

**GOVERNMENT OF INDIA
CENTRAL ELECTRICITY AUTHORITY
Sewa Bhawan (North Wing), Room No. 622, 6th Floor,
R. K. Puram, New Delhi-110066
Tel. Fax -011-26103246, email: celegal-cea@gov.in
Website: www.cea.nic.in**

PUBLIC NOTICE

In accordance with the Sub-Section (2) of Section 177 of the Electricity Act, 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 which were amended on 07.04.2015. It is now proposed to further amend specific clauses in the said regulations. The proposed draft amendments in the above regulations are available on the CEA Website **www.cea.nic.in**. The draft amendments of regulations can also be inspected in the office of Chief Engineer (Legal), Sewa Bhawan (North Wing), Room No. 622, 6th Floor, R. K. Puram, New Delhi-110066 on any working day till **21st August, 2019 between 1100 hrs to 1600 hrs.**

All the Stakeholders including the public are requested to send their comments on the draft regulations to Chief Engineer (Legal), Sewa Bhawan (North Wing), Room No. 622, 6th Floor, R. K. Puram, New Delhi-110066 by post or through e-mail (**celegal-cea@gov.in**) latest by **21st August, 2019.**

**(P C Kureel)
Secretary, CEA**

(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 **2019**

NOTIFICATION

No. CEA/TETD/MP/R/01/2010 - Whereas the draft regulation proposing to amend the Central Electricity Authority (Technical standards for Construction of Electrical Plants and Electrical lines) Regulations 2010 was published in six newspapers dailies, as required by sub-section (3) of section 177 of the Electricity Act, 2003 (36 of 2003) read with sub-rule (2) of rule (3) of the Electricity (Procedure for previous Publication) Rules, 2005, inviting objections and suggestions from all persons likely to be affected thereby, before the expiry of the period of thirty days, from the date on which the copies of the newspaper containing the said publications were made available to the public;

And whereas copies of the said newspapers containing the said regulations were made available to the public on the 13th April, 2017.

And whereas the objections and suggestions received from the public on the said draft regulations were considered by the Central Electricity Authority.

Now, therefore in exercise of the powers conferred by sub-section (2) of section 177 of the Electricity Act 2003 (36 of 2003), the Central Electricity Authority hereby makes the following regulations further to amend the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations 2010, namely:-

1. (1) These Regulations may be called the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Amendment Regulations, 2019.

(2) They 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 (hereinafter referred to as the said regulations) in regulation 2, sub-regulation (1)-
 - i) after clause (b), the following clause shall be inserted, namely:-

'(ba) "automatic voltage regulator" means a continuously acting automatic excitation control system to regulate a generating unit terminal Voltage;'
 - (ii) after clause (k), the following clause shall be inserted, namely:-

'(ka) "generator transformer" means power transformer required to step up generator voltage to connected bus voltage;';

(iii) after clause, (zb), the following clause shall be inserted, namely:-

'(zba) "motor control centre" means the switchgear which contains modules for electric supply to motor and its control;';

(iv) after clause (ze), the following clause shall be inserted, namely:-

'(zea) "power system stabilizer" 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;';

(v) after clause (zl), the following clause shall be inserted, namely:-

'(zla) "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;';

(vi) after clause (zv), the following clause shall be inserted, namely:-

'(zva) "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;';

(vii) after clause (zw), the following clause shall be inserted, namely:-

'(zwa) "ultra super-critical unit" in relation to coal or lignite based thermal generating unit means a supercritical unit with steam temperature of 600/ 600⁰C or higher at turbine inlet;';

3. In regulation 3 of the said regulations,-

(i) in sub-regulation (4), for clause (e), (f) and (g), the following shall be substituted, namely:-

"(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.";

(ii) In sub-regulation 8, for clause (b), (c) and (d), the following clauses shall be substituted, namely:-

“(b) copies of the project design memorandum, technical description, data sheets, O&M manuals and manufacturer’s warranties for all major items and/or equipment;

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

(d) technical documents relating to the design, engineering and construction of the electrical plant and/or electric line including technical specifications for Main Plant and major Balance of Plant systems (as applicable);”;

(iii) in sub-regulation (8), after clause (d), the following clause shall be inserted, namely:-

“(e) Indian Boiler Regulation/ Chief Controller of Explosive approved documents, Statutory clearances and safety procedures.”.

(iv) after sub-regulation (9), the following sub-regulation shall be inserted, namely:-

“(10) 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 authorisation. The standards like North American Electric Reliability Corporation critical infrastructure protection (NERC- CIP), Institute of Electrical and Electronics Engineers (IEEE) and International Electrotechnical Commission (IEC) addressing cyber security for control system and Guidelines of National Critical Information Infrastructure Protection Centre (NCIIPC), Government of India, shall be followed.”.

4. In regulation 5 of the said regulations,-

(i) for sub- regulation (1), the following 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.”;

(ii) in sub- regulation (3), for clause (b), the following 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, HP/LP Bypass Valve, Soot blowers/ Wall blowers, Regulating drain valves - 105 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”.

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

(iii) for sub- regulation (5), the following 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.”.

5. In regulation (6) of said regulations,-

i) in sub-regulation (2), for clause (d), the following 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 for unloading and maintenance purposes. The location of bays shall depend upon lifting method to be used for generator stator and also the functional requirements. 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.”;

ii) in sub-regulation (2), clause (j) shall be deleted:-

“(j) Deleted.”.

6. In regulation (7) of said regulations,-

i) in sub-regulation (1), for clause (c), the following shall be substituted, namely:-

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

ii) for sub-regulation (3), the following 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.”;

iii) for sub-regulation (4), the following 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).”.

7. In regulation (8) of said regulations,-

i) for sub-regulation (4), the following 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.”;

ii) for sub-regulation (11), the following shall be substituted, namely:-

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

iii) in sub-regulation (12), for clause (c), the following 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;”;

iv) for sub-regulation (16), the following shall be substituted, namely:-

“(16) The dust collecting system (electro-static precipitator, bag filter etc.) shall be provided for removing suspended particulate matter (SPM) from the flue

gases to meet the statutory stipulation as per environmental clearances. Electro-static precipitator (ESP) shall comply with the following requirements:

(a) ESP shall be able to meet the stipulated SPM emission requirement even when one electric field in each pass of the ESP is out of service while firing stipulated worst fuel with unit operation at MCR;

(b) ESP shall be provided with effective ash evacuation system having controls for ash temperature and ash level in the hopper. Each hopper shall have a storage capacity of minimum of eight (8) hours with unit operation at MCR. The hopper valley angle to the horizontal shall be minimum 60 degrees;

(c) Specific weight of ash may be considered not more than 650 kg/m³ for determining hopper storage capacity and not less than 1350 kg/m³ for ESP structural design;

(d) Pressure withstand capability of the ESP casing shall correspond to minimum ± 660 mmwc at 67% yield strength and flue gas temperature of 200°C.

Similar requirements shall be applicable for bag filter also.”.

8. In regulation (9) of said regulations,-

i) for Table 1, the following table 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 deg C cooling water temperature and 0% de-mineralised water make up.

** sub-critical units.”;

ii) for sub-regulation (4), the following 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. Further, the turbine output under VWO condition shall be minimum 105% of TMCR output.”;

iii) for sub-regulation (6), the following 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.”;

iv) for sub-regulation (7), the following 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 shall be used in control fluid system for all hydraulically operated valves/ servo motor of turbine stop and control valves.”;

v) in sub-regulation (18), for clause (d), the following 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.”

vi) for sub-regulation (19), the following 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 Standards (HIS) or equivalent.”;

vii) in sub-regulation (20), for clause (a), the following 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.”;

viii) in sub-regulation (20), for clause (b), the following shall be substituted, namely:-

“(b) Small Size Units (< 500 MW)

3x50% or 2x100% motor driven BFPs.”.

