~~

transformer or reactor at the respective sub-stations shall be resorted to. Suitable care shall be taken to address the impact of the addition of the series reactors or FCL on existing system based on system studies/dynamic simulations.

(3) The transformation capacity of any single sub- station for meeting loads at different voltage levels shall not normally exceed the values indicated in Table 7 below.

Table 7

1150 kV	12000 MVA
765 kV	4500 9000 MVA
400 kV	4500 2000 MVA and 3000* MVA
220 / 230 kV	500 650 MVA
110/ 132 kV	450 250 MVA
66 kV	75 100 MVA

* Transformation capacity for switchyard associated with generating station

(4) The size and number of interconnecting transformers (ICTs) at a sub-station shall be planned in such a way that the outage of any ICT (single three-phase unit or bank of three single-phase units) does not overload the remaining ICT(s) or the underlying transmission system.

(5) The location, layout, design and construction of the new installation shall provide for ~~automation and computerized coordinated operation through supervisory control and data acquisition system (SCADA) and Energy Management System and for~~ future expansion.

(6) The sub-station or switchyard shall be designed and constructed to give a life of not less than ~~25~~ 35 years.

(7) The sub-station or switchyard shall have IEC-61850 based Substation Automation System (SAS), Supervisory Control And Data Acquisition System (SCADA) system and Energy Management System. The SAS Gateway shall be capable of communicating with Load Dispatch Centre & backup Load Dispatch Centre and Central Control Centre through more than one SCADA system over IEC-60870-5-101/104 protocol (as applicable). To facilitate remote monitoring and control of the substation, Visual Monitoring System may be implemented at each substation. Remote Access System, to support remote configuration and disturbance record extraction of numerical relays, may also be provided.

(8) Rated normal current of Switchgears (CB, Disconnecter) and rated primary current of CT at an ambient temperature of 50°C shall normally be as indicated in Table 7(a) below:

Table 7(a)

1150 kV	4000A
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765 kV	3150A
400 kV	3150A
220 / 230 kV	1600A 2000A 2500A
110/ 132 kV	1250A 1600A 2000A
66 kV	1250A 2000A

103. In the said Regulations, for Regulation 42, the following Regulation shall be substituted, namely:-

42. Design Considerations for Sub-stations and Switchyards

(1) The sub-station or switchyard can be a conventional / digital; air insulated sub-station (AIS) or gas insulated sub-station (GIS) or hybrid substation or combination thereof. The factors to be taken into account for designing sub-stations shall be as under:

- (a) The choice of site for a sub-station or switchyard shall be based on technical, economic, geographic & environmental factors and overall life cycle cost. The approximate location shall be determined on grid considerations. The new substation shall enhance the operational flexibility, system reliability and transmission or transformation capacity after becoming a part of the network.
- (b) Land area required shall be considered based on the present requirement and the future expansion on a 10 to 15 years scenario.
- (c) ~~Reactive compensation as indicated by system studies shall be provided.~~ Requirement of installation of power compensating devices like shunt capacitors, shunt reactors (bus reactors or line reactors), Controlled Shunt Reactors (CSR), Static VAr Compensators (SVC), Static Synchronous Compensators (STATCOM), Fixed Series Capacitor (FSC), variable series capacitor (Thyristor Controlled or Thyristor Protected) or other Flexible AC Transmission System (FACTS) devices shall be assessed through appropriate system studies. The series compensation shall be fixed or variable or a combination of both (partly fixed and partly variable). Similarly shunt compensation shall be either switched or non-switched type.
- (d) The selection of switching schemes shall be based upon requirements for operational flexibility, system safety, reliability, availability, criticality of load, maintainability and cost.

(2) Air insulated sub-stations (AIS)

- (a) The switching schemes as per Table 8 shall generally be adopted at different voltage levels in AIS depending on the importance of the installation.

Table 8

Main and transfer bus or double bus scheme (with or without breaker bypass arrangement)	66 kV, 110 kV and 132kV
Double main and transfer bus scheme or double bus scheme (with or without breaker bypass arrangement)	220kV and 230kV
Breaker and a half scheme or double main and transfer bus scheme	400 kV, 765kV and 1150 kV

- (b) In case of AIS, bus-bars shall be either of the rigid type with tubular aluminium bus conductor or flexible stranded conductor with aluminium conductor steel reinforced (ACSR) or all aluminium alloy conductor (AAAC) or other suitable conductors. The conductor of appropriate rating and the number of conductors to be used in case of bundle conductors shall be selected considering power flow requirements, corona effect and ambient conditions. For the rigid bus-bar arrangement, aluminium pipes conforming to relevant standard shall be used.
- (c) Outdoor air insulated sub-station or switchyard shall be shielded against direct lightning stroke strike by provision of overhead shield wire or earthwire or spikes (masts) or any other new technology or a combination thereof.

(3) Gas insulated sub- stations

- (a) Gas insulated sub- station (GIS) installations shall generally be preferred to conventional AIS as a techno-economic solution for locations where space is a major constraint and also for seismic prone areas, and coastal areas, high altitude areas and very heavily polluted areas. However, techno-economic analysis, taking into consideration the life cycle cost, shall be done to determine the preference for each GIS installation. The GIS shall comply with relevant standards. The GIS installations shall be outdoor or indoor type.
- (b) The switching scheme has a large impact on the total cost of the GIS and shall be properly evaluated for a particular project. ~~Single bus with or without sectionalization and double main bus switching schemes shall be used. Other types of switching schemes can also be considered based on techno-economic analysis.~~ The switching schemes as per Table 8a shall generally be adopted at different voltage levels in GIS.

Table 8a

Main and transfer bus or double bus scheme	66 kV, 110kV and 132kV
Double bus scheme	220kV and 230kV
Breaker and a half scheme	400 kV, 765kV and 1150 kV

Note: For 400 kV GIS associated with Hydro Electric Generating Plants, Double Bus Scheme may also be adopted, if required.

- (c) GIS shall be isolated phase or three phase non-magnetic enclosure type for voltage less than 400kV. For 400kV and higher voltage levels, it shall be isolated phase **non-magnetic** enclosure type.
 - (d) The arrangement of gas sections or compartments shall be such as to facilitate future extension on either end without any drilling, cutting or welding on existing equipment from any manufacturer and without the necessity of moving or dislocating the existing switchgear bays or **taking shutdown of bus bar or bay, and to facilitate ease of maintenance and high voltage testing without outage of healthy bays.** The layout of Gas Insulated Bus Ducts shall be properly planned to optimize the length of bus ducts and for easy accessibility for maintenance.
 - (e) The design shall be such that all parts subjected to wear and tear are easily accessible **and removable** for maintenance purposes. The equipment shall be protected against all types of voltage surges **as per IEC limits** and shall necessarily include any component or assembly required for this purpose.
 - (f) **The length of busbars, bus ducts, isolator sections shall be optimized considering effects of fast transient voltage due to isolator operations.**
 - (g) **The crane of suitable capacity shall be installed in GIS building for movement of GIS Sections for maintenance.**
- (4) **Hybrid sub-station-** In a hybrid sub-station, the bus-bars shall be air insulated type. Switchgear for a hybrid sub-station shall have some or all functional units enclosed in SF₆ gas insulated housing. A hybrid substation would require less space than conventional AIS but more than GIS. A hybrid sub-station can be considered as a techno-economic solution, **taking into consideration the life cycle cost**, for locations where space is a constraint and also for sub-station renovation or augmentation. ~~A hybrid sub-station can be outdoor or indoor type.~~ The switching schemes as per Table 8 shall generally be adopted at different voltage levels.

(4A) The use of GIS/hybrid switchgear in existing AIS substation can also be considered to accommodate bay extensions.

(4B) Digital Substation: In order to improve efficiency, safety and system visibility in the grid, utilities shall take steps to move from traditional substation concept to new generation Digital Substations incorporating Intelligent Electronic Devices (IEDs) with integrated information and communication technology using fibre optic cables, Non-Conventional Instrument Transformers (NCIT) and merging units that are interfaced with the process bus and station bus architecture so as to reduce copper cable wirings and eliminate the dangers associated with conventional Instrument Transformers and electrical hazards in general. The use of conventional Instrument Transformers, Circuit Breakers and Disconnectors with merging unit can also be considered for Digital Substation. The input for revenue metering shall be as per Central Electricity Authority (Installation and Operation of Meters) Regulations.

(4C) Mobile Substations:

The vehicle mounted mobile substation (comprising of trailer, incoming and outgoing HV and LV hybrid switchgears, power transformer, and associated connectors) should be considered for putting into immediate service as a quick substitute to conventional substation of 220kV and below voltage class to resume power supply in short time in case of emergency/natural or other disasters leading to total collapse/disruption of power supply.

(5) The grounding system shall be designed for expected life of the substation for rated fault current as indicated in Table 6 under Regulation 41. Earthing system for the entire switchyard, equipment and buildings shall be provided in accordance with relevant IS/ IEEE standards. The touch and step potential limits shall be maintained within acceptable limits as per relevant IS/ IEEE standards. Special consideration shall be given for GIS earthing design to handle high frequency transients. The use of environmental friendly earthing enhancing compound / material may also be considered, where soil resistivity is very high, to achieve the objective of effective earthing system. Any other material as a better substitute to charcoal and sand in earth pit may also be considered. Exothermic welding technique may be adopted to have better contact between the electrodes used for earthing. Condition assessment of earthing mat, earthing pits, earth rod, surface layer material, and associated connections shall be carried out periodically to ensure effectiveness of earthing system. To ensure safety, the step and touch potential measurement within substation / switchyard shall be carried out as per IEEE 80 for new installations and measurement shall be repeated for old installation at regular interval and mitigation measures shall be taken if the measured values are exceeding the safe limit.

(6) The switchyard or sub-station layout shall be decided with due consideration to statutory safety requirements, ease of erection and maintenance etc. Safety clearances shall be maintained in accordance with the Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations ~~as and when~~

~~these are notified by the Authority.~~ The clearances shall be adequate for moving portable equipment for maintenance and maneuvering personnel for carrying out maintenance. Clearances from adjacent live parts shall be maintained for safety.

104. In the said Regulations, for Regulation 43, the following Regulation shall be substituted, namely:-

43. Salient Technical Particulars and Requirements of Sub-stations and Switchyards

(1) System design parameters

(a) The system design parameters of sub-stations and switchyards shall be as given below in Table 9.

Table 9 on next page

Table 9

Nominal System Voltage Parameter	66 kV	110 kV	132 kV	220kV	400 kV	765 kV	1150 kV
Highest system voltage (kV)	72.5	123	145	245	420	800	1200
Rated frequency	50Hz	50Hz	50Hz	50Hz	50 Hz	50Hz	50Hz
No. of phases	3	3	3	3	3	3	3
Rated insulation levels							
(i) Lightning impulse withstand voltage (1.2/50 micro sec.) (kV _{peak})	325	550	650	1050*	1425*	2100*	2400*
(ii) Switching impulse withstand voltage (250/ 2500 micro sec.) dry and wet (kV _{peak})(phase to earth)	-	-	-	-	1050	1550	1800
(iii) One minute power frequency withstand voltage dry(kV _{rms})	140	230	275	460	630	830	1200
Minimum corona extinction voltage (kV _{rms} phase to earth)	-	78	105	156	320	508	762
Maximum Radio Interference Voltage for any frequency between 0.5 MHZ to 2.0 MHZ in all positions (micro volts)			500 (at 92 kV rms)	1000 (at 156 kV rms)	1000 (at 320 kV rms)	2500 (at 508 kV rms)	1000 (at 762 kV rms)
System neutral earthing	Effectively earthed						

* for windings of transformers and reactors refer Table 10.

Note: The above parameters are for installations at altitudes upto 1000m above mean sea level (MSL). For higher altitudes, Insulation level requirements shall be kept higher as per relevant standards.

(b) The insulation level for the transformer and reactor windings and bushings shall be as per Table 10 below.

Table 10

Rated voltage (Highest voltage for equipment level)	Windings			Bushings		
	Rated power frequency withstand voltage (kV _{rms})	Rated switching impulse withstand voltage (kV _{peak}) (phase to earth)	Rated lightning impulse withstand voltage (kV _{peak})	Rated power frequency withstand voltage (kV _{rms})	Rated switching impulse withstand voltage (kV _{peak}) (phase to earth)	Rated lightning impulse withstand voltage (kV _{peak})
1200 kV		1800	2250	1200	1950	2550
800kV	-	1550	1950	880	1550	2100
420kV	-	1050	1300 1425	630	1050	1425
245kV	395	-	950 1050	460	-	1050
145kV	275	-	650	275	-	650
72.5kV	140	-	325	140	-	325
52kV	95	-	250	95	-	250
36kV	70	-	170	70	-	170
24 kV	50	-	125	50	-	125
17.5kV	38	-	95	38	-	95
12 kV	28	-	75	28	-	75

Note: The above parameters for bushings are for installations at altitudes upto 1000m above mean sea level (MSL). For higher altitudes, Insulation level requirements shall be kept higher as per relevant standards.

105. In the said Regulations, for Regulation 43(2)(a)(i) to 43(2)(a)(iv) & 43(2)(a)(vi) , the following Regulation shall be substituted, namely:-

(2) Main equipment

(a) Power Transformers

(i) The transformers shall comply with relevant standards in general. The transformers shall be of two winding type or autotransformers. Transformer

banks (formed out of single phase units) of 400 kV & above voltage class and 3 phase 5 or more limbed core transformer units only shall be provided with delta tertiary windings, if required, of rating one third of HV rating provided there is no other delta connected winding in the transformer. The transformers shall be provided with on load tap changer (OLTC) as per power system requirement. In case, transformers are to be provided with OLTC, the tap range shall be optimized depending on system requirement.

(ii) At existing sub-stations, the impedance, vector groups, OLTC connection and range etc. of a new transformer shall be matched with that of the existing transformer(s). Interconnecting transformers provided with suitable OLTCs shall be suitable for bi-directional flow of power. Noise level of transformer, when energized at normal voltage and frequency with fans and pumps running and measured under standard condition shall not exceed the values specified in National Electrical Manufacturers' Association (NEMA) standard , USA.

~~(iii) In order to reduce the risk of spreading fire shall be provided with 'transformer oil soak pits' filled with suitable size of gravels or pebbles below each transformer with voids of capacity adequate to contain the total quantity of oil in the transformer. Alternatively, common 'burnt oil pit' of adequate capacity (at least equal to oil quantity in the largest size transformer) shall be provided for a group of transformers, connected to all the soak pits of transformers with adequate size of pipes for fast draining of oil or water from soak pits to the burnt oil pit. Every soak pit below a Transformer shall be suitably designed to contain oil dropping from any part of the transformer. The burnt oil pit, when provided, shall also be provided with suitable automatic pumping facility, to always keep the pit empty and available for an emergency.~~

(iii) An oil soak pit of adequate capacity shall be provided below each oil filled transformer/reactor to accommodate 150% of full quantity of oil contained in the transformer/reactor and minimum 300 mm thick layer of gravels or pebbles of approximately 25 mm size. Alternatively, a soak pit of adequate capacity to accommodate 1/3rd of total quantity of oil contained in the transformer/reactor and minimum 300 mm thick layer of gravels or pebbles of approximately 25 mm size shall be provided below each transformer/reactor provided a common remote burnt oil pit of capacity at least equal to oil quantity in the largest size transformer/reactor is provided for a group of transformers/reactors. Bottom of the soak pit below the transformer/reactor shall be connected to the common burnt oil pit with drain pipe of minimum 150 mm diameter for fast draining of oil or water through gravity from soak pit to the burnt oil pit. Every soak pit below a transformer/reactor shall be suitably designed to contain oil dropping from any part of the transformer/reactor. The burnt oil pit and soak pit, when burnt oil pit is not provided, shall be provided with suitable automatic pumping facility, to always keep the pit empty and available for an emergency. The disposal of transformer oil shall be carried out in an environmental friendly manner.

(iv) Separation walls or fire barrier walls shall be provided between the transformers or reactors and also between transformer and reactors as per BIS

~~guidelines~~ Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations. Separation walls or fire barrier walls of minimum 4 hours fire resistance shall be provided between the transformer/reactor and nearby building in case clear distance as specified in IS:1646 is not available and the building is not suitable to withstand four (4) hour of continuous exposure to fire.