9. In regulation (10) of said regulations,-

i) in sub-regulation (2), for clause (d), the following 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.”;

ii) in sub-regulation (2), for clause (f), the following 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 each having 2x100% duty.”;

iii) in sub-regulation (2), in clause (g), for sub-clause (iii), the following sub-clause 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.”;

iv) in sub-regulation (3), in clause (b), for sub-clause (ii), the following 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.”;

v) In sub-regulation (3), in clause (b), the sub-clause (iii) shall be deleted :-

“(iii) Deleted.”;

vi) in sub-regulation (3), in clause (c), for sub-clause (ii), the following 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.”;

vii) in sub-regulation (3), in clause (c), the sub-clause (iii) shall be deleted :-

“(iii) Deleted.”;

viii) in sub-regulation (3), in clause (d), for sub-clause (i), the following shall be substituted, namely:-

“(i) For GCB scheme, Station transformer may not be required. In case of Non-GCB Scheme, the station transformer(s) shall be 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.”;

ix) in sub-regulation (3), in clause (d), for sub-clause (ii), the following shall be substituted, namely:-

“(ii) Station transformer shall be 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.”;

x) in sub-regulation (3), in clause (d), the sub-clause (iii) shall be deleted :-

“(iii) Deleted.”;

xi) in sub-regulation (3), for clause (g), the following 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 if ordered quantity is more than one (whether three phase or single phase) unless such test has been conducted on transformer of same design within last ten (10) years (from the date of placement of order). In case there is a change in design before ten (10) years, the new transformer design shall be validated by carrying out short circuit withstand test”;
- xii) for sub-regulation (4), the following 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.”;
- xiii) for sub-regulation (5), the following 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, diagnostic features and communication facility. The switchgear shall be designed for suitable fault withstanding capability.”;
- xiv) In sub-regulation (6), for clause (d), the following shall be substituted, namely:-
- “(d) The HT busduct (11/6.6/3.3 kV) shall be segregated phase type and LT busduct (415V) shall be non-segregated phase/ sandwich type.”;
- xv) in sub-regulation (7), for clause (c), the following 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.”;
- xvi) in sub-regulation (7), for clause (d), the following shall be substituted, namely:-

“(d) In thermal power stations with unit sizes greater than 100 MW, automatic bus transfer system (consisting of fast, slow etc. transfer in auto mode) shall be provided to minimize time for transfer from unit to station buses at 11/6.6 kV levels. Bus transfer scheme shall also have manual mode to initiate transfer including live changeover through synchronization. The 11/6.6/3.3kV switchgear buses for balance of plant facilities shall be provided with auto-closure facility to changeover supply from one source to another. Critical 415V switchgear buses shall also have auto closure facility to changeover supply from one source to another.”;

xvii) in sub-regulation (7), for clause (e), the following shall be substituted, namely:-

“(e) Auxiliary transformers, as required, shall be provided to meet the demand at various voltage levels of auxiliary power systems, with the criteria that each switchgear, motor control centre (MCC), distribution board (DB) shall be fed by 2x100% transformers/ feeders. The auxiliary transformers shall be designed to carry the maximum expected load. The LV auxiliary transformers shall be energy efficient as per relevant IS 1180.”;

xviii) in sub-regulation (10), for clause (a), the following shall be substituted, namely:-

“(a) Fully graded protection system with requisite speed, sensitivity and selectivity shall be provided for the entire station. Protection system shall be designed so as to avoid mal-operation due to stray voltages. Generator, Generator transformer, unit auxiliary transformer(s) shall be provided with protection systems connected to two independent channels/ groups, such that one channel/ group shall always be available for any type of fault in generator/ generator transformer/ unit auxiliary transformer(s).”;

xix) for sub-regulation (13), the following 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 design capacity.”;

xx) for sub-regulation (14), the following 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, 110/125 V DC may be provided for off-site areas and for Gas Turbines as

applicable. 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.”;

xxi) for sub-regulation (15), the following 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.”;

xxii) in sub-regulation (16), after clause (c), the following clause shall be inserted, namely:-

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

10. In regulation (11) of said regulations, in sub-regulation (2), in clause (b), for sub-clause (iii), the following 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 (ATT) system.”.

11. In regulation (12) of said regulations,-

i) in sub-regulation (4), for clause (e), the following shall be substituted, namely:-

“(e) Waste Water Treatment System

The waste water generated at various locations shall be segregated at the source of generation according to its type. Similar type of waste waters shall be collected at one point and suitably treated for reuse in the plant. The treatment of plant waste water shall be in accordance with the statutory requirements.”;

ii) in sub-regulation (9), for clause (a), the following 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 5% more than the single heaviest equipment to be lifted by the crane.”.

12. In regulation (13) of said regulations, in sub-regulation (7), for clause (c), the following shall be substituted, namely:-

“(c) Chimney windshield shall be of RCC construction. The flue and flue liners shall be of material appropriate as per flue gas condition and provided with suitable thermal insulation. Chimney shall have internal platforms and internal ladder. The top external portion of windshield shall be provided with alternate bands of red and white colours to meet aviation safety requirements. Chimney shall be provided with liner test port for continuous emission monitoring, lightning protection and grounding system, aviation obstruction lighting and an elevator.”.

13. In regulation (29) of said regulations, the following 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 25 MW and above. For hydro-electric generating stations having installed capacity less than 25 MW, the stipulations as appropriate, shall apply.”.

14. In regulation (30) of said regulations,-

i) for sub-regulation (1), the following shall be substituted, namely:-

“(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.”;

ii) for sub-regulation (2), the following shall be substituted, namely:-

“(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.”;

iii) for sub-regulation (4), the following shall be substituted, namely:-

“(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.”;

iv) for sub-regulation (6), the following shall be substituted, namely:-

“(6) 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.”.

15. In regulation (31) of said regulations, for sub-regulation (1), the following shall be substituted, namely:-

“(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.”.

16. In regulation (32) of said regulations, for sub-regulation (8), the following shall be substituted, namely:-

“(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.”.

17. In regulation (33) of said regulations,-

- i) for sub-regulation (5), the following shall be substituted, namely:-

“(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.”;

- ii) for sub-regulation (6), the following shall be substituted, namely:-

“(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, Deriaz & Propeller 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.”;

- iii) for sub-regulation (8), the following shall be substituted, namely:-

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

iv) for sub-regulation (9), the following shall be substituted, namely:-

“(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.”;

v) for sub-regulation (12), the following shall be substituted, namely:-

“(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.”;

vi) for sub-regulation (13), the following shall be substituted, namely:-

“(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.”;

vii) for sub-regulation (15), the following shall be substituted, namely:-

“(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.”;

viii) after sub-regulation (16), the following sub- regulation shall be inserted, namely:-

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

18. In regulation (34) of said regulations,-

i) for sub-regulation (2), the following shall be substituted, namely:-

“(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.”;

ii) for sub-regulation (3), the following shall be substituted, namely:-

“(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.”;

iii) for sub-regulation (4), the following shall be substituted, namely:-

“(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.”.

19. In regulation (35) of said regulations, after sub-regulation (6), the following sub-regulations shall be inserted, namely:-

“(7) 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;

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

20. In regulation (36) of said regulations, -

i) in sub-regulation (1), for clause (b), the following shall be substituted, namely:-

“(b) The hook capacity shall be taken as 5% 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.”;

ii) in sub-regulation (1), for clause (e), the following shall be substituted, namely:-

“(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.”;

iii) in sub-regulation (3), for clause (a), the following shall be substituted, namely:-

“(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.”;

iv) in sub-regulation (3), for clause (b), the following shall be substituted, namely:-

“(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.”;

v) in sub-regulation (5), for clause (a), the following shall be substituted, namely:-

“(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.”;

vi) in sub-regulation (7), for clause (a), the following shall be substituted, namely:-

“(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.”;

vii) in sub-regulation (8), for clause (c), the following shall be substituted, namely:-

“(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 water pumps, each capable of pumping water to fill the overhead water tank in 6 hours time shall be provided.”.

21. In regulation (37) of said regulations,-

i) In sub-regulation (2), in clause (a), for sub-clause (ii), the following shall be substituted, namely:-

- “(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.”;
- ii) In sub-regulation (2), in clause (a), for sub-clause (iv), the following shall be substituted, namely:-
- “(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.”;
- iii) in sub-regulation (2), in clause (a), for sub-clause (vi), the following shall be substituted, namely:-
- “(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.”;
- iv) in sub-regulation (2), in clause (a), for sub-clause (ix), the following shall be substituted, namely:-
- “(ix) Metal oxide surge arresters of suitable rating shall be provided for surge protection of generators.”;
- v) in sub-regulation (2), in clause (a), for sub-clause (xii), the following shall be substituted, namely:-
- “(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.”;
- vi) in sub-regulation (2), in clause (d), for sub-clause (i), the following shall be substituted, namely:-
- “(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.”;
- vii) in sub-regulation (3), for clause (e), the following shall be substituted, namely:-

“(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,2007 and Central Electricity Authority (Grid Standards) Regulations,2010 and as amended from time to time.”;

viii) in sub-regulation (4), for clause (c), the following shall be substituted, namely:-

“(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.”;

ix) in sub-regulation (4), for clause (j), the following shall be substituted, namely:-

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

x) in sub-regulation (4), for clause (k), the following shall be substituted, namely:-

“(k) Short circuit withstand test shall be conducted on one of each type and rating of Generator Transformers to validate the design and quality if ordered quantity is more than one (whether three phase or single phase) unless such test has been conducted on transformer of same design within last ten (10) years (from the date of placement of order). In case there is a change in design before ten (10) years, the new transformer design shall be validated by carrying out short circuit withstand test.”;

xi) in sub-regulation (5), in clause (b), for sub-clause (i), the following shall be substituted, namely:-

“(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.”;

xii) in sub-regulation (5), for clause (c), the following shall be substituted, namely:-

“(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.”;

xiii) in sub-regulation (6), for clause (a), the following shall be substituted, namely:-

“(a) The DC supply systems for hydro power stations shall comprise of batteries, battery chargers and DC distribution boards. The standard voltage rating for the DC system shall be 220V. Suitable converters may be used for other desired voltage levels.”;

xiv) in sub-regulation (6), for clause (f), the following shall be substituted, namely:-

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

xv) in sub-regulation (9), for clause (b), the following shall be substituted, namely:-

“(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.”;

xvi) in sub-regulation (9), for clause (d), the following shall be substituted, namely:-

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

xvii) in sub-regulation (9), after clause (d), the following clause shall be inserted, namely:-

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

xviii) for sub-regulation (10), the following shall be substituted, namely:-

“(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.”;

xix) in sub-regulation (12), after clause (g), the following clause shall be inserted, namely:-

“(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.”.