(vi) Short circuit withstand test shall be conducted on one unit of each type and rating of transformers, if ordered quantity is more than 2 nos. of 3-phase transformer or 6 nos. of single phase transformers of same type and rating, to validate the design and quality unless such test has been successfully conducted within last five ten years on transformer of same design and rating. In case there is change in design ~~before five years~~, the new transformer design shall be validated by carrying out short circuit withstand test.

106. In the said Regulations, after the Regulation 43(2)(a)(vi), the following Regulation 43(2)(a)(vii) to 43(2)(a)(xii), shall be inserted, namely:-

(vii) Fibre Optic Sensors shall also be used for Hot spot monitoring of winding/oil/core of transformers in addition to WTI/OTI for 400kV and above voltage class transformers. Fibre Optic Sensors in addition to WTI/OTI may also be considered, if required, for Hot spot monitoring of winding of 220 kV or below voltage class transformers.

(viii) Natural air & oil and forced Air cooling (ONAN/ONAF1/ONAF2) can also be considered as an alternative to natural air & oil, forced air & oil cooling (ONAN/ONAF/OFAF) of transformer.

(ix) Fast De-pressurization system (operation based on rate of rise of pressure) in addition to Pressure Relieve Device (PRD) (operating at a set static pressure) may also be considered for installation on transformers.

(x) Resin Impregnated Paper (RIP) / Resin Impregnated Synthetic (RIS) bushings can also be considered as an alternative to conventional Oil Impregnated Paper (OIP) bushings.

(xi) Use of Environmentally friendly, bio-degradable K- class oil / Ester oil (synthetic / Natural Ester) having higher fire point compared to mineral oil may also be considered for transformers upto 400kV level depending upon requirement.

(xii) No arcing horns shall be provided on any of the bushings of the transformer.

107. In the said Regulations, for Regulation 43(2)(b) to 43(2)(j), the following Regulation shall be substituted, namely:-

(b) **Reactive Compensation**

(i) **Shunt Reactors**

Shunt reactors, wherever provided, shall comply with relevant standards in general. Shunt reactors upto 420 kV rated voltage shall have linear voltage vs. current (V/I) characteristics upto 1.5 per unit voltage. 800 kV Shunt reactors shall have linear V/I characteristics upto 1.25 per unit voltage. If required, the neutral of the line reactors shall be grounded through adequately rated neutral grounding reactors to facilitate single phase auto-reclosure. The neutral of ~~line reactors of 420 kV rated voltage~~ shall be insulated to 550 kV peak for lightning impulse and shall be protected by means of 145 kV class surge arresters of suitable rating ~~in case of line reactors of 420kV or 800kV rated voltage~~ and the neutral of line reactor of 800 kV rated voltage shall be insulated to 650 kV peak for lightning impulse and shall be protected by means of 170 kV class surge arresters of suitable rating. The neutral of bus reactor shall be solidly grounded. The Neutral Grounding Reactor shall be provided with bypass arrangement through a breaker so that the line reactor can be used as Bus reactor as and when required. In case single phase shunt reactors are provided, then minimum one single phase unit shall be provided as spare for entire substation or switchyard.

(ii) **Shunt Capacitors**

Capacitor banks of adequate rating shall be provided preferably at voltages below 33kV and definitely not at voltages higher than 132kV. Suitable redundancy shall be provided in the number of Capacitor units to avoid reduction in reactive compensation due to failure of the Capacitor units. The objective shall be to ensure that voltage received by the consumers remain within the permissible limits.

(iii) **Controlled Shunt Reactor (CSR)**

As an alternative to Shunt Reactor, Controlled Shunt Reactor (CSR) having fast response time can be considered, based on system studies, to provide continuous variable Reactive Power support and reduced dynamic over voltage resulting in improved voltage profile and increased power transmission. The CSR shall comply with relevant IS/IEC. The CSR shall generally consist of Controlled Shunt Reactor Transformer (CSRT), thyristor valves, controller, neutral grounding reactor, necessary circuit breakers and other auxiliaries. The variable reactive power support shall be provided by controlling firing angle of the thyristor valves. Studies may be carried out to assess any requirement of harmonic filters.

(c) **Circuit Breakers**

(i) Circuit breakers shall comply with relevant standards. ~~The circuit Breaker shall be of live tank or dead tank design.~~ The interrupting medium of circuit breakers shall be SF₆/~~vacuum/any other suitable gas or combination of gases.~~ CBs of 220kV and above voltage class shall be suitable for single phase and three phase auto-reclosing. CBs of 132kV and below voltage class shall be suitable for three-phase auto-reclosing. ~~However, Circuit breakers of 110 /132kV~~

class shall be suitable for single phase auto- reclosing also, wherever required. The circuit breaker shall be of class M2 with regard to mechanical endurance as per IEC Standard. Each circuit breaker of ~~432 kV~~ 66kV and above rating shall be provided with 2 nos. of trip coils. Two sets of trip circuits shall be connected to separate fuse or miniature circuit breaker (MCB) controlled DC supplies for greater reliability. The circuit breaker shall have the provision for local manual trip which shall be at a position easily accessible to the operating person. Maximum rated break time for circuit breakers shall be as given in Table 11 below:

Table 11

1150 kV	50 ms
765 kV	40 45ms
400 kV	40 45ms
220 kV/ 230 kV	60ms
132 kV/ 110 kV	100 60 ms
66 kV	100ms

(ii) In accordance with the power system requirement, the circuit breakers of 400 kV and above class shall be provided with Preinsertion resistors (PIR) or **Controlled Switching Devices (CSD)** for controlling switching over voltage on lines of length more than 200 km. **CSD can also be considered as a tool for minimizing switching transients & inrush currents in 400kV and above voltage class transformers and reactors thereby increasing the life of high voltage equipment and enhancing Power system security. Due attention shall be given to the operating time and mechanical scatter of CBs and grid condition at the point of interconnection while going for use of CSDs. The CSD shall come into picture only during energization or de-energization of associated Circuit Breaker and shall remain bypassed otherwise.**

(d) Disconnectors and Earthing Switches

The disconnectors and earthing switches shall comply with relevant standards. Earthing switches shall be provided at appropriate locations to facilitate earthing of outgoing transmission lines to enable maintenance. Main blades and earth blades shall be interlocked with both electrical and mechanical means, which shall be fail-safe, in case of AIS. In case of GIS, main blades and earth blades shall be electrically interlocked alongwith mechanical padlock. AIS type disconnectors for ~~220 kV and higher rating~~ shall have provision for remote and ~~manual~~ local operation. Disconnectors shall be suitable for Bus Transfer Current Switching duty and M2 class duty as per IEC Standard. Earthing switches used in ~~double/multi-circuit~~ lines for ~~432~~ 110 kV and higher voltages shall be suitable for induced current switching duty and shall be of Class B as per relevant standard. Earthing switches shall be suitable for electrical and manual operation. Only local operation is recommended for earth switches. ~~High speed earth switches for GIS installation shall have rated fault making capability.~~ In case of GIS installations, high speed earthing switches shall be provided for grounding purpose at overhead line terminations & ~~and also for cable terminations~~ and shall

have rated fault making capability ~~—where cable length is long~~. AIS type disconnectors for 220 kV and higher rating shall have provision for remote and manual operation. AIS type disconnectors for 132kV and lower rating shall have provision for manual operation and may also have provision for remote operation as per requirement.

(e) **Current Transformers**

Current transformers shall comply with the relevant standards. The rated currents and ratio, the number of secondary cores, accuracy class, burden, secondary winding resistance, knee point voltage end excitation current shall be in accordance with the requirements of the protection and metering system. **However, for metering core, burden shall not exceed 20 VA; Instrument Security factor (ISF) shall be less than 5 for CTs upto 400 kV voltage class and less than 10 for CTs of 765 kV and 1150 kV voltage class.** The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and Operation of Meters) Regulations. Digital optical current transformers and SF6 current transformers shall also be acceptable in place of conventional current transformers. **Polymer insulator may also be considered for CT housing.**

(f) **Voltage Transformers**

Voltage transformers shall comply with the relevant standards. The number of secondary cores, accuracy class and burden shall be in accordance with the requirements of the protection and metering system. **Rated burden shall be nearest to the burden computed, however it shall not exceed 50 VA.** The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and Operation of Meters) Regulations. Voltage transformers can be either electromagnetic type or capacitive type. Wherever PLCC is required, capacitor type voltage transformers (CVT) complying with relevant standards shall be used as the same are suitable for carrier coupling. The capacitance of CVT shall be decided depending on PLCC requirements. Digital optical voltage transformers shall also be acceptable in place of conventional voltage transformers. In case of GIS installations, SF6 filled voltage transformers shall be electromagnetic type.

(g) **Surge Arresters**

Station class, heavy duty, gapless metal oxide (ZnO) type surge arresters conforming to relevant standards in general shall be provided. The rated voltage, continuous operating voltage (COV), energy handling capability, nominal discharge current and other characteristics of a surge arrester shall be chosen in accordance with power system requirements. Surge arresters shall be provided at locations decided in accordance with insulation coordination studies. These shall be fitted with pressure relief devices and diverting ports suitable for preventing shattering of porcelain housing providing path for the flow of rated currents in the event of failure of surge arrester. **Arrester with composite insulator housing with sufficient cantilever strength may also be used to prevent shattering**

during arrester failure. A leakage current monitor with surge counter shall be provided with each surge arrester. GIS surge Arrester can also be considered for GIS substation.

(h) **Line Trap**

A line trap, intended for insertion in a high voltage power transmission line between the point of connection of carrier frequency signals and adjacent power system elements such as bus bars, transformers etc., shall consist of a main coil in the form of an inductor, a tuning device and a protective device **and in conjunction with a coupling capacitor, it shall form a parallel resonant circuit.** The tuning device shall be so arranged as to permit replacement without removing the line trap. It shall be so designed that neither significant alteration in the line trap blocking requirements nor physical damage shall result from either temperature rise or the magnetic field of the main coil at rated continuous current or rated short time current. The protective device shall be so designed and arranged that neither a significant alteration in its protective function nor physical damage shall result either from temperature rise or the magnetic field of the main coil at rated continuous current or rated short time current.

(i) **Insulators**

The minimum specific creepage distances of insulators shall be 25 mm/kV line to line voltage or 31 mm/kV line to line voltage depending on ~~shall be decided for the maximum~~ pollution condition level in the area of installation, ~~including any transient conditions, causing different pollution levels. The minimum specific creepage distances, as per relevant standard, shall be as indicated in Table 12 below.~~

Table 12

Pollution level	Specific creepage distance (mm/kV of line-to-line voltage)
Light	16
Medium	20
Heavy	25
Very heavy	31

(j) **Insulation performance enhancement**

In highly polluted areas, the performance of insulation of substation equipment housing or insulators could be improved by using high temperature vulcanized silicone rubber insulation **with adequate cantilever strength** or room temperature vulcanized silicone ~~rubber~~ coating. **To ensure quality, the silicone content in Polymer insulator or RTV silicone coating shall be minimum 30%.**

108. In the said Regulations, after the Regulation 43(2)(j), the following Regulation 43(2)(k) shall be inserted, namely:-

(k) **Phase Shift Transformers(PST)**

Phase Shift Transformers (PST) can be planned to control real power flow in transmission lines for better utilization of existing network. The rating, phase shift angle and location shall be decided based on system studies. PST shall comply with relevant IS/IEC. If a variable phase shift is desired, On Load Tap Changers (OLTCs) are required. PST shall be provided with all necessary protection & control systems. Suitable provisions may be provided for bypassing of PST, if required.

109. In the said Regulations, for Regulation 43(3)(a), the following Regulation shall be substituted, namely:-

(3) Sub- station and switchyard support facilities

(a) AC & DC System:

(i) AC & DC supplies shall be provided as per requirements given in Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, . For computation of capacity of battery in attended sub- station or switchyard, in general, the minimum durations assumed shall be as per Table 13 below.

Table 13

	Where standby battery is provided	Where standby battery is not provided
Steady and continuous load	3 hours	6 hours
Emergency lighting loads	1 hour	2 hours

(ii) AC and DC distribution system shall be so designed as to meet the **present and future** requirement of the sub- station.

110. In the said Regulations, for Regulation 43(3)(b)(ii), the following Regulation shall be substituted, namely:-

~~(ii) The transformers or reactors of 10 MVA and higher rating or oil filled transformers or reactors with oil capacity of more than 2000 litres shall be provided with automatic high velocity water spray system or Nitrogen gas injection based fire protection system.~~ Fire protection system for transformers or reactors shall be provided as per Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations. The transformers or reactors of 220kV or higher voltage may preferably be provided with Nitrogen injection based fire protection system in addition to automatic high velocity water spray system.

111. In the said Regulations, for Regulation 43(3)(d), the following Regulation shall be substituted, namely:-

(d) Control Room

Sub- station or switchyard control room shall be provided to house ~~the control and relay panels~~, PLCC equipment, **Optical Line Terminal Equipment**, telemetry equipment and recording equipment, AC and DC distribution boards, DC batteries etc. Air conditioning shall preferably be provided in the building as a functional requirement. ~~In case of substation or switchyard with automation system with distributed architecture~~, **Bay Control Units**, intelligent electronic devices (IEDs) including protective relays, PLCC panels may be provided in air conditioned kiosks/**buildings** located in the switchyard.

112. In the said Regulations, for Regulation 43(4)(a), the following Regulation shall be substituted, namely:-

(4) Protection and control

(a) Protective Relaying System

Adequately **sectionalized selective** and graded protective relaying system shall be provided for transmission lines, transformers and bus bars so as to automatically isolate the faulty equipment and, thus, minimize the damage to the equipment in the event of faults and abnormal conditions. All main protection relays shall be of numerical type and communication protocol shall be as per IEC-61850/ relevant IS. **Any transmission element (line / transformer / reactor/ capacitor etc.) which has not been provided with required protection system shall not be energized or connected to grid.**

113. In the said Regulations, for Regulation 43(3)(d) to 43(3)(f), the following Regulation shall be substituted, namely:-

(d) Disturbance Recorders, Event Loggers and Time Synchronization Equipment- Each ~~765kV, 400 kV and 220 kV~~ **line of 66 kV and above voltage class** shall be provided with facility for disturbance recording, **event logging**, distance to fault locator and time synchronizing equipment (TSE). Event logger ~~and disturbance recorder shall be provided either stand alone or~~ as part of sub-station or switchyard automation system ~~shall be provided for each 66kV and higher voltage class substation or switchyard upto 400 kV voltage class and as standalone units for 765 kV and above voltage class substation or switchyard.~~ TSE complete with antenna, all cables, processing equipment etc., shall be provided to receive synchronizing pulse through global positioning system (GPS) compatible for synchronization of event logger, disturbance recorder, **Phasor Measurement Units (PMU)** and SCADA/automation system of the sub- station or switchyard.

~~(e) Optical Ground Wire (OPGW)/Power Line Carrier Communication (PLCC)- Power line carrier communication (PLCC) equipment complete for speech transmission, line protection, and data channels shall be provided on transmission line of voltage rating 220 kV and higher. The protection system for 400kV and higher voltage transmission line and the line compensating equipment shall have one hundred percent back up communication channels. Each 765kV or 400kV or 220kV line shall be provided with two protection channels in addition to one speech plus data channel for each direction. In case of 220kV or 110/132kV lines, the speech and data channel can also be used for protection wherever possible. The generating company and the transmission licensee shall coordinate with each other and ensure the compatibility of PLCC equipment at their respective ends. Optionally, the above functionality may be achieved using wide band communication based on optical ground wire (OPGW) or any other technology.~~

OPGW along with necessary terminal equipment shall be provided on transmission lines of voltage rating 66 kV and above for speech transmission, line protection, and data channels. In addition to OPGW, Power line carrier communication (PLCC) may also be provided, wherever required. The protection system for 400kV and higher voltage transmission line and the line compensating equipment shall have one hundred percent back up communication channels i.e. two protection channels in addition to one speech plus data channel for each direction. In case of 220kV or below lines, the speech and data channel can also be used for protection wherever possible. The generating company and the transmission licensee / licensees at both end of substation / switchyard shall coordinate with each other and ensure the compatibility of OPGW/PLCC equipment at their respective ends.

(f) Control Concept- All the breakers in sub- stations and switching stations shall be controlled and synchronized from the switchyard control room or control room of the generating station. ~~Disconnectors of 220kV and higher rating shall have control from remote as well as local whereas the earth switches shall have local control only. Disconnectors and associated earth switches shall be provided with electrical as well as constructional mechanical interlocks.~~ Provision for operation of circuit breakers and disconnectors from remote control stations may also be provided wherever required.

114. In the said Regulations, after the Regulation 43(3)(f), the following Regulation 43(3)(g) shall be inserted, namely:-

(g) Phasor Measurement Units (PMU)

Synchrophasor measurement using PMUs alongwith fibre optic connectivity and communication equipment shall be provided for monitoring the entire interconnected grid on real time basis on substations at 400 kV and above level and switchyard of generating stations at 220 kV and above level. The dispersedly located PMUs shall communicate with Phasor Data Concentrators (PDCs) installed at certain strategic locations at State, Regional and National level.

115. In the said Regulations, for Regulation 43(5)(a) & 43(5)(a)(i), the following Regulation shall be substituted, namely:-

(5) Power and Control Cables cabling

(a) Cables shall be Flame Retardant, Low Smoke and Halogen (FR-LSH) type as per relevant IS/ IEC. For laying of cables a broad based system involving cable galleries, trenches, cable racks, shafts, cable sealing system etc. shall be provided. In outdoor switchyards, a cable trench system shall be provided. The main considerations and practices shall be:

(i) A comprehensive philosophy of segregation and proper spacing shall be maintained- ~~control and power cables shall be laid in separate trays;~~ Power cables and control cables shall be laid on separate tiers. The laying of different voltage grade cables shall be on different tiers according to the voltage grade of the cables with higher voltage grade cables in topmost tier and control cables in bottommost tier.

116. In the said Regulations, for Regulation 44, the following Regulation shall be substituted, namely:-

44. Salient Technical Particulars/ Requirements of High Voltage Direct Current (HVDC) Terminals Stations- The design parameters given at Regulation 43 (1) shall be applicable for the AC equipment installed in the HVDC terminal station to be developed for bulk power transfer over long distances or asynchronous connections (back to back) between areas operating with different frequency regimes. The system parameters given for 400 kV or 220 kV or 132 kV AC system shall be applicable for the commutation voltage for both HVDC back to back and HVDC long distance Transmission systems. ~~The life of HVDC installation (s) shall not be less than 35 years. Line Commuted Converter (LCC) based Technology or Voltage Source Converter (VSC) based technology or combination of both can be adopted for HVDC transmission, based on Techno-Economic assessment on case to case basis. The interfacing with the DC line (overhead / cable), existing AC network, Telecommunication network, Load dispatch center shall be properly planned and designed. Technical details of HVDC terminals/ stations for Line Commuted Converter (LCC) based technology and Voltage Source Converter (VSC) based technology are given in Schedule-VI.~~

117. In the said Regulations, for Regulation 45, the following Regulation shall be deleted since these provisions have been incorporated under Schedule VI, namely:-

~~**45. Electrical and Mechanical Auxiliaries for HVDC system** (1) One DG set of adequate capacity with auto start facility shall be provided per pole as emergency backup. Batteries and battery chargers shall be provided for auxiliaries, DC power supplies, valve hall ventilation systems, etc.. Other~~

~~electrical auxiliaries provided shall include illumination, public address and communication system, UPS etc. The mechanical auxiliaries shall include air conditioning, ventilation systems, fire fighting including very early smoke detector acquisition (VESDA) system for valve hall, water supplies, etc.~~

~~(2) All auxiliaries shall give full output at voltage variation of $\pm 10\%$ and frequency variation of -5% to $+3\%$.~~ Deleted

118. In the said Regulations, for Regulation 46, the following Regulation shall be substituted, namely:-

46. Condition Monitoring of Equipment, Asset Management and security of Sub- station and Switchyard Equipment - Diagnostic equipment shall be provided to assess the health of various equipment in substations and switchyards of ~~132~~ 66kV and higher voltages. On-line diagnostic equipment shall be dedicated type for those critical equipment (**transformer, reactor, circuit breaker**) the health of which is to be monitored continuously. Portable type on-line diagnostic equipment and off-line diagnostic equipment shall be provided for one or a cluster of substations or switchyards, depending upon the size of the substations or switchyards. The diagnostic equipment shall include dissolved gas analyzer, winding resistance meter, and frequency response analyzer for transformers and reactors, capacitance and tan-delta measuring units for transformers, reactors and instrument transformers, circuit breaker analyser including dynamic contact resistance meter, and leakage current monitor for surge arrester, **Partial Discharge monitoring for GIS of 400 kV and above voltage class; Thermovision camera for thermal scanning, corona camera, devices for monitoring Power Quality**, and relay testing kit. Other necessary diagnostic equipment may be provided at the discretion of the Owner.

Condition Based Maintenance (CBM) / Reliability Centered Maintenance(RCM) Practice shall be followed for condition assessment of all substation equipment. Health indexing of transformer (s) / reactor (s) based on various indicators derived through condition based analysis shall be carried out for taking Run / Refurbish / Replacement decision. Asset management practices shall be adopted to manage asset information (such as serial/identification no., make, year of manufacturing/commissioning, technical and other relevant parameters) & operation performance; and plan, through latest scientific techniques, to optimize asset's depreciation, life cycle, monitoring & maintenance with the objective to maximize the efficiency and utilization of capital intensive assets.

The provisions for monitoring of substation security such as cameras, motion sensors, perimeter protection etc. along with associated software shall form part of smart security system of un-manned substations.

PART – B: SUB- STATIONS (33/11 kV, 33/22kV AND 22/11kV)

119. In the said Regulations, for Regulation 47 Table 14, the following Regulation shall be substituted, namely:-

Table 14

Parameter	33 kV	22 kV	11kV
Nominal system voltage(kV)	33	22	11
Highest system voltage(kV)	36	24	12
System earthing	Effectively earthed system	Effectively earthed system	Effectively earthed system
Frequency (Hz)	50	50	50
Lightning impulse withstand voltage (kV _{peak})	170	125	75
Power frequency withstand voltage (dry) (kV _{rms})	70	50	28

120. In the said Regulations, for Regulation 48(2), 48(3), 48(5) & 48(6) the following Regulation shall be substituted, namely:-

(2) The sub-station shall be indoor/ outdoor or underground type depending upon the site requirement. The sub-station shall be either air insulated (AIS) or gas insulated (GIS) or hybrid as the case may be.

(3) The sub-stations in urban areas shall be provided with Supervisory Control and Data Acquisition (SCADA) System for system monitoring and control. A suitable Transformer Health Monitoring system may be provided for monitoring the health of power transformers.

(5) The maximum capacity of 33/11 kV or 33/22 kV or 22/11 kV sub-station shall generally be 60 MVA, 40 MVA and 40 MVA respectively. However, higher capacities of sub-stations up to 100 MVA may also be used keeping in view the parameters of the interconnected system including capacities of the lines, switchgears, other equipment, fault current and also the impact on the technical losses etc.

(6) Each 33/11 kV or 33/22 kV or 22/11 kV sub-station shall normally have two or more transformers and two incoming feeders preferably from two different sources.

121. In the said Regulations, for Regulation 50(1) the following Regulation shall be substituted, namely:-

(1) The incoming and outgoing feeders shall be on multi circuit towers to minimize the Right of Way requirement.

122. In the said Regulations, for Regulation 54(3), 54(5), 54(6), 54(10), 54(13), 54(14) & 54(16) the following Regulation shall be substituted, namely:-

(3) The preferred ratings for 33/11 kV or 33/22 kV or 22/11 kV transformers shall be 1,1.6,3.15, 5, 6.3, 8, 10, 12.5,16, 20 and 25 MVA

(5) The transformer can be oil filled, gas filled or dry type depending on requirement and as per Central Electricity Authority(Measures relating to Safety and Electricity Supply) Regulations as amended up to date . Outdoor dry-type transformer may be non-ventilated type.

(6) Transformers shall withstand, without injurious heating, combined voltage and frequency fluctuations which produce the over fluxing conditions as: 125% for 1 minute, 140% for 5 seconds and 150% for 1 second.

(10) On load tap changing (OLTC) device shall be provided with transformers of 3.15 MVA and higher rating for better voltage control by manual and automatic and as per Central Electricity Authority(Measures relating to Safety and means. A transformer with on-load tap changer shall have taps ranging from (+) 5% to (-) 15% in steps of 1.25 -% each on 33 kV or 22 kV winding for voltage variation.

(13) Transformers shall be separated from one another and from all walls and partitions to permit free circulation of air complying with requirements of relevant IS Electricity Supply) Regulations as amended up to date.

(14) 33 kV voltage rating transformers shall be separated from one another by a fire wall as per Central Electricity Authority(Measures relating to Safety and Electricity Supply) Regulations as amended up to date

(16) A transformer shall be physically checked and tested for its electrical and mechanical performance characteristics as per relevant Indian standards before commissioning.

123. In the said Regulations, for Regulation 55(4) the following Regulation shall be substituted, namely:-

(4) Aluminium/Copper used for bus-bars shall conform to relevant IS.

124. In the said Regulations, for Regulation 56(4) the following Regulation shall be substituted, namely:-

(4) The **minimum** creepage distances for different pollution levels shall be as per ~~Table-IV-6 at~~ Regulation 43.

125. In the said Regulations, for Regulation 58(2) the following Regulation shall be substituted, namely:-

(2) In the areas where problem of insulator pollution is expected (such as near sea or thermal power station, railway station, industrial area, etc.) special insulators viz. semi conducting glazed porcelain or polymer insulators with higher leakage resistance and creepage distance shall be used to minimize the flashover. The special coating like Room Temperature Vulcanized (RTV) coating may also be used on the insulators in polluted areas as per requirement.

126. In the said Regulations, for Regulation 59(1) the following Regulation shall be substituted, namely:-

(1) Circuit breakers (CBs) shall comply with the provisions of relevant IS. The circuit breakers shall be SF₆ or vacuum type. ~~Normally vacuum type circuit breakers shall be used for voltage levels of 33 kV and below.~~ The rated voltage for the circuit breakers shall be 36 kV, 24kV and 12 kV for 33 kV, 22kV and 11 kV systems respectively.

127. In the said Regulations, for Regulation 60(1) & 60(5) the following Regulation shall be substituted, namely:-

(1) The isolators shall be of adequate capacity as per requirement and shall comply with relevant IS. ~~The rated current shall be at least 630 A at 36 kV and 24 kV. For 11 kV system, isolating switches of 400 Amps at 12 kV shall be used. The isolators shall be gang operated type.~~

(5) The earthing switch shall be capable of withstanding short circuit current for short duration as applicable to the corresponding isolator. Earthing switches shall be motor operated and suitable for manual operation.

128. In the said Regulations, for Regulation 61(1) & 61(4)(a) the following Regulation shall be substituted, namely:-

(1) The control and relay panels for incoming feeders, outgoing feeders, bus bars, power transformers and all other equipment installed in the sub-station like switch-gears, instrument transformers and capacitors etc. shall conform to relevant Indian Standards. In case Indian standards are not available, then conform to relevant International Standards.

- (4) The panel shall be provided with:
- (a) Suitable numerical over current and earth fault relays to protect the equipment and system against short circuit current and earth fault current.

The relays shall conform to relevant IS. All relays used shall be suitable for operation with CTs of secondary rated for 1 Amp or 5 Amps.

129. In the said Regulations, after the Regulation 61(4), the following Regulation 61(5) shall be inserted, namely:-

(5) The overall protection system of transformers and feeders would be as per Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as amended up to date.

130. In the said Regulations, for Regulation 62(2), the following Regulation shall be substituted, namely:-

(2) Distribution class, heavy duty, gapless metal oxide (ZnO) type surge arresters in general shall be provided on the buses, high voltage and low voltage sides of all transformers and on the incoming terminations of 33 kV/22 kV lines. The **Surge** arresters shall conform to relevant IS/IEC.

131. In the said Regulations, for Regulation 63(1)(e), 63(2)(c) & 63(2)(f), the following Regulation shall be substituted, namely:-

(1) Current transformers (CTs)

(e) The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and Operation of Meters) Regulations, as amended up to date..

(2) Voltage transformers (VTs)

(c) Voltage transformers shall be of electromagnetic type or solid state type.

(f) The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and Operation of Meters) Regulations as amended upto date.

132. In the said Regulations, after the Regulation 64(3), the following Regulation 64(4) & 64(5) shall be inserted, namely:-

(4) Operation & Maintenance manuals, recording instruments, layout drawing, Single Line Diagram and Safety manual/guidelines should be available in the control room.

(5) A separate room for Substation Batteries shall be provided with adequate ventilation and exhaust fan for taking out fume gases.

133. In the said Regulations, for Regulation 65(2), the following Regulation shall be substituted, namely:-

(2) Earthing shall be carried out in accordance with relevant IS and Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as amended upto date.

134. In the said Regulations, for Regulation 66(2) & 66(9), the following Regulation shall be substituted, namely:-

(2) Capacitors, ~~the~~ residual voltage transformer and neutral current transformer shall be as per relevant IS.

(9) In cases of sub-stations loaded with highly fluctuating loads like arc furnaces etc., flickers and voltage regulation problems shall be overcome by installation of static var compensators (SVC) or Statcom.

135. In the said Regulations, for Regulation 67(2), the following Regulation shall be substituted, namely:-

(2) Power cables shall be XLPE insulated, PVC sheathed type conforming to relevant IS. Cables shall be flame retardant low smoke (FRLS)/Low Helogen type. Cables shall be de-rated for the site's ambient and ground temperature, grouping and soil resistivity as per IS. Proper attention shall be given to ventilation/heat dissipation aspects particularly in case of HV cables.

136. In the said Regulations, for Regulation 68(1), the following Regulation shall be substituted, namely:-

(1) A dedicated & reliable telecommunication system based on radio frequency (RF), cellular/mobile technology fiber optics, satellite communication, PLCC, any other new communication technology or a combination of these shall be provided, besides usual public communication and local Public Address (PA) system.

137. In the said Regulations, for Regulation 69, the following Regulation shall be substituted, namely:-

Automation System - State-of-art systems such as supervisory control and data acquisition system (SCADA), and data acquisition system (DAS) shall preferably be provided in the 33 kV or 22 kV sub-stations, associated feeders and distribution transformers for improving the operational flexibility, minimizing restoration time of power supply and preventing overloading of lines and transformers in real time mode. Adequate cyber security measures should be ensured in SCADA and DAS. A suitable Transformer Health Monitoring system can also be provided for monitoring the health of power transformers.

138. In the said Regulations, for Regulation 70(2)(a), 70(3) & 70(5), the following Regulation shall be substituted, namely:-

(2) **Battery**

(a) The 24V/ 30V/ 48V/110 V/220 V DC batteries shall be stationary lead acid or nickel cadmium or any other new technology type and shall operate satisfactorily under normal prevalent ambient conditions. The capacity and discharge rate shall be as per the load requirement.

(3) **Battery charger-** The battery chargers shall be automatic float cum booster type. The battery charger shall be capable of continuous operation at the rated load in float charging mode. The charger in boost charging mode shall be capable of boost charging the associated DC battery at the desired rate.

(5) **Oil and SF₆ evacuating, filtering, testing and filling apparatus-** Oil and SF₆ filling, evacuation, filtering and testing plants with adequate storage facilities along with requisite operation and maintenance (O&M) tools and plants shall be provided for a cluster of sub- stations as per requirement.

139. In the said Regulations, for Regulation 71, the following Regulation shall be substituted, namely:-

Fencing and Approach Arrangement- Fencing/ boundary wall of suitable height shall be provided around the sub- station. A metalled approach road to transport the equipment should be provided leading from the main road.

140. In the said Regulations, for Regulation 72(2), the following Regulation shall be substituted, namely:-

(2) **DC emergency lighting-** Emergency lighting operated on the DC system shall be provided in strategic locations viz. control room, battery room, passages etc. It should be ensured to provide separate DC battery bank for emergency lighting in the sub station and Sub Station's main battery bank used for protection system is not used for emergency lighting to avoid the draining of the main battery bank.

141. In the said Regulations, for Regulation 73(2), the following Regulation shall be substituted, namely:-

(2) ~~Fire hydrant, carbon dioxide (CO₂) type fire extinguisher or dry chemical powder type fire extinguisher conforming to relevant IS shall be provided as per site requirement.~~ The fire fighting system at 33/11 KV ,33/22 kV & 22/11kV Sub stations shall be as per Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as amended upto date.