22. In regulation (38) of said regulations, in sub-regulation (2), for clause (c), the following shall be substituted, namely:-

“(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.”.

23. In regulation (39) of said regulations, -

i) for sub-regulation (6), the following shall be substituted, namely:-

“(6) The DC batteries, battery chargers and DC distribution boards 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.”;

ii) the sub-regulation (7) shall be deleted:-

“(7) Deleted.”.

24. For regulation (41) of said regulations, the following 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 to be installed at different voltage levels shall be considered as shown in Table 6 below.

Table 6

66 kV	31.5 kA (for 1 sec.)
110 kV / 132 kV	31.5 kA / 40kA (for 1 sec.)
220 / 230kV	40 kA / 50 kA (for 1 sec.)

400 kV, 765 kV & 1150 kV

50 kA / 63 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 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/ bus/ transformer/reactor at the respective sub-stations shall be resorted to. Appropriate measures 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 exceed the values indicated in Table 7 below:

Table 7

1150 kV	12000 MVA
765 kV	9000 MVA
400 kV	2000 MVA
220kV / 230 kV	650 MVA
110 kV/ 132 kV	250 MVA
66 kV	100 MVA

Note :- Transformation capacity for switchyard associated with generating station shall be as per requirement of the installed capacity of generating plant.

(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 does not overload the remaining ICTs or the underlying transmission system.

(5) The location, layout, design and construction of the new installation shall provide for future expansion.

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

(7) The sub-station or switchyard shall have IEC-61850 based Substation Automation System (SAS) or Supervisory Control and Data Acquisition (SCADA) System. The SAS / SCADA Gateway shall be capable of communicating with Load Dispatch Centre, backup Load Dispatch Centre and Central Control Centre.”.

25. For regulation (42) of said regulations, the following shall be substituted, namely :-

“(42) Design Considerations for Sub-stations and Switchyards:

(1) The sub-station or switchyard shall be conventional / digital type 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 geographic, environmental, technical and economic factors. 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.

(c) 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.

(b) The selection of switching schemes shall be based upon requirements for operational flexibility, system security, reliability, availability, criticality of load, maintainability and cost.

(c) For new substation with one and half breaker switching scheme, a double circuit line or two different transformers shall be provided in two different diameters.

(2) Air insulated sub-stations (AIS)

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

Table 8

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

--	--

(b) In case of AIS, busbars 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 busbar 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 by provision of overhead shield wire or earthwire or spikes (masts) or a combination thereof as per relevant IS/IEC/IEEE.

(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, seismic prone areas, coastal areas, high altitude areas and very heavily polluted areas. However, techno-economic analysis shall be done to determine the preference for each GIS installation. The GIS shall comply with relevant IS/ IEC standards. The GIS installations shall be outdoor/ indoor/ underground type depending on site requirement.

(a) The switching scheme has a large impact on the total cost of the GIS and shall be properly evaluated for a particular project. The switching schemes as per Table 8a shall be adopted at different voltage levels in GIS.

Table 8a

66 kV	Single bus scheme/ Main and transfer bus scheme
110kV / 132kV	Main and transfer bus scheme/ Double bus scheme
220kV / 230kV	Double bus scheme
400kV/765kV/1150kV	One and half breaker scheme/ Double bus scheme

(b) GIS shall be isolated phase or three phase non-magnetic enclosure type for voltage upto 220kV. For 400kV and above voltage levels, it shall be isolated phase non-magnetic enclosure type.

(c) 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. The layout of Gas Insulated

Bus Ducts shall be properly planned to optimize the length of bus ducts and for easy accessibility for maintenance.

(d) 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 IS/IEC limits and shall necessarily include any component or assembly required for this purpose.

(e) The length of busbars, bus ducts, isolator sections shall be optimized considering effects of fast transient voltage due to isolator operations.

(f) The crane of suitable capacity shall be installed in GIS building for movement of single largest module for maintenance.

(4) Hybrid sub-station- In a hybrid sub-station, the busbars 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 sub-station can be considered as a techno-economic solution for locations where space is a constraint and also for sub-station renovation or augmentation. The switching schemes as per Table 8a shall be adopted at different voltage levels.

(4A) Digital Substation: Digital Substations, wherever installed, shall incorporate 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. The use of conventional Instrument Transformers, Circuit Breakers and Disconnectors with merging unit can also be considered for Digital Substation.

(4B) Mobile Substations: Wherever required, the vehicle mounted mobile substation comprising of trailer, incoming and outgoing HV and LV hybrid switchgears, power transformer, and associated connectors etc. shall be considered for putting into immediate service to resume power supply in short time in case of emergency or disaster. The mobile substation shall comply with provisions of these Regulations, Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations, and other applicable Regulations and Codes.

(5) Grounding:

(a) Grounding system for the entire switchyard, equipment and buildings shall be provided in accordance with relevant IS/ IEEE.

(b) The touch and step potential limits shall be maintained within acceptable limits as per relevant IS/ IEEE standards.

- (c) Special consideration shall be given for GIS earthing design to handle high frequency transients.
 - (d) The use of environmental friendly earthing enhancing compound / material may also be considered, wherever soil resistivity is very high, to achieve the objective of effective grounding system.
 - (e) Condition assessment of earthing mat, earthing pits, earth rod, surface layer material, and associated connections shall be carried out periodically to ensure effectiveness of grounding system.
 - (f) To ensure safety, the step and touch potential measurement within substation / switchyard shall be carried out as per IS/EEE for new installations and measurement shall be repeated for old installations at regular interval and requisite measures shall be taken in case measured values exceed 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. 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.”.

26. In regulation (43) of said regulations, -

i) for sub-regulation (1), the following shall be substituted, namely:-

“(1) System design parameters

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

(Table on next page)

Table 9

Nominal System Voltage Parameter	66 kV	110 kV	132 kV	220kV/230 kV	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 1425 (for GIS)	1800
(iii) One minute power frequency withstand voltage dry(kV_{rms})	140	230	275	460	630 650 (for GIS)	830 960 (for GIS)	1200
Minimum corona extinction voltage (kV_{rms} phase to earth)	-	-	-	-	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)(at	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						

Note:-

(i) For insulation level of transformers and reactors refer Table 10.

(ii) Values given in the table are preferred values, however, better values may be adopted based on system requirement.

(iii) 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

Highest voltage for equipment	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	970	1550	2100
420kV	570	1050	1300	695	1050	1425
245kV	395	750	950	505	850	1050
145kV	275	-	650	305	-	650
123kV	255	-	550	255	-	550
72.5kV	140	-	325	155	-	325
52kV	95	-	250	105	-	250
36kV	70	-	170	77	-	170
24 kV	50	-	125	55	-	125
17.5kV	38	-	95	42	-	95
12 kV	28	-	75	30	-	75

Note:-

(i) Values given in the table are preferred values, however, better values may be adopted based on system requirement.

(ii) 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.”;

ii) in sub-regulation (2), for clause (a), the following shall be substituted, namely:-

“(a) Power Transformers

- (i) The transformers shall comply with relevant IS/IEC standards.
- (ii) Transformer banks (formed out of single phase units) or 5 limbed 3 phase units shall be provided with tertiary windings of rating one third of HV rating.
- (iii) The transformers shall be provided with on load tap changer (OLTC) based on power system requirement. In case, transformers are provided with OLTC, the tap range shall be optimized depending on system requirement.
- (iv) 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), if parallel operation is desired.
- (v) Interconnecting transformers provided with OLTCs shall be suitable for bi-directional flow of power.
- (vi) Noise level of transformer, when energized at normal voltage and frequency with fans and pumps running and measured under standard operating condition shall not exceed the values specified in NEMA standard.
- (vii) Soak Pit:
 - a) An oil soak pit of adequate capacity shall be provided below each oil filled transformer/ reactor to accommodate at least 150% of full quantity of oil contained in the transformer/reactor and minimum 300 mm thick layer of gravels or pebbles of approximately 40 mm size.
 - b) 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 40 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.
 - c) 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.
 - d) Every soak pit below a transformer/reactor shall be suitably designed to contain oil dropping from any part of the transformer/reactor.

- e) 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.
- f) The disposal of transformer oil shall be carried out in an environmental friendly manner.