PART-C: DISTRIBUTION SUB-STATIONS (33/0.4 KV, 22/0.4 KV AND 11/0.4 KV)

142. In the said Regulations, for Regulation 74(1), Table 15, the following Regulation shall be substituted, namely:-

Table: 15

Parameter	33 kV	22 kV	11kV	0.415 kV
Nominal system voltage(kV)	33	22	11	0.415
Highest system voltage(kV)	36	24	12	0.450
System earthing	Effectively earthed system	Effectively earthed system	Effectively earthed system	Effectively earthed system
Frequency (Hz)	50	50	50	50
Lightning impulse withstand voltage (kV _{peak})	170	125	75	-
Power frequency withstand voltage (dry) (kV _{rms})	70	50	28	3

143. In the said Regulations, for Regulation 74(2) & 74(3), the following Regulation shall be substituted, namely:-

(2) The distribution sub- stations (DSS) shall normally be located near load center.

(3) The DSS can be indoor or outdoor type. The sub-station can be constructed underground where there is paucity of space or for supply to underground installations ensuring that water should not enter the DSS and all safety measures are taken. DSS in flood prone areas shall be above the expected water level during flood.

144. In the said Regulations, for Regulation 75(1) & 75(2), the following Regulation shall be substituted, namely:-

(1) The transformer shall conform to relevant IS and shall be IS marked.

(2) The transformer can be oil filled, or dry type depending on requirements and shall be as per the Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as amended up to date.

145. In the said Regulations, for Regulation 75(4)(b) & 75(4)(c), the following Regulation shall be deleted, namely:-

75(4)(b) - deleted

75(4)(c) - deleted

146. In the said Regulations, for Regulation 75(4)(d) & 75 (5), the following Regulation shall be substituted, namely:-

(d) -The maximum losses for dry type transformers shall not be more than the values specified in latest Energy Conservation Building Code(ECBC) of BEE till Indian Standards(IS) for dry type transformer are published. Afterward, the maximum losses for dry type transformers shall be as per relevant Indian Standards.

(5) The transformer may be single phase or three phase. The cooling shall be ONAN/KNAN for oil filled transformers.

147. In the said Regulations, for Regulation 75(7), the following Regulation shall be deleted, namely:-

75(7) - deleted

148. In the said Regulations, for Regulation 78(1), the following Regulation shall be substituted, namely:-

(1) Surge arresters shall normally be installed on the high voltage side of the transformer connected to overhead lines. Surge arrester shall also be provided on the low voltage side in areas of high isoceraunic activity. Surge arresters shall be as per relevant IS.

149. In the said Regulations, for Regulation 79(4), the following Regulation shall be substituted, namely:-

(3) The capacity of lugs for cables, connecting strips, bus bars shall be as per requirement. All the fittings shall be as per relevant IS.

150. In the said Regulations, for Regulation 80, the following Regulation shall be inserted before 80(1), namely:-

Protection System - The protection system of transformers would be as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations as amended up to date.

151. In the said Regulations, for Regulation 81(1), the following Regulation shall be substituted, namely:-

(1) Pipe earthings or rod earthing shall preferably be provided for the DSS complying with relevant Indian Standards and Central Electricity Authority

(Measures relating to Safety and Electric Supply) Regulations as amended upto date and 3 earth pits with three grounding electrodes shall be provided.

152. In the said Regulations, for Regulation 82(1), the following Regulation shall be substituted, namely:-

(1) The adequate size of XLPE cables shall be used for connecting LT supply from transformer bushings to the LT circuit breaker in the distribution box and for taking out outgoing feeders from the fuse units to the overhead lines. These cables shall be as per relevant IS and IS marked.

153. In the said Regulations, for Regulation 83(2), the following Regulation shall be substituted, namely:-

(2) The installation of meters shall be in conformance to the Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006 as amended upto date..

CHAPTER – V

TECHNICAL STANDARDS FOR CONSTRUCTION OF ELECTRIC LINES

PART- A :

ELECTRIC LINES (66 KV AND ABOVE)

154. In the said Regulations, for Regulation 86(2), the following Regulation shall be substituted, namely:-

(2) The Owner shall ensure tie-up arrangements which are necessitated by the proposed installation and which must be carried out simultaneously by other entities before the new installation is commissioned and connected to the power system. The owner connecting installation shall abide by the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, ~~2007~~.

155. In the said Regulations, after the Regulation 87(3), the following Regulation 87(4) & 87(5) shall be inserted, namely:-

(4) Towers of any overhead line of 66kV and above voltage class shall be designed for at least Double circuit configuration. Multi-circuit towers (more than two circuits) for 400kV transmission line shall preferably be used in approach section of substation / switchyard.

(5) The upgradation of existing AC transmission line to higher voltage AC line with multi circuits line/ multi circuits multi voltages line / compact AC line or HVDC line (VSC/LCC based) and uprating by use of new generation High Temperature Low Sag (HTLS) / High Ampacity conductors may be planned for enhancement of power flow per unit (per meter) of Right of Way (RoW), reduction in losses and for addressing growing congestion in existing corridor of transmission network and RoW problems.

156. In the said Regulations, for Regulation 89(1)(a)(i) & 89(1)(a)(iii), the following Regulation shall be substituted, namely:-

(i) The design parameters of the transmission lines for . altitude upto 1000 m above mean sea level (MSL) shall be as indicated in Table 16 below:

Table 16

Parameter	66 kV AC	132 kV AC	220 kV AC	400 kV AC	765 kV AC	±500 kV DC	±800 kV HVDC	1150 kV AC
Nominal voltage (kV)	66	132	220	400	765	500	800	1150
Highest system voltage (kV)	72.5	145	245	420	800	525	840	1200
Full-wave Lightning impulse withstand voltage (1.2/50 micro sec)(kV _{peak})	325	650	1050	1550	2400	1800	1800	2400
Power frequency withstand voltage under dry condition (kV _{rms})	140	275	460	680	830	-	-	1200
Switching surge withstand voltage	-	-	-	1050	1550	1000	1600	1800

under wet condition (kV _{rms})								
Minimum corona extinction voltage under dry condition (kV _{rms} phase to earth)	-	-	456	320	540 610	550	880	762
Maximum radio interference voltage (micro volts) at 1 MHz for phase to earth voltage of ... kV under dry condition (micro volts)	-	-	1000 (at 156 kV rms)	1000 (at 320 kV rms)	1000 (at 610 kV rms)	1000 (at 550 kV)	1000 (at 880kV)	1000 (at 762kV rms)

(iii) The phases of AC transmission lines shall be transposed, ~~when the length of the line is more than 100 km or if required as per system studies depending upon the length of the line,~~ in approximately three equal parts.

157. In the said Regulations, for Regulation 89(1)(b) & 89(1)(c), the following Regulation shall be substituted, namely:-

(b) Conductor

(i) The conductor of appropriate size shall be selected considering . power flow requirements and other system considerations in consultation with neighbouring transmission and generation utilities. ~~For transmission lines of 400 kV or higher voltage class, , bundle conductor~~ Minimum two conductors per phase for 400 kV AC and minimum four conductors per phase for +/- 500 kV HVDC and 765 kV single circuit AC, minimum six conductors per phase for 765kV Double Circuit AC and +/- 800kV HVDC and minimum eight conductors per phase for 1200kV AC shall be used for satisfactory performance of transmission lines from corona and interference aspects. .

(ii) The conductors may be ~~of type~~ aluminum conductor steel reinforced (ACSR), all aluminum alloy conductor (AAAC) or Aluminium Alloy Conductor Steel Reinforced (AACSR) or other new technology conductor including High Temperature and Low Sag (HTLS) / High Ampacity conductors conforming to relevant IS or IEC or other international standards ~~and specifications~~ depending on system requirements.

(c) Earthwire- The earthwire of appropriate size to cater to predicted and design fault currents and lightning shall be used. Generally, one earthwire shall be used for transmission lines up to 220 kV and two earthwires shall be used for transmission lines of 400 kV and higher voltage classes. ~~The earthwire used in 66kV and above voltage class lines shall be OPGW. In case of 400kV and above voltage class lines, at least one out of two earthwires shall be OPGW and second~~ earthwire shall be either of galvanized stranded steel (GSS) or alternatively ACSR or AACSR conductor type. ~~OPGW shall comply with provisions of Regulation 43(4)(e).~~

158. In the said Regulations, for Regulation 89(1)(d)(i)(A) & 89(1)(d)(i)(D), the following Regulation shall be substituted, namely:-

(d) Towers

(i) General- (A) The towers shall be self-supporting lattice steel type and shall be a fully galvanised structure. ~~Alternatively, guyed or pole structure towers may also be used.—The use of narrow base lattice structure or steel monopole structure shall also be considered wherever required.~~

(D) Ground clearance shall be as per requirements of Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations ~~as and when these are notified by the Authority.~~

159. In the said Regulations, for Regulation 89(1)(d)(ii)(C) & 89(1)(d)(ii)(D), the following Regulation shall be substituted, namely:-

(ii) Design of towers

(C) The loads at conductor and earthwire ~~attachment~~ points under different loading conditions viz. reliability conditions (normal condition), security conditions (broken wire condition), safety conditions, anti-cascading condition etc. (as per relevant IS ~~or IEC Standards~~) considering various combinations of design temperatures, wind and snow loads shall be calculated and tower designs developed accordingly.

(D) Reliability level— 1 corresponding to 50 year return period design loads due to wind as per relevant IS shall be considered for design of towers for transmission lines upto 400 kV. For higher voltage level transmission lines, reliability level—2 corresponding to 150 year return period wind loads shall be

~~considered. Triple and quadruple circuit towers and towers with more than two sub-conductors per phase upto 400 kV shall be designed corresponding to the reliability level — 2 (150 year return period).~~

160. In the said Regulations, for Regulation 89(1)(d)(iii) & 89(1)(d)(vi), the following Regulation shall be substituted, namely:-

(iii) Materials

Mild steel and high tensile steel sections of tested quality in conformity with relevant IS shall be generally used in towers and their extensions. ~~Other equivalent grade of structural steel angle sections and plates conforming to International Standards may also be used.~~ Fasteners, bolts and nuts shall be generally as per relevant IS.

(vi) Earthing

Each tower shall be earthed such that tower footing resistance does not exceed 10 ohms. Pipe type or Counterpoise type earthing shall be provided in accordance with relevant IS. ~~As per site requirement, multiple earthing arrangements or earthing enhancement material can also be used for earthing of towers. Additional earthing shall be provided on towers after every 7 to 8 kms distance for direct earthing of shield wires.~~

161. In the said Regulations, for Regulation 89(1)(e)(i) & 89(1)(e)(ii), the following Regulation shall be substituted, namely:-

(e) Foundations

(i) Depending upon soil **parameters** and site conditions, economy and feasibility of construction at site, appropriate type of foundations (viz. open cast, pile, well or other alternative types) shall be considered for transmission line towers.

(ii) The design of foundations shall be as per applicable Indian Standards and Codes. Structural design of foundations shall be done by limit state method with minimum overload factor as 1.1. The minimum factor of safety for design of pile or well foundations shall be ~~2.5~~ **as per relevant IS.**

162. In the said Regulations, for Regulation 89(1)(f)(i) & 89(1)(f)(ii), the following Regulation shall be substituted, namely:-

(f) Insulators, Insulator Strings and Hardware Fittings

(i) Requisite type of suspension and tension insulator strings with disc insulators or long rod insulators offering equivalent performance shall be used.

Number of insulators and creepage Distance shall be selected based on electrical system parameters and requirements taking into account other factors and conditions viz. line attitude, expected environmental and pollution conditions etc. However, for critical locations with high pollution level, antifog type insulators or polymer insulators may be used for better performance. ~~For voltage levels upto 400kV, The minimum specific creepage distances of insulators shall be selected from Table 12 at Regulation 43~~ 25 mm/kV line to line voltage or 31 mm/kV line to line voltage based on the pollution level site requirement in the area of installation. ~~For 765kV, specific creepage distance shall be decided judiciously by the Owner.~~ For all power line crossings, railways/ river crossings or a telecommunication line crossing, either Room Temperature Vulcanized (RTV) silicone coated porcelain/glass insulator or polymer insulators shall be used.

(ii) Insulators shall generally conform to relevant IS or IEC standards. ~~Polymer or composite insulators conforming to relevant IEC or other international standards may also be used.~~ Insulators for HVDC lines shall be of anti-fog type having sacrificial zinc sleeve. ~~These shall generally conform to relevant IEC standard.~~ Room Temperature Vulcanized (RTV) silicone coated porcelain / glass insulators shall also be considered as an alternative to polymer or composite insulators to improve flashover performance. Corona rings shall be provided with all polymer insulator strings for 220kV and above voltage class lines. To ensure quality, the silicone content in Polymer insulator or RTV silicone coating shall be minimum 30%.

163. In the said Regulations, after the Regulation 89(1)(g), the following Regulation 89(1)(h) shall be inserted, namely:-

(h) Line Surge Arresters

Non-Gapped Line Arresters (NGLA) can be considered to reduce back flashovers, the stress on substation equipment due to incoming travelling waves and to provide protection against shielding failure. Use of these arresters can also be considered for voltage uprating of transmission line in order to reduce the phase to phase clearances and the length of the insulator strings. The Line Surge Arresters shall conform to relevant IEC/IS.

164. In the said Regulations, for Regulation 89(2)(a), 89(2)(b) & 89(2)(d), the following Regulation shall be substituted, namely:-

(2) Transmission line construction

(a) Crossing of a transmission line with roads or a railway or a river or a power line or a telecommunication line shall be finalized as per applicable rules & regulations specified by the concerned authorities. ~~The towers, with required body extension to maintain adequate safety clearance, on either side of crossing of the power line of 400kV and above voltage class transmission line shall be designed for dead end condition with large angle towers of deviation~~

angle of 30-60 degree. The crossing of Power lines below 400kV and upto 110kV class shall be done with tension towers with required body extension to maintain adequate safety clearance and the crossing of Power lines of 66kV class shall be done with any type of towers (suspension / tension towers) with required body extension to maintain adequate safety clearance. If required, the removal of the overhead Ground wire from section of the existing transmission line, over which the new transmission line is to cross, and providing diamond arrangement of earthwires may be considered to reduce the height of the body extension required for crossing the existing line. In such cases, the use of line surge arrester as an alternative to diamond arrangement of earthwires may also be considered to provide protection against direct lightning strike.

(b) Clearances form ground, buildings, roads, power lines, telecommunication lines etc. shall be provided in conformity with Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations ~~as and when these are notified by the Authority.~~

(d) Normal design span for various voltage level transmission lines shall generally be as indicated in the Table 17 below:

Table 17

Voltage (kV)	Normal design span (metres)
± 800 HVDC	350 to 450
±500 HVDC	350 to 450
765, 1200 AC	400,450 350 to 450
400 AC	400 350 to 450
220 AC	335,350,375 325 to 400
132 AC	315,325,335 300 to 350
66 AC	240,250,275 200 to 300

The normal design span of monopole/narrow base structure for all voltage class AC transmission lines shall be reduced in order to reduce the weight of structure.

165. In the said Regulations, for Regulation 89(3)(b), the following Regulation shall be substituted, namely:-

(b) For condition assessment of conductors, clamps, connectors, insulators etc., provision for on- line or off- line diagnostic tools and equipment shall be made. On- line tools shall include thermo-vision camera for detection of hot spots, corona camera and live line punctured insulator detector. Off- line tools shall include insulation resistance measuring instrument ~~and contact resistance measuring instrument~~. The off line fault locator or travelling wave based fault locator or both shall be used for locating the transmission line faults more accurately. Transmission line tower footing impedance measuring tool shall also be included as one of the diagnostic tools. Other necessary diagnostic equipment may be provided at the discretion of the Owner.

166. In the said Regulations, for Regulation 89(4), the following Regulation shall be substituted, namely:-

(4) Cables- Wherever construction of an overhead transmission line is not possible due to space constraints or right- of- way problems etc., the Owner can use high-voltage XLPE cables for transmission of power. XLPE cables shall be provided with required terminations, straight through joints (wherever required), surge arrester at GIS interconnection / outdoor terminations, line differential protection, and Distributed Temperature Sensor (DTS) for hot spot monitoring. The earthing of terminations and joints including cross bonding arrangement (wherever required) shall be properly done for successful operation of cable. Gas Insulated Lines (GIL) may be considered as an alternative to EHV XLPE cables where high current / power flow is required taking into account the Life Cycle Cost (LCC).

167. In the said Regulations, for Regulation 89(5), the following Regulation shall be deleted, namely:-

(5) ~~Applicable standards-BIS or IEC or Equivalent~~ deleted

168. In the said Regulations, after the Regulation 89(5), the following Regulation 89(6) to 89(10) shall be inserted, namely:-

(6) **Strengthening of existing towers**

The towers of old lines, which have not exceeded their useful life, and have been designed according to old standards, shall be strengthened in phased manner in line with latest IS codes.

(7) **Condition Assessment of Towers and earthing system**

Utilities shall assess the condition of structure of towers, its foundation and earthing system periodically using modern techniques and diagnostic tools.

(8) **Use of Helicopter and UAV**

Use of helicopter for faster erection and commissioning of transmission line and use of Unmanned Aerial Vehicle (UAV) for survey and patrolling of transmission line, particularly in difficult and inaccessible terrain, may be considered by the transmission licensees as some of the technology options. However, required clearance from Director General Civil Aviation (DGCA) / any other competent authority shall be obtained before taking up such activity.

(9) Emergency Restoration System:

Every transmission licensee shall have an arrangement for restoration of transmission lines of at least 220 kV and above through the use of “Emergency Restoration Systems (ERS)” as per CEA (Grid Standards) Regulations.

(10) Use of GIS platform

Transmission system asset mapping, Route alignment and optimization of route of new transmission line for transmission projects should be carried out on GIS platform. BHUVAN of National Remote Sensing Centre (NRSC) should be used as the base platform for GIS application.

**PART – B:
ELECTRIC LINES (33 KV AND BELOW)**

169. In the said Regulations, for Regulation 90(2), the following Regulation shall be substituted, namely:-

(2) The Owner shall ensure tie-up arrangements which are necessitated by the proposed installation and which shall be carried out simultaneously by other entities before the new installation is commissioned and connected to the existing power system network. The Owner who is connecting his new installation has to abide by the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended upto date..

170. In the said Regulations, for Regulation 91 Table IV-4, the following shall be substituted, namely:-

Table: IV- 4

Parameter	33 kV	22 kV	11 kV	0.415 kV
Nominal system voltage (kV)	33 kV	22 kV	11 kV	0.415
Highest system voltage (kV)	36 kV	24 kV	12 kV	0.450

System earthing	Effectively earthed system	Effectively earthed system	Effectively earthed system	Effectively earthed system
Frequency (Hz)	50	50	50	50
Lightning Impulse withstand voltage (kV _{peak})	170	125	75	-
Power frequency withstand voltage (kV _{rms}) in dry condition	70	50	28	3

171. In the said Regulations, for Regulation 92(1)(d) & 92(4), the following Regulation shall be substituted, namely:-

- (1) The system shall be constructed so as to ensure:
- (d) Adequate capacity for load growth at least for next 5 years;
- (4) Composite lines (i.e. lines having different voltage levels) and multi circuits lines shall be adopted by the Owner as per requirement.

172. In the said Regulations, for Regulation 93(5) & 93(8), the following Regulation shall be substituted, namely:-

- (5) The 33 kV or 22 kV line route shall be such as to avoid large habitations, and densely populated areas as far as possible.
- (8) The electric line shall be far off from slaughterhouses and garbage dumping grounds to prevent interruptions by bird hits.

173. In the said Regulations, for Regulation 95(1), 95(2), 95(3), 95(6) & 95(7), the following Regulation shall be substituted, namely:-

- (1) The supports shall preferably be poles. The narrow based lattice towers with fully galvanised structure can also be used for 33 KV and 22 KV lines as per site requirement. The lines shall preferably be double circuit or multi circuit.
- (2) Poles shall be used for ~~33 kV, 22 kV~~, 11 kV and LT lines (lines below 500 V) as per requirement. The poles shall be pre-cast concrete (PCC) pole, pre-stressed cement concrete (PSCC) pole, rolled steel joist, rail pole, H beam or steel tubular pole as required.,
- (3) Poles shall conform to relevant IS/IEC as the case may be.
- (6) For locations involving long spans or higher clearances on account of crossing of power or communication lines or a railway line, specially designed poles/lattice towers may be used ,or underground cable may be used as per requirement.

(7) Double pole structure may be used as per site conditions ensuring safe operation of lines.

174. In the said Regulations, for Regulation 98, the following Regulation shall be substituted, namely:-

The supports shall be suitable for the wind loads as per relevant IS. The minimum factor of safety for supports shall be as per Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as amended upto date.

175. In the said Regulations, for Regulation 99(2) & 99(6), the following Regulation shall be substituted, namely:-

(2) Metal cross arms and insulator pins for PCC and PSCC poles shall be bonded together and normally earthed at every pole for above 650 V lines and at every 3rd pole for lines below 650 volts.

(6) All poles above 650 volts, irrespective of inhabited areas, shall be earthed. For poles below 650 V, guarding with continuous earth/messenger-wire shall be provided invariably in Aerial bunched cable and shall be connected to earth at three equidistant points in one km.

176. In the said Regulations, for Regulation 103, the following Regulation shall be substituted, namely:-

Danger Plates shall be provided on electric lines in accordance with Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as amended upto date.

177. In the said Regulations, for Regulation 108(1), 108(3), 108(4), 108(5), 108(6) & 108(7), the following Regulation shall be substituted, namely:-

(1) Underground cables or aerial bunched cables (ABC) or insulated cable or covered conductor or any other new technology cable of adequate rating can also be used for supplying power. Cables shall conform to relevant Indian Standards. In case Indian Standards are not available, cables may conform relevant International standards.

(3) Aerial bunched cables/insulated cables/ covered conductor etc may be used in the congested , theft and accident-prone areas.

(4) Underground Cables shall normally be laid in tranches as per the relevant standards and utility practices. Direct burying of underground cables shall not be adopted except where cables enter and take off from a trench. Cables may also be laid in pipes through trench less method as per the site requirement.

(5) The underground cables shall be segregated by running in separate trenches or on separate racks/ pipes.

(6) The cable trenches/pipes shall be properly sloped so as to drain freely any water, which may enter.

(7) Cable trenches/pipes shall not be run through oil rooms.

178. In the said Regulations, for Regulation 109(3) & 109(4), the following Regulation shall be substituted, namely:-

(3) The supplier shall provide and maintain on the consumer's premises for the consumer's use a suitable earthed terminal in an accessible position at or near the point of commencement of supply in accordance with Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as amended upto date.

(4) The meters for the consumer connections shall be provided in accordance with the Central Electricity Authority (Installation and Operation of Meters) Regulations,2006 as amended upto date.

179. In the said Regulations, for Regulation 111(1) & 111(2), the following Regulation shall be substituted, namely:-

(1) The overall protection system of feeders would be as per Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as amended up to date. The protection scheme settings shall be finalized by the Owner based on prudent utility practice.

(2) An earth leakage protective device shall be provided at consumer premises as per requirement of Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as amended upto date. .

180. In the said Regulations, for Schedule-V, the following Schedule shall be substituted, namely:-

SCHEDULE- V

[See Regulation 43 (4) (c)]

Protection Details of Transmission Lines, Transformers, Reactors and Bus Bars

1. Transmission Line Protection

Sl. No.	Protection	765 kV	400 kV	220 kV	132 kV or 66 kV
(a)	Main I- Distance protection*	Y	Y	Y	Y
(b)	Main II- Distance protection* or directional comparison protection or phase segregated line differential protection	Y	Y	Y/N	N
(c)	Directional instantaneous inverse definite minimum time (IDMT) type earth fault relay	Y	Y	'Y' if both Main-I & Main-II are distance protections otherwise 'N'	N
(d)	Directional IDMT over current and earth fault back up protection	N	N	'Y' if Main-II is not provided otherwise 'N'	Y
(e)	Two stage over voltage protection	Y	Y	Y/N	Y/N
(f)	Auto reclosing#	Y (Single phase and three phase)	Y (Single phase and three phase)	Y (Single phase and three phase)	Y/N (Three phase)

***For short line (less than 10kms) / cable / combination of overhead line and cable, line differential protection with distance protection as inbuilt feature shall be used. For 400kV and above voltage level, line differential protection shall be inbuilt feature of distance protection.**

For cable / combination of overhead line and cable, autoreclosing is not required.

Note: (1) Y- Required; N- Not required; Y/N- Optional.

(2) Transmission lines with distance protection shall, in general, have carrier aided inter-tripping or blocking feature. Separate cores of current transformer and voltage transformer shall be used for Main-I and Main-II.

2. Transformer Protection

Sl. No.	Protection	76.5 kV	400 kV	220kV or 132 kV	66 kV
(a)	Differential protection	Y	Y	Y	Y
(b)	Over fluxing protection	Y	Y	Y	N
(c)	Restricted earth fault (REF) protection	Y	Y	Y	Y
(d)	Backup directional over current and earth fault protection (HV and LV side) or impedance protection	Y	Y	Y	Y
(e)	Buchholz, WTI and OTI (for 1 MVA and above), MOG with low oil level alarm, OSR for OLTC, PRD, SA on both primary and secondary sides of transformers located outdoors and connected	Y	Y	Y	Y

	to over head lines				
(f)	Tertiary winding protection	Y	Y	N Y (above 100 MVA rating)	N
(g)	Over load alarm	Y	Y	Y	N Y

Note: (1) Y- Required; N- Not required.

(2) WTI- winding temperature indicator; OTI- oil temperature indicator; OLTC- on load tap changer; PRD- pressure relieve device; OSR- oil surge relay; MOG- magnetic oil gauge; SA- surge arrester.

Duplication of transformer protection is not considered necessary but the protection shall be divided in two groups viz. Gr A and Gr B. Transformer Protection may be grouped in two groups in the following manner:

Group- A	Group- B
Differential protection	Restricted earth fault (REF) protection
Backup directional over current and earth fault protection (HV side) or impedance protection	Backup directional over current and earth fault protection (IV/LV side) or impedance protection
Buchholz (main tank) protection	Buchholz (OLTC) protection
Over fluxing protection (HV)	Over fluxing protection (IV/LV)
Oil temperature protection	Winding temperature protection
Pressure relief tripping	Overload protection (Alarm only)
Tertiary winding protection	Oil level high/low tripping

Fire protection	Fire protection
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Note: Secondary winding has been indicated as IV for transformers with tertiary winding and LV for transformers without tertiary winding.

3. Reactor Protection

Sl. No.	Protection	765 kV	400 kV
(a)	Differential protection	Y	Y
(b)	REF protection	Y	Y
(c)	Reactor backup protection (impedance type or definite time over current (O/C) and earth fault (E/F) protection)	Y	Y
(d)	Buchholz, WTI, OTI, MOG with low oil level alarm, SA (if required)	Y	Y

Note: (1) Y- Required.

(2) WTI- winding temperature indicator; OTI- oil temperature indicator; MOG- magnetic oil gauge; SA- surge arrester.

Duplication of reactor protection is not considered necessary but the protection and monitors shall be divided in two groups viz. Gr A and Gr B. Reactor protection may be grouped in two groups in the following manner:

Group- A	Group- B
Differential protection	Restricted earth fault (REF) protection
Reactor backup protection	Buchholz protection

Oil temperature protection	Winding protection temperature
Pressure relief tripping	Oil level high/low trip
Fire protection	Fire protection

4. Bus Bar Protection and Local Breaker Backup Protection (breaker failure protection)

Bus bar protection and local breaker backup protection shall be provided in ~~220kV~~ 132 kV and higher voltage interconnecting sub- stations as well as in all generating station switchyards. Duplication of bus bar protection shall be done for all main buses of 400 kV and above voltage class. LBB shall be in-built feature of Bus-bar protection. The bus bar protection scheme shall be centralized or distributed type and shall have provision for future expansion. .

181. In the said Regulations, for Schedule-VI, the Schedule has been bifurcated for LCC based and VCC based HVDC Systems and following Schedule shall be substituted, namely:-

SCHEDULE- VI (See Regulation 44) PART-A

Technical Details of Classical HVDC Terminals/ Stations

1. **General:** The conventional Thyristor (Gate Turn On device) based HVDC converter technology or Line Commuted Converter (LCC) technology or Current Source Converter (CSC) technology shall only be used for $\pm 500\text{kV}$ / $\pm 600\text{kV}$ / $\pm 800\text{kV}$ and above voltage level for long distance bulk power HVDC transmission system. Gate Turn Off devices / other better devices capable of handling similar or higher quantum of power may also be considered.
2. **Design Consideration:** (a) The converter configuration and rating for HVDC installation shall be based on following considerations:
 - The amount of power to be transmitted
 - The transmission distance
 - Staging consideration of the project
 - Location of converter station

- The amount of power to be transmitted at the different stages of the project
- Reliability and availability requirements
- Loss evaluation
- Size and weight of the Converter transformers for transport

Note: The DC power rating shall include nominal, reverse, forward and overload power levels, specific loading cycle and weightage factor to calculate load losses.

- (b) Electric design of HVDC transmission lines shall take into account the following considerations:
 - (i) Corona performance (Corona loss, Radio Interference, Audible Noise, Electric field and ion current in the vicinity of the line)
 - (ii) Air Insulation Performance
 - (iii) Insulator performance
- (c) The minimum conductor height above Ground level shall be selected mainly on the basis of ensuring human safety, Ground level electric field and ion current density level. The corona loss with I²R losses in the conductors shall be considered for economic choice of the optimum conductor bundle.

3. System Data: The following environmental, AC & DC system information, shall be required:

- (a) Environmental information:
 - (i) Ambient temperature
 - (ii) Humidity, Air pollution, rain fall intensity
 - (iii) Geographical co-ordinates
 - (iv) Isokeraunic level
 - (v) Wind velocity
 - (vi) Seismic Level
 - (vii) Altitude above sea level
 - (viii) Pollution level
 - (ix) Soil Properties
- (b) AC System information:
 - (i) Short Circuit Ratio and Short Circuit Current:
 - (ii) System voltage and frequency
 - (iii) Harmonic impedance characteristics
 - (iv) System Voltage distortion
 - (v) System Grounding
 - (vi) Torsional mode frequencies (Sub-synchronous Resonance)
 - (vii) AC system topology
 - (viii) AC system equivalent
 - (ix) MVAR exchange with AC system
- (c) HVDC line / Cable:

- I. In case of overhead lines, the detail information shall include
 - (i) Line length
 - (ii) Conductor type
 - (iii) Conductor configuration
 - (iv) Rated DC Voltage
 - (v) Impulse withstand levels
 - (vi) Tower configuration for the Pole conductors & Dedicated Metallic Return (DMR) conductor / earth electrode
 - (vii) and earth electrode station (if applicable)

- II. In case of Cable, the detail information shall include
 - (i) Cable length
 - (ii) Cable size and insulation
 - (iii) Rated and maximum DC voltage
 - (iv) Current rating
 - (v) Capacitance and resistance at rated load
 - (vi) Impulse withstand levels

4. System Performance:

The HVDC system shall be designed to meet all performance requirements and shall be compatible to existing system. The HVDC system shall not cause instability to the AC existing Network and should not adversely affect other nearby HVDC Systems as well as Generating Units. This can be verified by stability, multi infeed and Sub Synchronous Resonance (SSR) studies.