(viii) Separation walls or fire barrier walls:

- a) Separation walls or fire barrier walls shall be provided between the transformers or reactors and also between transformer and reactor as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations.
- b) Separation walls or fire barrier walls of minimum 4 hours fire resistance shall be provided between the transformer/reactor and nearby buildings 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.
- c) Separation wall or fire barrier wall shall extend at least 300 mm above the top of the transformer casing and oil conservator tank and at least 600 mm beyond the width of the transformer and cooling radiators.

(ix) The transformers may be single phase or three-phase type depending upon transportation constraints.

(x) In case single phase transformers are provided, one single phase transformer of each rating shall be provided as spare for the entire substation or switchyard.

(xi) 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 10(ten) years on transformer of same design and rating. In case there is change in design, the new transformer design shall be validated by carrying out short circuit withstand test.

(xii) Fibre Optic Sensors shall be used for Hot spot monitoring of winding/ oil/ core of transformers in addition to WTI/OTI for 400kV and above voltage class transformers.

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

iii) in sub-regulation (2), in clause (b), for sub-clause (i), the following shall be substituted, namely:-

“(i) Shunt Reactors

a. Shunt reactors, wherever provided, shall comply with relevant IS/IEC standards.

b. Shunt reactors upto 420 kV rated voltage shall have linear voltage vs. current (V/I) characteristics upto 1.5 p.u. voltage. 800kV Shunt reactors shall have linear V/I characteristics upto 1.25 p.u. voltage.

c. Wherever required, the neutral of the line reactors shall be grounded through adequately rated Neutral Grounding Reactors (NGR) to facilitate single phase auto-reclosure. 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. The neutral of bus reactor shall be solidly grounded.

d. The neutral of shunt reactor of 420kV and 800kV rated voltage shall be insulated to 550kV peak for lightning impulse. The neutral of shunt reactor of 145kV and 245kV rated voltage shall be insulated to 170kV peak for lightning impulse.

e. The NGR, wherever used with line reactors of 420 kV and 800 kV rated voltage, shall be protected by means of 145 kV class surge arresters of suitable rating.

f. In case single phase shunt reactors are provided, then one single phase unit shall be provided as spare for entire substation or switchyard.”;

iv) in sub-regulation (2), in clause (b), for title of sub-clause (ii), the following shall be substituted, namely:-

“(ii) Shunt Capacitors”;

v) in sub-regulation (2), in clause (b), after sub-clause (ii), the following sub-clause shall be inserted, namely:-

“(iii) Controlled Shunt Reactor (wherever provided)

a. The Controlled Shunt Reactor (CSR) shall comply with relevant IS/IEC.

b. The CSR shall generally consist of Controlled Shunt Reactor Transformer (CSRT), thyristor valves, controller, neutral grounding reactor, necessary circuit breakers and other auxiliaries.

c. Studies shall be carried out to assess any requirement of harmonic filters.”;

vi) In sub-regulation (2), for clause (c) to (j), the following shall be substituted, namely:-

“(c) Circuit Breakers

- i) Circuit breakers shall comply with relevant IS/IEC standards.
- ii) The Circuit Breaker shall be of live tank or dead tank design.
- iii) The interrupting medium of circuit breakers shall be vacuum/ SF6/ any other suitable gas or combination of gases.
- iv) 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 132kV class suitable for single phase auto- reclosing is also acceptable.
- v) The circuit breaker shall be of class M2 with regard to mechanical endurance as per IEC Standard.
- vi) Each circuit breaker shall be provided with 2 nos. of trip coils. Two sets of trip circuits shall be connected by separate fuse or miniature circuit breaker (MCB) to two separate DC supply feeders for greater reliability.
- vii) The circuit breaker shall have the provision for local manual trip which shall be at a position easily accessible to the operating person.
- viii) Rated break time for circuit breakers shall be as given in Table 11 below:

Table 11

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

- ix) In accordance with the power system requirement, the circuit breakers of 400kV and above class shall be provided with Pre insertion resistors (PIR) or Controlled Switching Devices (CSD) for controlling switching overvoltage on lines of length more than 200 km.

- x) CSD can also be considered as a tool for minimizing switching transients & inrush currents in 400kV and above voltage class transformers and reactors. 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

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

(e) Current Transformers

- i) Current transformers shall comply with the relevant IS/IEC standards.
- ii) 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.

- iii) The rated burden of cores shall be closer to the maximum burden requirement of metering & protection system for better sensitivity and accuracy.
 - iv) Instrument Security factor (ISF) shall be less than 5 for CTs upto 400kV voltage class and less than 10 for CTs of 765 kV and 1150kV voltage class.
 - v) 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.
 - vi) Digital optical current transformers and SF₆ current transformers shall also be acceptable in place of conventional current transformers.
- (f) Voltage Transformers
- i) Voltage transformers shall comply with the relevant IS/IEC standards.
 - ii) The number of secondary cores, accuracy class and burden shall be in accordance with the requirements of the protection and metering system.
 - iii) The rated burden of VT cores shall be closer to the maximum burden requirement of metering & protection system for better sensitivity & accuracy and it shall not exceed 50VA.
 - iv) 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.
 - v) Voltage transformers can be either electromagnetic type or capacitive type. Wherever PLCC is provided, 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.
 - vi) Digital optical voltage transformers shall also be acceptable in place of conventional voltage transformers.
 - vii) In case of GIS installations, SF₆ filled voltage transformers shall be electromagnetic type.
- (g) Surge Arresters
- i) Station class, heavy duty, gapless metal oxide (ZnO) type surge arresters shall comply to relevant IS/IEC standards.

- ii) 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.
- iii) Surge arresters shall be provided at locations decided in accordance with insulation coordination studies.
- iv) 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.
- v) Arrester with composite insulator housing with sufficient cantilever strength is also acceptable to prevent shattering during arrester failure.
- vi) A leakage current monitor with surge counter shall be provided with each surge arrester.

(h) Line Trap

- i) Wherever Power Line Carrier Communication (PLCC) has been provided, the line trap shall be used complying with the relevant IS/IEC standards.
- ii) Line trap 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.
- iii) The tuning device shall be so arranged as to permit replacement without removing the line trap.
- iv) The tuning as well as protective device shall be so designed that neither significant alteration in the line trap blocking requirements/protective function 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.

(i) Insulators

- i) Porcelain, Glass or composite type insulators complying with the relevant IS/ IEC standards shall be used.
- ii) The minimum specific creepage distances of insulators shall be 25 mm/ kV line to line voltage for medium & heavy pollution level areas and 31 mm/kV line to line voltage for very heavy pollution and coastal areas.

(j) Insulation performance enhancement

In highly polluted areas, coastal areas etc. composite insulators or porcelain/glass insulators coated with proven coating material of long life shall be used as a measure for further improvement in insulator performance.”;

vii) in sub-regulation (2), after clause (j), the following clause shall be inserted, namely :-

“(k) Phase Shift Transformers(PST)

i) Phase Shift transformers shall comply with the relevant IS/IEC standards.

ii) Phase Shift Transformers (PST) can be planned to control real power flow in transmission lines for better utilization of existing network.

iii) The rating, phase shift angle and location shall be decided based on system studies.

iv) For variable phase shift, On Load Tap Changers (OLTCs) shall be provided.

v) The PST shall be provided with all necessary protection & control systems.

vi) Suitable provisions shall be made for bypassing of PST, wherever required. ”;

viii) in sub-regulation (3), in clause (a), after sub clause (ii), the following sub clauses shall be inserted, namely :-

“(iii) DC system shall comprise of two DC battery sets (both battery sets of full capacity) each with one float cum boost charger.

(iv) The voltage rating for the DC system for control & protection for 66 kV and 132 kV substations shall be 110V or 220V DC and for 220 kV and above substations it shall be 220 V DC.”;

ix) in sub-regulation (3), in clause (b), for sub-clause (ii), the following shall be substituted, namely:-

“(ii) Fire protection system for transformers or reactors shall be provided as per Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations, 2010 and as amended from time to time.”;

x) in sub-regulation (3), for clause (d), the following shall be substituted, namely:-

“(d) Control Room

- i) Sub-station or switchyard control room shall be provided to house the SAS/ SCADA system.
- ii) In case of centralized system, the control and relay panels shall also be placed in control room.
- iii) The PLCC equipment, Optical Line Terminal Equipment, telemetry equipment and recording equipment, AC and DC distribution boards, DC batteries etc. shall be kept in separate rooms depending on sub-station layout.
- iv) Air conditioning shall preferably be provided in the control room as a functional requirement.
- v) In case of substation or switchyard with distributed architecture, Bay Control Units, intelligent electronic devices (IEDs) shall be placed appropriately in kiosks/ control building within the sub-station.”;

xi) in sub-regulation (4), for clause (a), the following shall be substituted, namely:-

“(a) Protective Relaying System

- (i) Selective, sensitive, fast, graded and reliable protection system shall be provided for transmission lines, transformers, reactors, bus bars, EHV cables, etc. so as to automatically isolate the faulty element.
- (ii) All main protection relays shall be of numerical type and communication protocol shall be as per IEC-61850/ relevant IS.
- (iii) 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.”;

xii) in sub-regulation (4), for clause (d) to (f), the following shall be substituted, namely:-

“(d) Disturbance Recorders, Event Loggers and Time Synchronization Equipment-

- (i) Each line shall be provided with facility for disturbance recording, event logging, distance to fault locator and time synchronizing equipment (TSE).