5. System Studies- HVDC control parameters and equipment shall be designed by carrying out the following studies at different stages of the project:

- (a) Main circuit parameters;
- (b) Short circuit studies;
- (c) Insulation co-ordination;
- (d) AC, DC and PLC filter design, rating and performance;
- (e) Reactive power studies, switching arrangement & logic;
- (f) Temporary overvoltage;
- (g) Transient overvoltage, surge arrester stress;
- (h) Runback and run up studies;
- (i) Sub- synchronous resonance (SSR) studies
- (j) AC breaker recovery voltage (TRV) and rate of rise of recovery voltage (RRRV) studies;
- (k) Overload study;
- (l) AC equivalent study;

- (m) DC switchgear requirements;
- (n) Load flow, stability, modulation and frequency controller design study;
- (o) Dynamic over voltage study;
- (p) Electrical interface study;
- (q) Reliability and availability study;
- (r) Audible noise study;
- (s) Loss calculation;
- (t) Dynamic performance study (DPS);
- (u) Studies for deciding operational logics/ sequences;
- (v) Design of electrode line and its impact on dc equipment;
- (w) Application of VAR compensation equipment;
- (x) Commutation failure and recovery study;
- (y) Real time digital simulator (RTDS) studies;
- (z) HVDC control and protection coordination study;
- (aa) Overall efficiency study;
- (bb) AC/ DC system interaction.
- (cc) Muti-infeed studies, if applicable

6. Insulation co-ordination

- (a) HVDC System shall be suitably protected against Impulses and disturbances external and internal to the system such as switching impulses, lighting impulses, dynamic over voltages and load rejection. The insulation of all equipment shall be properly protected and coordinated with surge arresters and/or surge capacitors. Insulation coordination shall be done keeping in mind the minimum electrical clearances, safety clearances and maintenance clearances as per Switching Impulse Withstand Level (SIWL). Insulation coordination shall be done as per relevant CIGRE and IEC / IS Standards. Insulation levels of oil filled equipment shall be less than other equipment considering its cost.
- (b) The insulation of the equipment and protection levels of Surge Arresters connected to the converter ac bus bars of the converter stations at both rectifiers and inverter shall be coordinated with the insulation and surge arrester characteristics of the connected ac systems to which the converter stations are to be connected without exceeding the discharge duty of these arresters.
- (c) Overvoltages caused by Bipole link HVDC transmission shall be controlled to 1.4 p.u or below. Events caused by other equipment in the A.C. network shall be controlled within the limits of the capability of the deblocked converter. In case the converter is tripped, and not possible to restart within seconds, filter tripping shall be allowed to limit overvoltages.
- (d) The tripping action for lines shall be initiated if the over voltage exceeds 1.1 p.u. for 5 seconds and if 1.5 p.u. voltage persists for more than 100

milliseconds. The HVDC over voltage strategy shall be co-ordinated with such setting.

- (e) The ratio of impulse withstand voltage to impulse protective level shall be in line with IEC-60071-5.
- (f) The minimum insulation levels for 800 kV shall be as follows:

HV Transformer LIWL/SIWL (kV)	Smoothing reactor LIWL/SIWL (kV)	Thyristor Valve Structure LIWL/SIWL (kV)	DC Busbar LIWL/SIWL (kV)
1800/1600	1800/1600	1800/1600	1900/1600

LIWL- Lightning Impulse Withstand Voltage;

SIWL- Switching Impulse Withstand Voltage

7. Radio Interference (RI), Acoustic Noise (AN) and DC field

- (a) All the necessary precautions shall be made during HVDC design to ensure that there shall be no mal-operation, damage or danger to any equipment, system or personnel due to electromagnetic or electrostatic interference effects. The converter terminal(s) shall neither damage or cause mal-operation of the DC control and protection system or the DC tele-control system.
- (b) All the necessary precautions shall be taken in the form of noise suppression techniques, shielding and filtering devices to prevent harmful interference, which may be generated by the converter terminals, with the Power line carrier (PLC) systems, Radio communication systems, Television systems, VHF, UHF & microwave radio systems.
- (c) The noise generated by HVDC System shall also be limited by noise reducing measures. Noise shall be less than 45 dBA in control room and office areas, 70 dBA at the station boundary and 70 – 90 dBA at various HVDC equipment areas.

8. Dynamic Performance:

- (a) The purpose of dynamic performance design is to determine the control parameters for HVDC system and to ensure that the HVDC system shall have smooth, stable and fast operation for both steady state and transient conditions without adversely affecting the connected AC grid.
- (b) The HVDC system shall recover to 90% of the pre-fault dc power transfer level consistently within 120 ms from the instant of fault clearing, without subsequent commutation failure or sustained oscillation for all inverter ac system fault conditions. For all rectifiers ac system fault conditions, the

recovery time, to 90% pre- fault power level, shall be within 100 ms from the instant of fault clearing.

- (c) HVDC should continue operation at reduced power if conditions get outside the voltage, frequency and short circuit capacity ranges specified in system data as much as possible with its inherent capability.

9. Main Circuit Design-The purpose of Main Circuit design is mainly to determine the operating characteristics and rating of thyristor valves and converter transformers (MVA, tap changer range etc). It also forms the input for AC Filter and Reactive compensation design. The main circuit arrangement and circuit shall depend on type of HVDC system, Power Transmission requirements, DC Voltage Levels, connected AC voltage levels, Reactive Power requirements and AC & DC Harmonic requirements. The system shall meet various harmonic performance parameters on both AC Side and DC side.

10. HVDC Equipment- The function blocks of converter station are Converter area (converter valves, converter transformer, Smoothing Reactor), DC yard (DC filters, DCCT, DCVT, PLC filters of DC side, DC pole arresters, Disconnectors and ground switches), AC filter yard, AC yard and auxiliaries. A typical LCC based HVDC station shall consist of the following main equipment:

- (a) Thyristor valves and its accessories e.g. damping and grading circuits, converter cooling system, etc.;
- (b) Converter transformers;
- (c) Smoothing reactors*;
- (d) DC filters*;
- (e) AC filters (Harmonic filters and PLC filters) and shunt compensation;
- (f) Control and protection of AC and DC side;
- (g) Electrical and mechanical auxiliaries;
- (h) Earth electrode station* / Dedicated Metallic Return (DMR) *;
- (i) AC switchyard equipment;
- (j) DC switchyard equipment*;
- (k) Surge arresters;
- (l) Measuring instruments;
- (m) Communication system between converter stations (Optical/ PLCC).
- (n) DC wall bushings

* Not applicable for back to back schemes.

11. Converter Station AC Yard

- (a) **AC commutating bus equipment-** The AC circuit breakers, disconnectors, instrument transformers and other switchyard equipment shall be similar to that of the equipment specified under Regulation 43. The bus rating shall be adopted according to the calculation considering single bus operation. The switching duties of the AC circuit breakers will be decided based on transient over voltage study, insulation co-ordination, AC filters and protection studies.

(b) **Dynamic over voltage limiter devices-** Converters connected to relatively weak AC systems may cause dynamic over voltages (DOVs) during load rejection / disturbance. The DOV limiter shall consist of parallel arrester elements connected phase to phase or phase to ground and designed to absorb the desired amount of energy during a system disturbance. The DOV limiter shall be coordinated with recovery of DC system following a disturbance. The requirements of surge arresters shall be based on the insulation co-ordination study in line with relevant standards. The arresters used shall be metal oxide (ZnO) type conforming to relevant standard. For control of DOV, use of STATCOM, SVC and high power gapless arresters shall be evaluated.

(c) **AC harmonic filters and shunt compensation**

- (i) To maintain the system security, reactive compensation requirement (both static and dynamic), series and shunt type in AC system shall be studied and identified. The HVDC converter generates harmonics during the Conversion process and AC harmonic filters shall be used to limit ac voltage distortion due to harmonics to acceptable levels and also to meet the reactive power exchange requirements based on the studies carried out.
- (ii) The AC harmonic filters shall be switched in and out by circuit breakers. Based on the studies, the reactive power requirement for the terminal and bank or sub-bank size shall be determined such that reactive power exchange with the AC bus shall remain within specified limits. Suitable redundancy shall be provided in the sub-bank filters to avoid reduction of transmission capacity of the station due to outage of any particular sub-bank for maintenance.
- (iii) The main filter equipment namely capacitors, reactors and resistors shall comply with the requirements of following IEC
 - (A) Capacitors : IEC 60871;
 - (B) Reactors : IEC 60289;
 - (C) Resistors : IEC 62001.
- (iv) Dynamic compensation: If required, dynamic compensation in the form of static compensator (STATCOM), static var compensator (SVC), thyristor controlled series capacitor (TCSC) etc. may be used to improve stability during AC system transient faults. The requirement of dynamic compensation and the rating shall be derived from the studies.
- (v) Shunt Reactor Banks: Shunt reactors of suitable size shall be provided to meet reactive power exchange requirements derived from the studies. The shunt reactor shall be oil filled and can be switched in or out by a circuit breaker. The shunt reactor shall conform to relevant standard. The shunt reactor shall be covered under automatic switching under the reactive power control strategy.

- (vi) **AC filter Design:** The Total Harmonic Distortion (V_{thd}) of AC filter, as defined below, shall not exceed 2%.

$$V_{THD} = \sqrt{\sum_{n=2}^{n=40} \frac{V_n^2}{V_1^2}} \times 100$$

'1' refers to fundamental frequency (50 Hz)

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

Additional requirements as per relevant IEC shall also be fulfilled. In all Modes of operation, except the reduced dc line voltage modes, the performance requirement shall be met up to rated power with one larger size filter sub-bank and one characteristic harmonic sub-bank(largest) being out of service. All filter banks, sub-banks and branches shall be rated such that the remaining filter components are not overloaded and there is no restriction on the operating power level for any operating conditions with one filter bank outage for power level up to 1.0pu.

- (d) **Power line carrier (PLC) filtering-** PLC filters shall be installed close to converter transformers to mitigate high frequency harmonic currents generated during thyristor switching.

(e) **Converter transformers:**

- (i) The converter transformers shall be three phase / single phase two winding or three winding units which shall be decided by size and transportation limitations. The transformers shall comply with the requirements of relevant standards. The maximum flux density in any part of the core and yoke at the rated MVA, voltage and frequency shall be such that under 10% continuous over voltage condition it does not exceed 1.9 Tesla. The maximum temperature rises of top oil and winding shall be 40°C and 45°C respectively over an ambient temperature of the terminal where the equipment are installed and operated. For 2 hours of overload rating with redundant cooling, the maximum temperature rises of oil and winding shall be 45°C and 50°C respectively over an ambient temperature of the terminal where the equipment is installed and operated. Temperature rise test shall be conducted as per IEC-61378-2 / IS. The Converter transformer shall be capable of withstanding minimum DC current of 10A per single phase transformer entering through the neutral.
- (ii) The insulation level for the transformer AC (line side) windings and bushings shall be as given at Regulation 43 and insulation levels of the valve side windings shall be determined in accordance with studies. The impedance of the transformer shall be determined in accordance with studies and variations in impedance shall be as per system requirements.

- (iii) Converter transformers shall be equipped with on load tap changer (OLTC) mechanism and metal oxide varistor (MOV) devices shall be provided between tap leads of the OLTC. The OLTC tap steps shall be determined in accordance with the operating strategy of both the converters. The OLTC shall be designed for a minimum 2,50,000 operations without repair or change of any part including oil. The OLTC shall be designed for a contact life of minimum 6,00,000 operations.
- (iv) The requirements of soak pits and firewalls shall be in line with Regulation 43.
- (v) Two Nos. of Single phase Converter transformers of each type and rating shall be provided in each converter station. It shall be possible to replace a failed converter transformer within 72 hrs with the standby converter transformer.

(f) Thyristor valves

(i) The thyristor valves, used for converting AC to DC or vice versa, shall be complete with associated auxiliaries and cooling system. Twelve pulse scheme shall be used. Each twelve pulse thyristor valve group shall consist of two six pulse bridge in series. Each valve module shall consist of series connected thyristor modules and valve reactor. Each thyristor in thyristor module shall have voltage grading circuit and electronic firing system complete with individual thyristor over voltage and over current protection, break over diode firing/ protective firing, thyristor control, protection, monitoring, damping and auxiliary power. The thyristor valve assembly shall be tested as per relevant standards. One / Two twelve pulse valve group in series or parallel combination shall be used depending on the power rating and other requirement of specific project. In case of two series converter configuration, a bypass switch shall be provided to bypass any faulty converter and use the remaining series converter at lower DC voltage. The thyristor valve assembly shall be designed and tested as per relevant IEC/IS.

(ii) The thyristor valves shall be water cooled, air insulated and indoor type. The valves shall be either suspended type or floor mounted type depending upon the operating DC voltage and seismic requirements. The Double or Quadruple valve design shall be used depending on voltage level. A redundancy of 3% (minimum 3 Nos. of Thyristor per valve module) shall be included in design consideration.

(iii) The thyristor valve cooling system shall use de-ionized water circulated in a closed cycle. The cooling unit shall comprise of a de-ionizer, expansion vessel, conductivity, flow and temperature sensors, mechanical filters, etc. Adequate redundancies shall be

provided. Necessary control and monitoring including tripping of the HVDC system in case of cooling system failure shall be provided.

(iv) The valves shall be placed in the valve hall which shall have a positive pressure over atmospheric pressure and humidity control feature. The pressurization will be maintained by ventilation system.

12. Converter Station DC Yard

(a) The DC yard comprises equipment such as HVDC bushings, smoothing reactors, DC filters, DC current and voltage measuring instruments and switchgear, surge arrester, insulators, clamps and connectors.

(b) The creepage distance for DC yard and other areas shall be maintained as indicated below:

Insulator type	Under light pollution	Under heavy pollution
Indoor porcelain or composite insulators for valve hall and indoor smoothing reactor area	20 mm/kV	20 mm/kV
Indoor DC yard (other than smoothing reactor)	NA	30 mm/kV
Outdoor porcelain insulators or bushings with RTV coating	50 mm/kV	60 mm/kV
Outdoor composite insulators or bushings	50 mm/kV	50 mm/kV

The base voltage applicable for calculation of valve arrester creepage distance shall be

$$U_{creepage} = \left(\sqrt{\frac{1}{3} + \frac{\sqrt{3}}{8\pi}} \right) * CCOV$$

(c) **DC wall bushing-** DC wall bushings, used for electrical connection between the equipment inside the valve hall and the outdoor DC yard shall be of polymer housing as per relevant standards. All bushings inside the valve hall including HVDC wall bushing shall be dry type / SF6 gas filled or combination of both.

(d) **Smoothing Reactor-** The smoothing reactor shall be of air core type. The reactors shall generally comply with relevant standards and shall also have been subjected to DC tests as per their application. The smoothing reactor shall be equally divided between pole and neutral for DC voltage above 500kV. Each converter station shall be provided with one spare coil of smoothing reactor.

For the design of smoothing reactor, the **Si factor** has to be within the limits (0.22 < Si < 1) where Si factor is defined as

$$Si = U_{dn} / L_d \cdot I_{dn}$$

U_{dn} = Nominal HVDC Voltage level per pole

I_{dn} = Nominal HVDC Current

L_d = Total DC side inductance = $L_{dr} + 3.5 L_{tr}$

where L_{dr} - Smoothing Reactor inductance

L_{tr} - Converter transformer inductance

The smoothing reactor shall be designed for Class H for inter turn insulation as per IEC 60085, however, the maximum allowed hot-spot temperature rise shall be limited to one class lower i.e Class F insulation.

(e) **DC Voltage and Current Measuring Devices-** The DC voltage measuring equipment shall be installed at each pole. The DC measuring equipment at pole and neutral bus shall be suitably located based on the control philosophy and different protection zones such that complete pole and neutral equipment are protected.

(f) **DC Filters-** DC harmonic filters shall be provided in DC yard to limit harmonic voltages present on the DC lines (pole lines and electrode lines / DMR line). The DC Filters generally consist of Blocking Filter, Low order filters, Harmonic Filters and High Frequency Filters. The main filter equipment like capacitors, reactors and resistors shall comply with the requirements of relevant IS/IEC standards/ CIGRE documents. A series blocking filter shall be provided at each converter of the inverter station. A parallel low order (2nd Harmonic) DC Filter shall be provided across each converter of each station.

(g) **DC Filter Design**

The individual harmonic current (I_n) at any harmonic shall not exceed the value which could cause mal-operation of the HVDC system control and protection equipment supplied.

The maximum equivalent disturbing current (I_{eq}), without any filter outage, for balanced bipolar and monopolar mode with metallic return or Dedicated Metallic Return (DMR) modes of operation shall be as follows:

Operating Mode	I_{eq}
Balanced bipolar operation	1500 mA
Monopolar mode with metallic or DMR mode	2200 mA

The DC filter components shall be adequately rated to allow unrestricted operation of the HVDC system in all operating modes and for all power levels upto 1 p.u with any possible combination of filter branches connected.

The rating of the dc filter components shall be based on the assumption that the per pole harmonic voltage is individually maximized at each harmonic for any particular operating mode, and the filter component currents due to the harmonic voltages at the terminals shall be assumed to add as RSS (Root sum squared) at each harmonic.

Blocking filter reactor shall be designed for Class H for inter turn insulation as per IEC 60085, however, the maximum allowed hot-spot temperature rise shall be limited to one class lower i.e Class F insulation. The AC/DC/PLC/RI reactor shall be designed for Class F insulation as per IEC 60085, however, the maximum allowed hot-spot temperature rise shall be limited to one class lower i.e. Class B insulation.

(h) **Surge Arresters**

Surge arresters shall be gapless Metal Oxide arresters and shall be designed, and tested as per relevant IS / IEC. The arresters shall be designed to absorb the desired amount of energy during a system disturbance and shall be coordinated with recovery of DC system following a disturbance as applicable.

The HVDC main arresters generally found in a HVDC System are as follows:

- (i) Valve Arrester
- (ii) Bridge Arrester (6 pulse/12 pulse)
- (iii) DC Line Arrester
- (iv) DC Neutral and DC Filter Arrester
- (v) Converter Transformer and AC Filter Bus Arrester
- (vi) Electrode line arrester / DMR line arresters
- (vii) Smoothing Reactor Arrester
- (viii) DC Neutral Switch Arresters

13. Control and Protection System

(a) **Control System:** The control system shall have redundancy with hot standby.

i) DC converter terminals shall be either manned by operator or controlled by remote operation of SCADA system. The control system hierarchy shall be as follows:

- (A) Bipole Control
- (B) Pole Control
- (C) Converter control and Valve control

ii) The HVDC Bipole shall have control features including but not limited to the following:

- (A) Reactive power controller:

The reactive power interchanges between the converter stations and the ac system shall be guaranteed and shall be maintained within the desired limits. The Reactive Power element switching shall not result in AC system voltage variation of more than 5 percent for 400kV and above voltage level and 10% for below 400kV.

(B) Current and power controller

(C) Frequency controller:

Under asynchronous operation of rectifier and inverter end ac system, it shall be possible to operate the HVDC system in frequency control mode in which the HVDC power flow is used to control the frequency of one grid provided the frequency of the other grid does not deviate beyond the specified band.

(D) Power modulator, pole power compensation:

The modulator shall have feature which shall provide positive damping of ac network oscillations over the range of frequencies considered during system studies.

(E) Sub Synchronous Resonance (SSR) Damping Controller (if required):

All necessary studies shall be carried out to ensure that the DC system shall not excite the mechanical, electromechanical or other natural frequencies of the nearby region generators and turbines under any operating mode. It shall be demonstrated by studies (simulation as well as field test) that the nearby generators shall not be adversely affected by the HVDC system, particularly with regard to Sub Synchronous Oscillation (SSO) / Sub Synchronous Resonance (SSR) and harmonic injection and self-excitation. Sub Synchronous Damping (SSD) Controller shall be provided for converter Stations near Generating stations.

(F) Load frequency controller (LFC)

(G) Current margin controller

(H) Excessive reactive power consumption controller

(I) AC system stability function, such as power swing damping function.

(J) Run back / Run up controller with provision to be linked to SPS of System Operator

i) The pole control, converter control, and valve control modules shall also be provided.

ii) The control shall be designed to give fast stable and proper response to normal control actions as well as during disturbances such as AC & DC faults.

(b) **Protection System**

i) HVDC system protection shall consist of two parts:

(A) AC side protection:

AC side protection function shall cover the zone for converter transformer, AC filters, shunt capacitors, shunt reactors, and busbars. These protections shall generally follow the same philosophy as in a typical substation i.e. detection of fault by relay and tripping of circuit breaker.

(B) DC side protection:

DC side protection covers the zones consisting of the valve hall, DC switchyard including smoothing reactor and DC filters, DC line, DMR line / electrode line and ground electrode. The protection equipment shall be designed to be fail safe and shall ensure high security to avoid mal-operation/ unwanted shutdown due to protection equipment failures.

ii) Following a DC Line fault, the HVDC System shall have the facility to restart, one or more times, the faulted pole at a variable pre-selected DC voltage level(s), not below 80% of the nominal voltage rating. The dc transmission system shall be capable of recovery in a controlled and stable manner without commutation failures during recovery following ac and dc system faults. The post fault power order shall be equal to the pre-fault power order unless AC/ DC systems dictate otherwise

iii) Each protection system shall have two identical independent electrical and mechanical systems with following protections.

(A) Converter differential protection;

(B) DC over current protection;

(C) DC differential protection;

(D) AC conductor ground fault protection;

(E) Commutation failure protection;

(F) DC filter protection (not applicable for back to back schemes);

(G) DC smoothing reactor protection;

(H) DC line ground fault protection with restarts;

(I) DC line differential protection;

(J) DC under voltage/ over voltage protection;

(K) Ground Return mode / Dedicated Metallic Return (DMR) protection

(L) AC filter and DC filter protections

(M) Electrode line monitoring and protection

(N) Thyristor Failure Monitoring

iv) DC online fault locators shall be provided to monitor the entire DC line length and give location of the fault with good accuracy in the range of ± 1000 meters

(c) Software based controls and protection shall be used to permit flexibility in effecting modifications at a later date. Protection and controls shall be duplicated for reliability. Protection shall be provided by numerical relays complying with IEC 61850 protocol to suit the requirements of reliability and fast controllability of the HVDC system. Operation of the HVDC bipole system shall be possible in the following modes:

- i) Balanced/ unbalanced bipolar operation;
- ii) Monopolar operation with metallic return;
- iii) Monopolar operation with ground operation/ with Dedicated Metallic Return (DMR) mode;
- iv) Reduced voltage operation;
- v) Power reversal mode.

(d) The 'Sequence of events' recorder, transient fault recorder, on-line DC Line fault locator, GPS system, visual display system, operator control protection and monitoring system shall be a part of the HVDC system.

14. Telecommunication- For smooth operation of the HVDC system, communication network with high reliability and availability shall be provided for transmission of control and protection signals between the two or more (in case of multi-terminal DC) HVDC terminals. The communication system shall be through optical fibers. There shall be main as well as back up communication link.

15. Valve Hall: The valve hall shall mainly contain thyristor valves, its associated structure and cooling and arresters. No oil filled equipment shall be present inside the valve hall. In case the turret of converter transformers (having oil) is protruding inside the valve hall, suitable fire barrier matching with adjacent valve hall fire rating shall be provided. The valve halls shall be provided with interference screening. In addition, the control cable and cable termination rooms shall be suitably screened to minimize radio interference. Two nos. scissor lift for erection and maintenance of valve modules shall be provided per station. Proper cable sealing shall be provided for cable entry into valve hall and control room to avoid entry of water and moisture. High frequency earthing shall be provided inside valve hall as well as for control panels in service building.

16. Valve Hall Ventilation: Each valve hall shall have independent ventilation systems. Each ventilation system shall consist of two 100% capacity systems, one system in operating mode and other one in stand-by mode. The total air volume in the valve hall shall be re-circulated through the main filters at least once every one hour. The ventilation system shall be a closed cycle with fresh air intake limited to

a maximum of 20% of the total air requirement. To ensure that the air being supplied to the valve hall is free from dust particles, a minimum three stage dust filtration process shall be supplied. This shall consist of at least the following:

- (a) Pre Filters: To remove dust particles down to 10 microns in size with at least 95% efficiency.
- (b) Fine Filters: To remove dust particles down to 5 microns in size with at least 99% efficiency.
- (c) Absolute Filters: To remove dust particles down to 0.3 microns in size with at least 99.5% efficiency.

The valve hall shall be kept at a positive pressure above the atmospheric pressure under all conditions. The test shall be conducted at site to measure the pressure inside the valve hall for 48 hours. The pressure inside valve hall shall be at least 3 mm of water Column over the pressure outside the valve hall for total duration of test. The humidity inside valve hall shall be controlled to below values as required for normal operation of equipment inside (below 55 % typically).

17. Safety Grounding

- (a) The electrical safety clearances for the DC side shall not be less than the clearances applicable for an AC switchyard at the equivalent BIL level.
- (b) The total electric field excluding space charge at ground level shall not exceed 20kV/m and ion current density shall be less than 20 nA/sq. m at ground level in the DC yard.
- (c) Fencing and electrical & mechanical key interlocking arrangements shall be provided for all areas where entry of Human being shall be permitted only after proper de-energization & grounding. Accordingly, key interlocking scheme shall be provided for valve halls, smoothing reactor area, AC and DC filter areas. The interlocking scheme shall comply with provisions of Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations.
- (d) The design of the grounding system shall be based on latest IEEE 80.

18. Dedicated Metallic Return (DMR) / Earth Electrode

In case of a bipolar configuration, unbalanced operation of both poles requires a DC current return path in the neutral connection of the converters. The current return path can be either via a Dedicated Metallic Return (DMR) conductor or via earth return using earth electrodes at both converter terminals. The earth electrode station shall not affect the nearby electrical installation, buried metallic pipelines, oil & gas pipelines, and railway lines etc. DMR mode shall be preferred if it is difficult to identify a suitable site for earth electrode station meeting above requirements.

If earth electrodes are to be used the following requirements shall also be considered:

- (a) The earth electrode station shall be connected to the terminal by means of

an overhead transmission line. The earth electrode shall be located at a minimum distance of approximately 25 km (radial distance) away from the converter station. It shall be designed to operate continuously at nominal load and overload as per the requirement. The thorough soil investigation shall be carried out for shallow & deep resistivity, thermal conductivity and moisture content etc. at the proposed location. The electrodes shall be designed for both types of operation, anodic and cathodic.

- (b) The earth electrode station shall have sub-electrodes. The maximum current density at the sub-electrode surface, i.e. the boundary between backfill (coke) and soil shall not exceed 0.5 A/m^2 in clay soils. The number of sub-electrodes shall be determined considering that 30% of the sub-electrodes are not available. The amp hour rating for earth electrode shall be selected based on the study for duration of earth electrode current and the service life of the earth electrode station.
- (c) Each ground electrode shall have a resistance of less than or equal to 0.3 ohm (both working as an anode and cathode) at 50°C ambient temperature
- (d) **Touch voltage (V_t)-** The touch voltage between any grounded metallic object in the electrode station (including the connection to the overhead electrode line) and any point in the soil which can be touched by a person simultaneously shall not exceed 40 V when the electrode is operating at the 5 sec overload rating.
- (e) **Step Voltage (V_s)-** The step voltage at ground level above the ground electrode when the electrode is operating at the temporary over-toad rating shall not exceed $(V_s) = 5.0 + 0.03 \rho_s$, where ρ_s is the local surface resistivity in ohm-m.
- (f) The above values of resistance: touch and step voltages would depend on the actual geophysical characteristics of the soil at the place where the electrode station is located. Suitable mitigation measures shall have to be adopted in case the site has high resistivity.
- (g) In addition, following interference effects shall be considered.
 - (i) Corrosion of buried metallic structure of foundations
 - (ii) DC Current in power lines, especially via power transformer neutrals (risk of saturation of transformers).
 - (iii) DC current in telephone circuits.
 - (iv) Effect on the cathodic protection of the buried metallic pipe lines.

19. Cables: Fibre optic cables conforming to IEC – 60793 shall be used to transmit the signals to and from various equipments and panels located in the AC/DC switchyards, Valve Halls, control rooms, valve cooling rooms, etc. The material used in the manufacturing of the optical fibre cables and splicing / maintenance shall be self-extinguishing, non-toxic, low halogen and impervious to water penetration and dermatological safe in its life time and

shall not pose any health hazards. The power and control cables shall generally be in line with Regulation 43 for substations.

20. Auxiliary Power Supply System: The auxiliary power supply system shall have the following:

- (a) Highly reliable duplicated supply sources from two separate sources, with automatic change-over facilities.
- (b) Completely separated secondary distribution (415 V) systems for the auxiliaries of each converter.
- (c) Duplicated supply by two different 415 V power sources to essential loads (e.g., cooling pumps, fans, heat exchangers, etc.).
- (d) Provision of the diesel-generator set(s) to meet essential and emergency loads and which starts-up automatically in case of loss of all the normal and stand-by supply sources. One DG set per converter shall be provided at all the converter stations.
- (e) In order to limit fault currents, prevent back feed into the AC bus and to ensure independence of supply sources, parallel operation between station service transformers shall not be permitted at any voltage level. Also parallel operation shall not be permitted between transformers and the diesel generator.
- (f) Suitable protection on all primary MV or LV supply connections to ensure fast selective protection as per engineering practice of various Indian and International standards.
- (g) All auxiliaries shall give rated output at voltage variation of $\pm 10\%$ and frequency variation of -5% to $+3\%$.
- (h) The station services DC system shall cater to the following:
 - i) DC loads of HVAC and HVDC switchyards, auxiliary services control, circuit breaker operating mechanisms, valve and pole control, protection circuits, communication system loads, etc.
 - ii) An indispensable minimum lighting load shall be connected to the station DC system.
- (i) The 220VDC supply system(s) per converter shall consist of at least two independent DC systems; each system consisting of one charger, one battery bank and one distribution panel.
- (j) A 48 V DC system consisting of two battery sets, two Battery chargers and two distribution boards shall also be supplied for communication panels (wherever supplied).

21. Fire Detection, Alarm and Protection system: A comprehensive fire detection, alarm and protection system as per Regulation 43 shall be provided. Valve Hall shall have Very Early Smoke Detection Apparatus (VESDA) system. Suitable Infra-Red (IR) detector to detect the flashover inside the Valve Hall shall also be provided. The Valve hall shall be suitable for minimum 3 hour fire rating.

22. Testing and trial Operation: All equipment / component including Thyristor valves, Converter Transformers, smoothing reactors, EHV DC Transformer bushings and wall bushings shall be subjected to Type tests, Routine tests, Factory Acceptance Test (FAT), Site Acceptance Test (SAT) as per relevant

IS / IEC/ IEEE as applicable. The SAT shall consist of sub-system & system tests and shall be carried out after installation of equipment at site. The subsystem tests cover the major sub-system like valve cooling, AC&DC filters, HVDC converter, auxiliary systems, communication etc. After completion of sub-system tests, system tests covering power transmission tests, transient & dynamic control tests, measurement of electric field and RFI etc. shall be conducted. After completion of all system tests, final trial operation of the HVDC System shall be carried out for uninterrupted continuous period of normal operation of not less than 10 days during which the converter equipment shall be fully operational.

- 23. Spares:** The following main equipment shall have one spare of each type and rating
- (a) DC Current Transformer
 - (b) DC Voltage Divider
 - (c) DC High Speed Switches
 - (d) DC Yard Disconnectors
 - (e) Valve Hall Grounding Switches
 - (f) AC Circuit Breaker with operating mechanism (1 pole of each type and rating)
 - (g) AC Isolators with Grounding Switch (2 pole of each type and rating)
 - (h) Connectors for DC yard and valve hall (1 complete set of units to make one no of each type and rating)
 - (i) AC & DC Surge Arresters (3 nos. of each type and rating)
 - (j) AC Current Transformer
 - (k) Capacitive and Inductive Voltage Transformers
 - (l) Cards Relays and Contactors for C & P Panels (min 10 % of each type and rating)
 - (m) Capacitor Units (min 1 % of each type and rating)
 - (n) AC/DC/PLC Filter Reactors (1 complete reactor of each type and rating)
 - (o) Filter Resistors (1 module of each type)

24. Performance Guarantee:

- (a) The power Transmission Capacity:**
The rated power transmission capacity shall be defined and guaranteed at inverter end of AC yard and rated transmission voltage shall be defined at the rectifier end. The reverse Power transmission capacity shall also be indicated.
- (b) HVDC System losses:**
The Guaranteed losses of HVDC transmission shall include the no load loss and equivalent load loss. The equivalent load loss is the sum of load losses at specific loadings multiplied by weightage factors as per expected loading cycle. The Guaranteed losses shall be verified as per IEC 61803. No load loss shall be guaranteed corresponding to converter transformer

set at principal tap with nominal AC system voltage and nominal frequency at 40° C ambient temperature.

(c) The system shall meet various harmonic performance parameters on both AC Side and DC side.