(ii) Event logger and disturbance recorder shall be provided as part of sub-station or switchyard automation system for substation or switchyard upto 400 kV voltage class.

(iii) In addition to inbuilt disturbance recorder, a common Standalone disturbance recorder shall also be provided for 765 kV and above voltage class substation or switchyard.

(iv) 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.

(e) Optical Ground Wire (OPGW)/Power Line Carrier Communication (PLCC)-

(i) OPGW along with necessary terminal equipment shall be provided on transmission lines of voltage rating of 132 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.

(ii) 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.

(iii) 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

i) All the breakers in sub-stations and switching stations shall be monitored, controlled and synchronized from the substation control room.

ii) In case of switchyard associated with generating station, the incoming and outgoing feeder circuit breakers shall be monitored, controlled and synchronized from the plant control room.

iii) Provision for operation of circuit breakers and disconnectors from remote control stations may also be provided wherever required.”;

xiii) in sub-regulation (4), after clause (f), the following clause shall be inserted, namely:-

“(g) Phasor Measurement Units (PMU)

i) Synchro- phasor measurement using PMUs alongwith fibre optic connectivity, GPS Receiver and communication equipment shall be provided for monitoring the entire interconnected grid on real time basis on substations at 400kV and above level, switchyard of generating stations at 220kV & above level, AC side of converter bays of HVDC stations and pooling point of renewable energy generation of 50MW and more.

(ii) PMUs shall comply with IEC/IEEE Standards. Data transmission of PMUs shall comply to latest IEEE C37.118 Standard.

(iii) The dispersedly located PMUs shall communicate with Phasor Data Concentrators (PDCs) installed at certain strategic locations at State, Regional and National level.”;

xiv) for sub-regulation (5), the following shall be substituted, namely:-

“(5) Power and Control Cables

a) Cables shall be Flame Retardant Low Smoke & Halogen (FRLSH) type as per relevant IS/ IEC.

b) 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.

c) In outdoor switchyards, a cable trench system shall be provided.

d) A comprehensive philosophy of segregation and proper spacing shall be maintained.

e) Power cables and control cables shall be laid on separate tiers.

f) 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.”.

27. In regulation (44) of said regulations, the following shall be substituted, namely:-

“(44) **Salient Technical Particulars/ Requirements of High Voltage Direct Current (HVDC) Terminals Stations-** (a) 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.

(b) 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.

(c) The life of HVDC installation (s) shall not be less than 35 years.

(d) 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.

(e) The interfacing with the DC line (overhead / cable), existing AC network, telecommunication network and load dispatch center shall be properly planned and designed.

(f) 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.”.

28. The regulation (45) of said regulations shall be deleted, namely:-

“(45) Deleted.”.

29. For regulation (46) of said regulations, the following shall be substituted, namely:-

“(46) **Condition Monitoring of Equipment, Asset Management and security of Sub- station and Switchyard –**

(a) Diagnostic equipment shall be provided to assess the health of various equipment in substations and switchyards.

(b) 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.

(c) 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 for circuit breaker, and leakage current monitor for surge arrester for measurement of third harmonic resistive current, 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.

(d) Condition Based Maintenance (CBM)/ Reliability Centered Maintenance(RCM) Practice shall be followed for condition assessment of all substation equipment.

(e) 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.

(f) 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, to optimize asset's depreciation, life cycle, monitoring & maintenance with the objective to maximize the efficiency and utilization of capital intensive assets.

(g) 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.”.

30. In regulation (47) of said regulations, for Table 14, the following table 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

”.

31. In regulation (48) of said regulations,-

i) for sub-regulation (2), the following 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.”;

ii) for sub-regulation (3), the following shall be substituted, namely:-

“(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.”;

iii) for sub-regulation (5), the following shall be substituted, namely:-

“(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.”;

iv) for sub-regulation (6), the following shall be substituted, namely:-

“(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.”.

32. In regulation (50) of said regulations, for sub-regulation (1), the following shall be substituted, namely:-

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

33. In regulation (54) of said regulations,-

i) for sub-regulation (3), the following 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.”;

ii) for sub-regulation (5), the following shall be substituted, namely:-

“(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,2010 and as amended from time to time. Outdoor dry-type transformer may be non-ventilated type.”;

iii) for sub-regulation (6), the following shall be substituted, namely:-

“(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.”;

iv) for sub-regulation (9), the following shall be substituted, namely:-

“(9) A transformer with off-circuit tap changer shall have taps ranging from (+)5 % to (-) 10% in steps of 2.5% each on the higher voltage winding for variation in the voltage. The tap changing switch shall be located in a convenient position so that it can be operated from ground level. The switch handle will be provided with a locking arrangement along-with tap position indication, for locking the switch.”;

v) for sub-regulation (10), the following shall be substituted, namely:-

“(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 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.”;

vi) for sub-regulation (13), the following shall be substituted, namely:-

“(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 and as per Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations,2010 and as amended from time to time.”;

vii) for sub-regulation (14), the following shall be substituted, namely:-

“(14) 33kV 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,2010 and as amended from time to time and relevant IS.”;

viii) for sub-regulation (16), the following shall be substituted, namely:-

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

34. In regulation (55) of said regulations, for sub-regulation (4), the following shall be substituted, namely:-

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

35. In regulation (57) of said regulations, for sub-regulation (4), the following shall be substituted, namely:-

“(4) The creepage distances for different pollution levels shall be as per table 12 at Regulation 43.”.

36. In regulation (58) of said regulations, for sub-regulation (2), the following 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.”.

37. In regulation (59) of said regulations, for sub-regulation (1), the following 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. The rated voltage for the circuit breakers shall be 36 kV, 24kV and 12 kV for 33 kV, 22kV and 11 kV systems respectively.”.

38. In regulation (60) of said regulations, -

- i) for sub-regulation (1), the following shall be substituted, namely:-

“(1) The isolators shall be of adequate capacity as per requirement and shall comply with relevant IS.”;

- ii) for sub-regulation (5), the following shall be substituted, namely:-

“(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.”.

39. In regulation (61) of said regulations, -

- i) for sub-regulation (1), the following 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.”;

- ii) in sub-regulation (4), for clause (a), the following shall be substituted, namely:-
- “(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.”.
40. In regulation (61) of said regulations, after sub-regulation (4), the following sub-regulation 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.”.
41. In regulation (62) of said regulations, for sub-regulation (2), the following 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.”.
42. In regulation (63) of said regulations,-
- i) in sub-regulation (1), for clause (e), the following shall be substituted, namely:-
- “(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,2006 and as amended from time to time.”;
- ii) in sub-regulation (2), for clause (c), the following shall be substituted, namely:-
- “(c) Voltage transformers shall be of electromagnetic type or solid state type.”;
- iii) in sub-regulation (2), for clause (f), the following shall be substituted, namely:-
- “(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,2006 and as amended from time to time.”.
43. In regulation (64) of said regulations, after sub-regulation (3), the following sub-regulations 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.”.
44. In regulation (65) of said regulations, for sub-regulation (2), the following 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, 2010 and as amended from time to time.”.
45. In regulation (66) of said regulations,-
- i) for sub-regulation (2), the following shall be substituted, namely:-
- “(2) Capacitors, residual voltage transformer and neutral current transformer shall be as per relevant IS.”;
- ii) for sub-regulation (9), the following shall be substituted, namely:-
- “(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.”.
46. In regulation (67) of said regulations, for sub-regulation (2), the following 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.”.
47. In regulation (68) of said regulations, for sub-regulation (1), the following 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.”.
48. For regulation (69) of said regulations, the following shall be substituted, namely:-

“(69) **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.”.

49. In regulation (70) of said regulations,-

i) in sub-regulation (2), for clause (a), the following shall be substituted, namely:-

“(a) The 24V/ 30V/ 48V/110V/ 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.”;

ii) for sub-regulation (3), the following shall be substituted, namely:-

“(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.”;

iii) for sub-regulation (5), the following shall be substituted, namely:-

“(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.”.

50. For regulation (71) of said regulations, the following shall be substituted, namely:-

“(71) **Fencing and Approach Arrangement**- Fencing/ boundary wall of suitable height shall be provided around the sub- station as per CEA (Measures relating to Safety and Electric Supply) Regulations, 2010 and as amended from time to time. A metalled approach road to transport the equipment should be provided leading from the main road.”.

51. In regulation (72) of said regulations, for sub-regulation (2), the following 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 substation 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.”.

52. In regulation (73) of said regulations, for sub-regulation (2), the following shall be substituted, namely:-

“(2) The firefighting 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, 2010 and as amended from time to time.”.

53. In regulation (74) of said regulations, for Table 15, the following table 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

54. In regulation (74) of said regulations, -

- i) after sub-regulation (1), the following sub-regulation shall be inserted, namely:-

“(1A) For consumers supplied at voltage not exceeding 650 V (except mines and oil fields), the r.m.s value of voltage at the point of commencement of supply of electricity shall be as follows:

- (a) Single phase 230 volts between phase and neutral,
- (b) Three phase 400 volts between phases.

Provided that the permissible variation in voltage at the point of commencement of supply of electricity shall be as per relevant Indian Standard”;

ii) for sub-regulation (2), the following shall be substituted, namely:-

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

iii) for sub-regulation (3), the following shall be substituted, namely:-

“(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.”;

iv) for sub-regulation (5), the following shall be substituted, namely:-

“(5) The DSS can be conventional, package type or completely self protected (CSP) type or Vertical Type (DT on ground with RMU & LT switches above DT on another platform or vice versa).”.

55. In regulation (75) of said regulations,-

i) for sub-regulation (1), the following shall be substituted, namely:-

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

ii) for sub-regulation (2), the following shall be substituted, namely:-

“(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, 2010 and as amended from time to time.”;

iii) in sub-regulation (4), the clause (b) shall be deleted:-

“(b) Deleted.”;

iv) in sub-regulation (4), the clause (c) shall be deleted:-

“(c) Deleted.”;

v) in sub-regulation (4), for clause (d), the following 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.”;

vi) for sub-regulation (5), the following shall be substituted, namely:-

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

vii) the sub-regulation (9) shall be deleted:-

“(9) Deleted.”.

56. In regulation (77) of said regulations, for sub-regulation (5), the following shall be substituted, namely:-

“(5) The plinth shall be higher than the surroundings. The plinth shall be of Concrete/ Metal (properly earthed)/ fire resistant fibre glass of adequate strength to withstand the load. The plinth can be pre-fabricated also. The plinth foundation shall be of Concrete.”.

57. In regulation (78) of said regulations, for sub-regulation (1), the following 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.”.

58. In regulation (79) of said regulations, -

i) for sub-regulation (3), the following shall be substituted, namely:-

“(3) The distribution box shall be mounted at a height of 1.5 metres for pole mounted distribution transformers while the feeder pillar box can be installed at ground level with adequate clearance. For single phase transformer, the distribution box can also be directly mounted on the body of transformer.”;

ii) for sub-regulation (4), the following shall be substituted, namely:-

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

59. In regulation (80) of said regulations, before sub-regulation (1), following shall be inserted, namely:-

“Protection System - The protection system of transformers shall be as per Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010 and as amended from time to time.”.

60. In regulation (81) of said regulations, for sub-regulation (1), the following 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 Electricity Supply) Regulations, 201 and as amended from time to time and three (3) earth pits with three (3) grounding electrodes shall be provided.”.
61. In regulation (82) of said regulations, for sub-regulation (1), the following 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.”.
62. In regulation (83) of said regulations, for sub-regulation (2), the following 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 and as amended from time to time.”.
63. In regulation (86) of said regulations, for sub-regulation (2), the following 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 his new installation shall abide by the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and as amended from time to time.”.
64. In regulation (87) of said regulations, after sub-regulation (3), the following sub-regulations shall be inserted, namely:-
- “(4) As far as possible, transmission towers of the overhead lines shall be designed for at least Double circuit configuration.
- (5) Multi-circuit (more than two circuits) towers for overhead lines shall be considered as an alternative for parallel lines passing through forest, eco- sensitive zone, wildlife sanctuary and urban areas.”.
65. In regulation (89) of said regulations, -

i) in sub-regulation (1), for clause (a) to (c), the following shall be substituted, namely:-

“(a) Electrical Design Parameters of the Transmission Lines

(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	110kV/ 132kV AC	220kV/ 230 kV AC	400 kV AC	765 kV AC	±500kV HVDC	±800 kV HVDC	1150 kV AC
Nominal voltage (kV)	66	110/ 132	220/ 230	400	765	500	800	1150
Highest system voltage (kV)	72.5	123/ 145	245	420	800	525	840	1200
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 under wet condition (kV _{peak})	-	-	-	1050	1550	1000	1600	1800
Minimum corona extinction voltage under dry condition (kV _{rms} phase to earth)	-	-		320	610	550	880	762
Maximum radio interference voltage 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 880 kV)	1000 (at 762 kV rms)

ii) For the transmission lines at altitudes higher than 1000 m above MSL, basic insulation level, impulse & switching surge withstand voltage requirements

shall be kept higher than those indicated in Table 16 as per relevant standards and practices.

iii) Values given in the Table 16 are preferred values, however, better values may be adopted based on system requirement.

iv) The phases of AC transmission lines shall be transposed in approximately three equal parts, wherever the length of the line is more than 100 km or as per system studies requirements.

(b) Conductor

i) The conductor of appropriate size shall be selected considering power flow requirements and other system considerations.

ii) 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. .

iii) The conductors shall be Aluminum Conductor Steel Reinforced (ACSR), All Aluminum Alloy Conductor (AAAC) or Aluminium Alloy Conductor Steel Reinforced (AACSR) or High Performance conductors (HPC)/ High Temperature and Low Sag (HTLS) conforming to relevant IS/ IEC.

(c) Earthwire

(i) The earthwire of appropriate size to cater to predicted and design fault currents and lightning shall be used.

(ii) Single earthwire shall normally 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.

(iii) The earthwire used in 132 kV 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.

(iv) OPGW shall comply with provisions of Regulation 43(4)(e).”;

ii) in sub-regulation (1), in clause (d), for sub-clause (i), the following shall be substituted, namely:-

- “(i) General- (A) The towers shall be self-supporting lattice steel type and shall be a fully galvanised structure. Alternatively, guyed or pole/ monopole structure towers and towers with insulated cross arms shall also be acceptable.
- (B) Type of towers, design and ruling span, wind & weight spans, extension and truncation provisions etc. shall be selected by the Owner as per prudent utility practices.
- (C) Live-metal clearances, mid-span clearance, shielding angle etc. shall be decided as per prudent utility practices following applicable standards and codes and keeping in view electrical system parameters and requirements, line altitude and other service conditions and factors.
- (D) Ground clearance shall be as per requirements of Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010 and as amended from time to time.”;
- iii) in sub-regulation (1), in clause (d), for sub-clause (ii), the following shall be substituted, namely:-
- “(ii) Design of Towers
- (A) The lattice towers shall be designed to meet all design requirements and design criteria stipulated in relevant IS.
- (B) The Guyed towers, pole/monopole towers and lattice towers with insulated cross-arms shall be designed as per applicable IS or IEC.
- (C) Wind loading corresponding to applicable wind zone shall be considered as per relevant IS.
- (D) The towers shall also be designed for appropriate snow or ice loads, wherever applicable.
- (E) 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) considering various combinations of design temperatures, wind and snow loads shall be calculated and tower designs shall be developed accordingly.
- (F) 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, provided that multi circuit towers (towers with more than 2 circuits) for transmission lines upto 400 kV shall be designed corresponding to the reliability level-2 (150 year return period).

- (G) Reliability level-2 corresponding to 150 year return period design loads due to wind as per relevant IS shall be considered for design of towers for transmission lines above 400 kV.
- (H) Reliability level-3 corresponding to 500 year return period shall be considered for tall river crossing towers and special towers.
- (I) Normal towers shall be prototype tested as per relevant IS. It shall not be mandatory to have prototype testing of tall river crossing towers and other special towers designed for reliability level-3 (500 year return period).”;
- iv) in sub-regulation (1), in clause (d), for sub-clause (iii), the following shall be substituted, namely:-
- “(iii) Materials
- (A) Mild steel and high tensile steel sections of tested quality in conformity with relevant IS shall be used in towers and their extensions.
- (B) Fasteners, bolts and nuts shall be as per relevant IS.
- (C) Material for monopole structure shall conform to relevant IS/ASCE/ASTM.”;
- v) in sub-regulation (1), in clause (d), for sub-clause (vi), the following shall be substituted, namely:-
- “(vi) Earthing
- (A) 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.
- (B) As per site requirement, multiple earthing arrangements or earthing enhancement material can also be used for earthing of towers.
- (C) Additional earthing shall be provided on towers after every 7 to 8 kms distance for direct earthing of shield wires.”;
- vi) in sub-regulation (1), in clause (e), for sub-clause (i), the following shall be substituted, namely:-
- “(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.”;
- vii) in sub-regulation (1), in clause (e), for sub-clause (ii), the following shall be substituted, namely:-

“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 foundations shall be as per relevant IS.”;

viii) in sub-regulation (1), for clause (f), the following 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 complying with the relevant IS/IEC standards shall be used.

ii) Number of insulators and creepage distance shall be selected based on electrical system parameters and site specific factors like line altitude, expected environmental and pollution conditions etc.

iii) The minimum specific creepage distance of insulators shall be 25 mm/ kV line to line voltage for low, medium & heavy pollution level areas and 31 mm/ kV line to line voltage for very heavy pollution and coastal areas.

iv) For low, medium and heavy pollution level areas, porcelain/glass disc or longrod insulators shall generally be used. In very heavily polluted areas, coastal areas etc. composite insulators or porcelain/glass insulators (with or without RTV coating) shall be used. To ensure quality, the silicone content in composite insulator or RTV silicone coating shall be minimum 30%.

v) For major crossings like river crossings /power line crossings (132 kV or above), railways/ road crossings (express way, national highway & state highway) porcelain longrod insulators or glass insulators in double string configuration shall be used.

vi) Grading rings shall be provided with porcelain disc insulator strings for 132 kV and above voltage class lines and corona rings shall be provided with all polymer insulator strings for 220kV and above voltage class lines.”;

ix) in sub-regulation (1), after clause (g), the following clause shall be inserted, namely:-

“(h) Line Surge Arresters

Line Surge Arresters 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 IS/ IEC.”;

x) for sub-regulation (2), the following shall be substituted, namely:-

“(2) Transmission Line Construction

(a) Crossing by a transmission line

i) 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.

ii) For power line crossing of 400kV and above voltage class, large angle towers of deviation angle of 30-60 degree & designed for dead end condition, with required body extension to maintain adequate safety clearance, shall be used on both sides of the power line crossing.

iii) 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.

(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, 2010 and as amended from time to time.

(c) Clearances from trees, forest clearances etc. shall be provided in accordance with Forest Conservation Act and guidelines issued by Ministry of Environment, Forest & Climate Change.

(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)
\pm 800 kV HVDC	350 to 450
\pm 500 kV HVDC	350 to 450
1200 kV/ 765 kV AC	350 to 450

400 kV AC	350 to 450
230 kV/ 220 kV AC	325 to 400
132 kV/110 kV AC	300 to 350
66 kV AC	200 to 300

Note :-The reduced design span for monopole/narrow base structure shall be considered based on techno-economic analysis.”;

xi) for sub-regulation (3), the following shall be substituted, namely:-

“(3) Service conditions: Equipment and material to be used in the transmission line shall be suitable for satisfactory continuous operation under tropical conditions as specified in the Table 18 below:

Table 18

Maximum ambient temperature (°C)	As per meteorological or climatological data published by Indian Meteorological Department
Minimum ambient temperature (°C)	
Relative humidity (% range)	
Maximum annual rainfall/ snowfall (cm)	
Wind zone	As per relevant IS
Maximum wind velocity (m/sec)	
Altitude above mean sea level (metres)	As per actual

”;

xii) for sub-regulation (4), the following shall be substituted, namely:-

“(4) Cables and Gas Insulated Lines (GIL)- Wherever construction of an overhead transmission line is not possible due to space constraints or right- of- way problems, XLPE cables conforming to relevant IS/IEC shall be considered for transmission of power. Gas Insulated Lines (GIL) conforming to relevant IS/IEC shall be considered as an alternative to EHV XLPE cables based on techno-economic analysis.”;

xiii) the sub-regulation (5) shall be deleted, namely:-

“(5) Deleted.”;

xiv) after sub-regulation (5), the following sub-regulations shall be inserted, namely:-

“(6) **Strengthening of existing towers**

The towers of old lines which have been designed according to old standards, shall be strengthened in line with latest IS codes in phased manner on case to case basis depending upon the history of failures.

(7) Condition assessment of towers and earthing system

(a) Utilities shall assess the condition of structure of towers, conductors, earthwire, all associated accessories, foundation and earthing system periodically using modern techniques & diagnostic tools and shall take appropriate action, wherever abnormality is noticed.

(b) For condition assessment of conductors, clamps, connectors, insulators etc, provision for on-line/ off-line diagnostic tools and equipment shall be made.

(c) On-line tools shall include thermo-vision camera for detection of hot spots, corona camera and live line punctured insulator detector and aeolian vibration measuring device.

(d) Off-line tools shall include insulation resistance, contact resistance and tower footing impedance measuring devices.

(e) The on-line/ off-line fault locator shall be used for locating the transmission line faults.

(8) Use of helicopter and UAV

Use of helicopter/ Unmanned Aerial Vehicle (UAV) for faster erection & commissioning of transmission line and also for survey and patrolling of transmission lines, particularly in difficult and inaccessible terrain, may be considered by the transmission licensees as technology options. However, required clearance from Director General of 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 its 220kV and above voltage class transmission lines through the use of "Emergency Restoration Systems (ERS)".

(10) Use of GIS platform

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

66. In regulation (90) of said regulations, for sub-regulation (2), the following 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.”.

67. In regulation (91) of said regulations, for Table 19, the following table shall be substituted, namely:-

“Table: 19

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

68. In regulation (92) of said regulations, -

- i) in sub-regulation (1), for clause (d), the following shall be substituted, namely:-

“(d) Adequate capacity for load growth at least for next 5 years;”;

- ii) for sub-regulation (4), the following shall be substituted, namely:-

“(4) Composite lines (i.e. lines having different voltage levels) and multi circuit lines shall be adopted by the Owner as per requirement.”.

69. In regulation (93) of said regulations, -

- i) for sub-regulation (5), the following 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.”;

ii) for sub-regulation (8), the following shall be substituted, namely:-

“(8) The electric line shall be far off from slaughterhouses and garbage dumping grounds to prevent interruptions by bird hits.”.

70. In regulation (95) of said regulations,-

i) for sub-regulation (1), the following 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 33kV and 22kV lines as per site requirement. The lines shall preferably be double circuit or multi circuit.”;

ii) for sub-regulation (2), the following shall be substituted, namely:-

“(2) Poles shall be used for 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.”;

iii) for sub-regulation (3), the following shall be substituted, namely:-

“(3) Poles shall conform to relevant IS/ IEC as the case may be.”;

iv) for sub-regulation (6), the following shall be substituted, namely:-

“(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.”;

v) for sub-regulation (7), the following shall be substituted, namely:-

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

71. In regulation (98) of said regulations, the following shall be substituted, namely:-

“(98) **Factor of Safety-** 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, 2010 and as amended from time to time.”.

72. In regulation (99) of said regulations,-

i) for sub-regulation (2), the following 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.”;

i) for sub-regulation (6), the following shall be substituted, namely:-

“(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.”.

73. In regulation (103) of said regulations, the following shall be substituted, namely:-

“(103) **Danger Plates-** Danger Plates shall be provided on electric lines in accordance with Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations, 2010 and as amended from time to time.”.

74. In regulation (107) of said regulations, the following shall be substituted, namely:-

“(107) **LT Spacers-** To avoid clashing and accidental mutual touching of bare overhead conductors on LT lines, spacers (of adequate Dielectric strength), which can be either spiral or composite shall be provided in between conductors at appropriate locations in different spans (particularly for lines having longer spans or lines having large sags encountering high winds).”.

75. In regulation (108) of said regulations,-

i) for sub-regulation (1), the following 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 to relevant International standards.”;

ii) for sub-regulation (3), the following shall be substituted, namely:-

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

iii) for sub-regulation (4), the following shall be substituted, namely:-

“(4) Underground Cables shall normally be laid in trenches 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 be laid in pipes or cables with co-extruded pipes may also be laid, through trench less method as per the site requirement.”;

iv) for sub-regulation (5), the following shall be substituted, namely:-

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

v) for sub-regulation (6), the following shall be substituted, namely:-

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

vi) for sub-regulation (7), the following shall be substituted, namely:-

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

76. In regulation (109) of said regulations,-

i) for sub-regulation (3), the following 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, 2010 and as amended from time to time.”;

ii) for sub-regulation (4), the following shall be substituted, namely:-

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

77. In regulation (111) of said regulations,-

i) for sub-regulation (1), the following shall be substituted, namely:-

“(1) The overall protection system of feeders shall be as per Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010 and as amended from time to time. The protection scheme settings shall be finalized by the Owner based on prudent utility practice.”;

ii) for sub-regulation (2), the following shall be substituted, namely:-

“(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, 2010 and as amended from time to time.”.

78. In the said regulations, for SCHEDULE- V, the following SCHEDULE- V 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/ 230 kV	132 kV/ 110 kV/66 kV
(a)	Main I- Distance protection*	Y	Y	Y	Y (for 132 kV/110 kV) Y/N (for 66 kV)
(b)	Main II- Distance protection* or directional comparison protection or phase segregated line differential protection	Y	Y	Y/N	N
(c)	Directional 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	Y	Y	Y/N

(*) For short line (less than 10kms) / cable / combination of overhead line and cable of 132 kV and above voltage class, line differential protection shall be used.

(#) For cable / combination of overhead line and cable, autoreclosing shall not be provided.

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.

(3) Separate cores of current transformer and voltage transformer shall be used for Main-I and Main-II.

2. Transformer Protection

Sl. No.	Protection	765 kV	400 kV	230 kV/ 220 kV/ 132 kV/ 110 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 to overhead lines	Y	Y	Y	Y
(f)	Tertiary winding protection	Y	Y	Y	N
(g)	Over load alarm	Y	Y	Y	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.

The transformer protection shall be divided in two groups viz. Gr A and Gr B 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 (main tank) & Buchholz (OLTC) protection
Over fluxing protection (HV)	Over fluxing protection (IV/LV)
Oil temperature protection	Winding temperature protection
Pressure relief tripping	Pressure relief tripping
Tertiary winding protection	Overload protection (Alarm only)
Fire protection	Oil level high/low tripping
	Fire protection

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.

The reactor protection shall be divided in two groups viz. Gr A and Gr B in the following manner:

Group A	Group B
Differential protection	Restricted earth fault (REF) protection
Buchholz protection	Buchholz protection
Reactor backup protection	Winding temperature protection
Oil temperature protection	Oil level high/low trip
Pressure relief tripping	Pressure relief tripping
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 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. The bus bar protection scheme shall be centralized or distributed type and shall have provision for future expansion.”.

79. In the said regulations, for SCHEDULE- VI, the following SCHEDULE- VI 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 + 500kV / + 600kV / + 800kV and above voltage level for back to back and 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 Characteristic
- (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 considered:

(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 shall not adversely affect other nearby HVDC Systems as well as Generating Units. This shall be verified by stability, multi infeed and Sub Synchronous Resonance (SSR) studies.

5. System Studies- HVDC control parameters and equipment shall be selected 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 Power Line Carrier (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 Transient 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 IS/IEC 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 nor 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 within the levels prescribed in relevant standards.

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 arrestors;
- (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.
- (c) **AC harmonic filters and shunt compensation**
- (i) 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. shall 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 must 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 nth 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 single phase/ three 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 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 as in accordance with

studies and variations in impedance shall be as per the requirement of relevant standards.

- (iii) Converter transformers shall be equipped with on load tap changer (OLTC) 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) One No. of Converter transformer of each type and rating per bipole 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 valve assembly shall be designed and tested as per relevant IEC/IS.
 - (ii) 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.
 - (iii) 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.
 - (iv) 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.
 - (v) 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. Requisite redundancy shall be kept through a provision of suitable number of spare thyristor in valve modules.
 - (vi) 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.

(vii) 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 shall comprise of 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 glass or composite insulators for valve hall and indoor smoothing reactor area	20 mm/ kV	20 mm/ kV
Indoor DC yard (other than smoothing reactor)	30 mm/ kV	30 mm/ kV
Outdoor porcelain/ glass insulators or bushings with RTV coating	50 mm/kV	60 mm/kV
Outdoor composite insulators or bushings	50 mm/kV	50 mm/kV

Note:- Creepage distances less than 50 mm/kV but not less than 45mm/kV can be accepted for outdoor silicone rubber bushings due to manufacturing limitations and for HVDC equipment requiring necessary internal/ external insulation co-ordination. However, creepage distance less than 50 mm/ kV and flash distance less than 12 mm/ kV shall not be acceptable for outdoor jointed bushing.

(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 comply with relevant standards and shall have successfully passed DC tests as per their application. The smoothing reactor shall be 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 ($0.22 < S_i < 1$) where S_i factor is defined as

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

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 shall 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, if required based on system studies, at each converter of the inverter station. A parallel low order (2nd Harmonic) DC Filter shall be provided across each converter of the 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 typically 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 arrestor / DMR line arresters
- (vii) Smoothing Reactor Arrester
- (viii) DC Neutral Switch Arresters

13 Control and Protection System

(a) Control System:

- (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:
- (B) Current and power controller
- (C) Frequency controller:
- (D) Power modulator, pole power compensation:
- (E) Sub Synchronous Resonance (SSR) Damping Controller (if required):
- (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

(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 shall cover 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, PLCC or both. There shall be main and back up communication link.

15 Valve Hall: The valve hall shall mainly contain thyristor valves, its associated structure & 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: Suitable ventilation systems and filters with adequate redundancy shall be provided for the valve hall.

17 Grounding & Safety

- (a) The design of the grounding system shall be based on relevant IS/ IEEE.
- (b) 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.
- (c) The total electric field excluding space charge at ground level shall be as prescribed in relevant standards.
- (d) Fencing and electrical & mechanical key interlocking arrangements shall be provided for all accessible areas and for valve halls, smoothing reactor area, AC and DC filter areas.

18 Dedicated Metallic Return (DMR) / Earth Electrode

The current return path shall be either via a Dedicated Metallic Return (DMR) conductor or via earth return using earth electrodes at both converter terminals. DMR mode shall be preferred if it is difficult to identify a suitable site for earth electrode station.

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 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/m² 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) The earth electrode station shall not affect the nearby electrical installation, buried metallic pipelines, oil & gas pipelines, and railway lines etc.
- (d) 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
- (e) **Touch voltage (Vt)**- 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.
- (f) **Step Voltage (Vs)**- The step voltage at ground level above the ground electrode when the electrode is operating at the temporary over-toad rating shall not exceed $(Vs) = 5.0 + 0.03 \rho_s$, where ρ_s is the local surface resistivity in ohm-m.
- (g) 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.
- (h) 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 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) 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.
- (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).

20 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.

21 Applicable Standards: All equipment and material shall be designed, manufactured, tested and commissioned in accordance with latest Indian

Standards/ IEC standards, IEEE/ CIGRE guidelines 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 1000 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

PART-B

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

1. General: 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
 - (i) Main Circuit Parameter
 - (ii) AC Over-Voltage [DOV, Temporary Over Voltage and Transient Over Voltage]
 - (iii) DC Over-voltage
 - (iv) Low Frequency Characteristics
 - (v) High Frequency Characteristics
 - (vi) Transient Stresses
 - (vii) External Insulation and Clearances
 - (viii) Insulation co-ordination
 - (ix) AC Circuit Breaker Requirements
 - (x) Equipment design studies
 - (xi) Station Earthing
 - (xii) 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 Equivalent
- (iii) Sub-Synchronous Torsional Interaction
- (iv) Black start islanded operation studies

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

- (a) VSC valves and associated equipment & cooling system
- (b) Interface transformers;
- (c) Converter reactors;
- (d) DC reactors*;
- (e) Phase reactor*
- (f) DC filters*;
- (g) AC filters*;
- (h) Radio frequency interference filters
- (i) Valve side harmonic filters*
- (j) Control and protection of AC and DC side;
- (k) Electrical and mechanical auxiliaries;
- (l) Earth electrode station*;
- (m) AC switchyard equipment;
- (n) DC switchyard equipment;
- (o) Surge arresters;
- (p) Measuring instruments;
- (q) Communication system between converter stations (Optical/ PLCC).
- (r) Wall bushings (AC and DC side)
- (s) Insertion resistors
- (t) DC voltage balancing device* (for symmetrical monopole configuration only)
- (u) High Impedance Grounding of Symmetrical Monopoles
(*) 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 shall be used to limit inrush currents during energization of the converter. They shall be located on the primary or converter side of the interface transformer. After the energization process is completed the resistor shall be 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 Equivalent IS as follows:

Capacitors	: IEC 60871;
Reactors	: IEC 60076-6 & 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.

(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) The IGBT valves 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.
- (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 shall comprise of 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 glass or composite insulators for valve hall and indoor smoothing reactor area	20 mm/ kV	20 mm/ kV
Indoor DC yard (other than smoothing reactor)	30 mm/ kV	30 mm/ kV
Outdoor porcelain/ glass 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) DC Voltage control
 - (E) Frequency controller (if applicable);
 - (F) Power modulation control (if applicable);
 - (G) Runback and run-up functions (if applicable);
 - (H) 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)
 - (Q) AC connection Harmonic protection
 - (R) Phase current unbalance
 - (S) Protection Block Failure or Repetitive Blocking failure protection
 - (T) Phase arm harmonic protection
 - (U) DC Line Overcurrent Protection
 - (V) DC Line harmonic protection

- (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. There shall be main and backup communication link.
9. **Electrode** –The current return path shall be either via a Dedicated Metallic Return (DMR) conductor or via earth return using earth electrodes at both converter terminals. 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/m² 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) The earth electrode station shall not affect the nearby electrical installation, buried metallic pipelines, oil & gas pipelines, and railway lines etc.
 - (d) Each ground electrode shall have a resistance of less than or equal to 0.3 ohm (both working as an anode and cathode) at 50oC ambient temperature
 - (e) **Touch voltage (Vt)**- 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.
 - (f) **Step Voltage (Vs)**- The step voltage at ground level above the ground electrode when the electrode is operating at the temporary over-load rating shall not exceed $(Vs) = 5.0 + 0.03 ps$, where ps is the local surface

resistivity in ohm-m.

- (g) 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.
- (h) 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.”.

P.C. Kureel, Secy.
[ADVT.III/4/Exty./187G/15]

Note- The Principal regulations were published in the Gazette of India, Extraordinary, Part-III, Section-4, vide notification number CEA/ TETD/ MP/ R/ 01/ 2010, dated the 20th August, 2010 and subsequently amended vide notification number 502/ 11/ DP&D/ 2015, dated the 7th April,2015.