(d) Availability, Reliability and Transient disturbance:

1	Overall Energy availability of HVDC scheme (a) Overall Performance (b) Excluding transformer failure	Not less than 97.5% Not less than 98.5%
2	Forced Energy Unavailability (FEU)	Not more than 0.6 %
3	Schedule Energy Unavailability (FEU)	Not more than 1 %
4	Single pole outage per pole per station per year	Not more than 8 (with average outage duration of 7.5hours)
5	Bipole outage per station per year	Not more than 0.2 (with average outage duration of 8.0hours)

25. Applicable Standards: All equipment and material shall be designed, manufactured, tested and commissioned in accordance with latest Indian Standard / IEC / IEEE standards / relevant CIGRE documents (as applicable) and the Acts, Rules, Laws and Regulations of India. Some of them are as follows:

- (a) IEC 60633 - Terminology for High-Voltage Direct Current (HVDC) transmission
- (b) IEC 60700 (1-2) - Thyristor valves for High Voltage Direct Current (HVDC) power transmission
- (c) IEC 60919 (1-3) - Performance of High-Voltage Direct Current (HVDC) systems with line-commutated converters
- (d) IEC 61803 - Determination of power losses in High-Voltage Direct Current (HVDC) converter stations with line-commutated converters
- (e) IEC-61975 - High-Voltage Direct Current (HVDC) installations - System tests
- (f) IEC-62001 (1-4) - High-Voltage Direct Current (HVDC) systems - Guidance to the specification and design evaluation of AC filters
- (g) IEC 65700 – Bushings for DC Applications
- (h) IEC 60071 (1- 5) – Insulation Coordination
- (i) CIGRE report 33/14-05: “Application guide for metal oxide arresters without gaps for HVDC converter stations”
- (j) IEC 61378(2-3) - Converter transformers
- (k) IEC – 600076-6 Power transformers - Part 6: Reactors
- (l) IEC 60871-(1-4) -Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V

- (m) IEC 60747-6 - Semiconductor devices - Part 6: Discrete devices – Thyristors
- (n) CIGRE- TB 136 1999 SC 14 TF 14.01.04 Fire aspects of HVDC thyristor valves and valve halls.
- (o) PWI/TR 115-6 Ed. 1.0 -Guidelines for the system design of HVDC project
- (p) IEC/TS 63014 Ed. 1.0 -High voltage direct current (HVDC) power transmission - System requirements for dc-side equipment - Part 1: Line-Commutated Converters
- (q) IEC/TR 63065 Ed. 1.0 - Guidelines for operation and maintenance of HVDC converter station
- (r) IEC/TR 62978 Ed. 1.0 -Guidelines on Asset Management for HVDC Installations

Note: HVDC Switchgear- As no Standard exists for DC equipment, the relevant portion of the corresponding standard for ac equipment shall be applicable to the extent possible. The switches which are current interrupting or making devices shall generally comply with the requirements HVAC Circuit Breakers (as appropriate to DC switches). The commutation switches shall be capable of commutating DC Current from DMR (Dedicated Metallic Return) to PMR (Pole Metallic Return) and vice versa.

Part-B

Technical Details of Voltage Source Converter (VSC) based HVDC Terminals/ Stations

1. **General:** The VSC are self-commuted converters capable of controlling the reactive power at both end converter stations independent of active power flow and requires less foot prints compared to LCC based HVDC installation. VSC can operate at approximately zero active power transfer while providing full reactive power support. The VSC based HVDC system shall use Insulated Gate Bipolar Transistor (IGBT) technology and shall be considered primarily for the following without concerns about the available Short Circuit Ratio:
 - Point to point transmission scheme (overhead / cable)
 - Back to Back transmission scheme
 - Parallel operation with LCC HVDC system
 - Multi-terminal system
 - Supplying load in isolated areas
2. **Design Consideration:** The following minimum technical information shall be required for VSC based HVDC installation:
 - (a) The amount of power to be transmitted including overload requirement
 - (b) The transmission distance and type of DC transmission line (cable or

- overhead line or a combination thereof)
- (c) Length of overhead line, length of cable as applicable
- (d) DC transmission voltage
- (e) Power system characteristics of sending and receiving end system to which VSC transmission system is connected, including all the parallel transmission system, if any
- (f) Steady State performance requirements
- (g) Dynamic performance requirements, including control and monitoring facilities
- (h) Transient performance

3. System Studies: HVDC control parameters and equipment shall be designed by carrying out the following studies at different stages of the project:

- (a) Design Studies
 - a) Main Circuit Parameter
 - b) AC Over-Voltage [DOV, Temporary Over Voltage and Transient Over Voltage]
 - c) Low Frequency Characteristics
 - d) High Frequency Characteristics
 - e) Transient Stresses
 - f) External Insulation and Clearances
 - g) AC Circuit Breaker Requirements
 - h) Station Earthing
 - i) Lightning Protection
- (b) Performance Studies
 - i) Losses
 - ii) Electrical Interference
 - iii) Electric and Magnetic Fields
 - iv) Reliability, Availability and Maintainability
 - v) Audible Noise
- (c) Network Studies
 - i) Stability, Modulation and Frequency Control
 - ii) AC System Equivalents
 - iii) Sub-Synchronous Torsional Interaction

4. HVDC Equipment- A typical HVDC station shall consist of the following main

equipment:

- (a) VSC valves and associated equipment and cooling system
- (b) Interface transformers;
- (c) Converter reactors;
- (d) DC reactors*;
- (e) DC filters*;
- (f) AC filters*;
- (g) Control and protection of AC and DC side;
- (h) Electrical and mechanical auxiliaries;
- (i) Earth electrode station*;
- (j) AC switchyard equipment;
- (k) DC switchyard equipment;
- (l) Surge arresters;
- (m) Measuring instruments;
- (n) Communication system between converter stations (Optical/ PLCC).
- (o) Wall bushings (AD and DC side)
- (p) Insertion resistors
- (q) DC voltage balancing device* (for symmetrical monopole configuration only)

* if applicable

5. Converter Station AC Yard

- (a) **AC bus equipment-** The AC circuit breakers, disconnectors, instrument transformers and other switchyard equipment shall be similar to that of the equipment specified under Regulation 43. The bus rating shall be adopted according to the calculation considering single bus operation. The switching duties of the AC circuit breakers will be decided based on transient over voltage study, insulation co-ordination, AC filters (if applicable) and protection studies.
- (b) **Insertion resistors-** Insertion resistors are used to limit inrush currents during energization of the converter. They may be located on the primary or converter side of the interface transformer. After the energization process is completed the resistor is bypassed by a disconnector or bypass switch.

(c) **AC harmonic filters**

- (i) State-of-the-art Voltage-Sourced Converters (VSC) in modular multi-level converter (MMC) topologies generate nearly no or only a small amount of harmonics. The need of ac harmonic filters shall be evaluated based on study results.
- (ii) If filters are required, the main filter equipment namely capacitors, reactors and resistors shall comply with the requirements of following IEC or or Equivalent IS as follows:

Capacitors : IEC 60871;
Reactors : IEC 60289;
Resistors : IEC 62001.

- (d) If study results confirm the need for power line carrier (PLC) filtering- PLC filters shall be installed close to interface transformers to mitigate high frequency harmonic currents generated during IGBT switching.

(e) **Interface transformers**

- (i) The interface transformers shall be single phase units. For smaller HVDC ratings (e.g. back-to-back schemes) three phase transformers may be possible. The transformers shall comply with the requirements of relevant standards. The maximum flux density in any part of the core and yoke at the rated MVA, voltage and frequency shall be such that under 10% continuous over voltage condition it does not exceed 1.9 Tesla. The maximum temperature rises of top oil and average winding shall be 40°C and 45°C respectively over an ambient temperature of the terminal where the equipment are installed and operated.
- (ii) The insulation level for the transformer AC (line side) windings and bushings shall be as given at Regulation 43 and insulation levels of the valve side windings shall be determined in accordance with studies. The impedance of the transformer shall be determined in accordance with studies and variations in impedance shall be as per requirements of relevant standards.
- (iii) Interface transformers shall be equipped with On Load Tap Changer (OLTC) mechanism, Metal Oxide Varistor (MOV) devices (if applicable) shall be provided between tap leads

of the OLTC. The OLTC tap steps shall be determined in accordance with the operating strategy of the converters.

- (iv) The requirements of soak pits and firewalls shall be in line with Regulation 43

(f) **VSC valves**

- (i) With VSC valves of the “controllable voltage source” type, each VSC level is effectively a single phase VSC in its own right, and contains power semiconductors and a capacitor for energy storage. Each level has two main terminals used for the series connection of the VSC levels within the valve. By appropriate control of the IGBTs within the valve level, either the voltage of the capacitor or zero volts can be applied to the main terminals of the VSC level. The IGBT valves, used for converting AC to DC or vice versa, shall be complete with associated auxiliaries and cooling system. The VSC valves shall be tested as per IEC 62501. Adequate redundant devices shall be provided to enable continued operation in case of failure of an individual component. Advanced converter topologies shall be used to reduce losses of VSC based HVDC converters. Modular Multilevel Converter (MMC) topology, consisting of several sub-modules (combination of IGBT switches and capacitors), shall be preferred. MMC topology for VSC-HVDC system can have half bridge or full bridge submodules and the configuration shall be decided based on system requirement, loss and DC fault ride through capability.
- (ii) The VSC valves shall be water cooled, air insulated and indoor type. The valves shall be either suspended type or floor mounted type depending upon the operating DC voltage and seismic requirements.
- (iii) The VSC valve cooling system shall use de-ionized water circulated in a closed cycle. The cooling unit shall comprise of a de-ionizer, expansion vessel, conductivity, flow and temperature sensors, mechanical filters, etc. Adequate redundancies shall be provided. Necessary control and monitoring including tripping of the HVDC system in case of cooling system failure shall be provided.
- (iv) The valves shall be placed in the valve hall which shall have a positive pressure over atmospheric pressure and humidity control feature. The pressurization will be maintained by ventilation system. The valve hall shall have fire and early smoke detection system.

6. Converter Station DC Yard

- (a) The DC yard comprises equipment such as HVDC bushings, DC reactors, DC filters (if applicable), DC current and voltage measuring instruments and switchgear.
- (b) The creepage distance for DC yard and other areas shall be maintained as indicated below:

Insulator type	Under light pollution	Under heavy pollution
Indoor porcelain or composite insulators for valve hall and indoor smoothing reactor area	20 mm/kV	20 mm/kV
Indoor DC yard (other than smoothing reactor)	NA	30 mm/kV
Outdoor porcelain insulators or bushings with RTV coating	50 mm/kV	60 mm/kV
Outdoor composite insulators or bushings	50 mm/kV	50 mm/kV

- (c) **DC wall bushing** - DC wall bushings, used for electrical connection between the equipment inside the valve hall and the outdoor DC yard shall be of polymer housing as per relevant standards.
- (d) **DC Reactors** - The DC reactors (if used) shall be of air core type. The reactors shall generally comply with relevant standards and shall also have been subjected to DC tests as per their application.
- (e) **DC Voltage and Current Measuring Devices**- The DC voltage measuring equipment shall be installed at each pole. The DC measuring equipment at pole and neutral bus shall be suitably located based on the control philosophy and different protection zones such that complete pole and neutral equipment are protected.
- (f) **DC Filters**- If required DC harmonic filters shall be provided in DC yard to limit harmonic voltages present on the DC lines (pole lines and electrode lines).

7. Control and Protection

- (a) Control
 - i) DC converter terminals shall be either manned by operator or controlled by remote Operation of SCADA system. The control system hierarchy shall be as follows:
 - (A) Station/ Bipole Control (only for bipolar arrangements);
 - (B) Pole Control;

(C) Converter and valve control;

ii) The HVDC converter shall have control features including but not limited to the following:

- (A) Active power control
- (B) Reactive power control;
- (C) AC Voltage control
- (D) Frequency controller (if applicable);
- (E) Power modulation control (if applicable);
- (F) Runback and run-up functions (if applicable);
- (G) Sub synchronous torsional interaction damping control (if applicable);

(b) Protection

i) The protection equipment shall be designed to be fail-safe and shall ensure high security to avoid mal-operation/ unwanted shutdown due to protection equipment failures.

ii) HVDC system protection shall consist of following protection zones:

- a) AC System Protection zone
- b) Converter Transformer Protection Zone
- c) Secondary Busbar Protection Zone
- d) Converter Protection Zone
- e) DC Busbar Protection Zone
- f) DC line & cable Protection Zone

iii) Each protection system shall have two identical independent electrical and mechanical systems including the following protections.

- (A) AC over- and under-voltage protection
- (B) Over- and under-frequency protection
- (C) AC busbar differential protection;
- (D) Insertion resistor overload protection
- (E) AC overcurrent protection
- (F) Converter overcurrent protection
- (G) Converter overload protection
- (H) Converter differential protection
- (I) Converter current imbalance protection
- (J) DC voltage imbalance protection
- (K) DC busbar differential protection

- (L) DC line differential protection
 - (M) DC over- and under-voltage protection
 - (N) Electrode line monitoring and protection (if applicable)
 - (O) DC filter protection (if applicable)
 - (P) AC filter protection (if applicable)
- (c) Software based controls and protection shall be used to permit flexibility in effecting modifications at a later date. Protection and controls shall be duplicated for reliability. Protection shall be provided by numerical relays to suit the requirements of reliability and fast controllability of the HVDC system.
- (d) For bipolar schemes the following operation modes shall be possible:
- i) Balanced/ unbalanced bipolar operation;
 - ii) Monopolar operation with metallic return;
 - iii) Monopolar operation with ground return / DMR
- (e) The 'Sequence of events' recorder, transient fault recorder, on-line DC Line fault locator, GPS system, visual display system, operator control protection and monitoring system shall be a part of the HVDC system.

8. Telecommunication- For smooth operation of the HVDC system, communication network with high reliability and availability shall be provided for transmission of control and protection signals between the two HVDC terminals. The communication system shall be through optical fibers, PLCC or both.

9. Electrode – In case of a bipolar configuration, unbalanced operation of both poles requires a DC current return path in the neutral connection of the converters. The current return path can be either via a Dedicated Metallic Return (DMR) conductor or via earth return using earth electrodes at both converter terminals. The earth electrode station shall not affect the nearby electrical installation, buried metallic pipelines, oil & gas pipelines, and railway lines etc. DMR mode shall be preferred if it is difficult to identify a suitable site for earth electrode station meeting above requirements. If earth electrodes are to be used the following requirements shall also be considered:

- (a) The earth electrode station shall be connected to the terminal by means of an overhead transmission line. The earth electrode shall be located at a minimum distance of approximately 25 km (radial distance) away from the converter station. It shall be designed to operate continuously at nominal load and overload as per the requirement. The thorough soil investigation shall be carried out for shallow & deep resistivity, thermal conductivity and moisture content etc. at the proposed location. The electrodes shall be designed for both types of operation, anodic and cathodic.

- (b) The earth electrode station shall have sub-electrodes. The maximum current density at the sub-electrode surface, i.e. the boundary between backfill (coke) and soil shall not exceed 0.5 A/m^2 in clay soils. The number of sub-electrodes shall be determined considering that 30% of the sub-electrodes are not available. The amp hour rating for earth electrode shall be selected based on the study for duration of earth electrode current and the service life of the earth electrode station.
- (c) Each ground electrode shall have a resistance of less than or equal to 0.3 ohm (both working as an anode and cathode) at 50°C ambient temperature
- (d) **Touch voltage (V_t)-** The touch voltage between any grounded metallic object in the electrode station (including the connection to the overhead electrode line) and any point in the soil which can be touched by a person simultaneously shall not exceed 40 V when the electrode is operating at the 5 sec overload rating.
- (e) **Step Voltage (V_s)-** The step voltage at ground level above the ground electrode when the electrode is operating at the temporary over-toad rating shall not exceed $(V_s) = 5.0 + 0.03 \rho_s$, where ρ_s is the local surface resistivity in ohm-m.
- (f) The above values of resistance: touch and step voltages would depend on the actual geophysical characteristics of the soil at the place where the electrode station is located. Suitable mitigation measures shall have to be adopted in case the site has high resistivity.
- (g) In addition, following interference effects shall be considered.
 - (i) Corrosion of buried metallic structure of foundations
 - (ii) DC Current in power lines, especially via power transformer neutrals (risk of saturation of transformers).
 - (iii) DC current in telephone circuits.
 - (iv) Effect on the cathodic protection of the buried metallic pipe lines.
