CHAPTER – 26: SPECIFICATION FOR DESIGN AND FABRICATION OF SUBSTATION STEEL STRUCTURES

26.1.0 SCOPE

26.1.1 The scope of this section covers specifications for fabrication, proto-assembly, supply and erection of galvanised steel structures for towers, girders, lightning masts and equipment support structures. Towers, girders and lightning masts shall be lattice type structure fabricated from structural steel conforming to IS 2062 (latest). All equipment support structures shall be fabricated from GI pipe conforming to YST 22 or of higher grade as per IS 806.

26.1.2 Support structure for Circuit breaker and Isolators is not standardized and shall be designed by the Contractor and approved by the Employer. Any other structures of 400kV, 220 kV, 132kV and 33kV class necessary to complete the substation to complete the work in all respects shall be designed by the contractor.

26.1.3 The scope shall include supply and erection of all types of structures including bolts, nuts, washers, hangers, shackles, clamps ant-climbing devices, bird guards, step bolts, inserts in concrete, gusset plates, equipment mounting bolts, structure earthing bolts, foundation bolts, spring washers, fixing plates, ground mounted marshaling boxes (AC/DC Marshaling box & equipment control cabinets), structure mounted marshaling boxes and any other items as required to complete the job.

26.1.4 The connection of all structures to their foundations shall be by base plates and embedded anchor/foundation bolts. All steel structures and anchor/foundation bolts shall be fully galvanized. The weight of the zinc coating shall be at least 0.610 kg/m2 for anchor bolts / foundation bolts and for structural members. One additional nut shall be provided below the base plate which may be used for the purpose of levelling.

26.1.5 In case of equipment support structure, Contractor may require to change the dimensions to match the equipment bus bar height and to match the mounting arrangement of a particular equipment. Further suitable modification shall be carried out in the drawings of equipment support structures by the Contractor in order to suit fixation of accessories such as marshalling boxes, MOM boxes, Control Cabinets, Junction box, surge counter, etc. in the standard structure fabrication drawings. The Contractor will make these changes without any price implication. The final drawings of mounting structures shall be submitted to Employer for approval.

26.2.0 MATERIALS

26.2.1 **Structural Steel**

The structures shall be of structural steel conforming to any of the grade, as appropriate, of IS 2062 (latest edition) Steel conforming IS 8500 may also be used.
Medium and high strength structural steels with known properties conforming to any other national or international standards may also be used.

26.2.2 **Bolt**

Bolts used shall conform to IS12427 or bolts of property class 4.6 conforming to IS 6639 may also be used.
High strength bolts, if used (only with steel conforming to IS 8500) shall conform to property class 8.8 of IS 3757. Foundation Bolts shall conform to IS 5624.
Step bolts shall conform to IS 10238

26.2.3 **Galvanisation**

Structural members, plain and heavy washers shall be galvanized in accordance with the provisions of IS 4759.

Spring washers shall be hot dip galvanized as per service grade 4 of IS 4759 or IS 1537.

26.2.4 **Other Materials**

Other materials used in the construction of the supporting structures shall conform to appropriate Indian Standards wherever available.

26.3.0 DESIGN REQUIREMENTS FOR STRUCTURES

26.3.1 This clause and sub-clauses shall be referred only for structures for which design is in the scope of Contractor.

26.3.2 For design of steel structures loads such as dead loads, live loads, wind loads etc. shall be based on IS:875,Parts I to V.

26.3.3 For materials and permissible stresses IS:802, Part-I, Section-2 shall be followed in general. However, additional requirements given in following paragraphs shall be also considered.

26.3.4 Minimum thickness of galvanized tower member shall be as follows:

ITEM	Minimum thickness in mm
Leg members, Ground wire Peak members/ other load carrying members	6
Other Members and Redundant members	5

26.3.5 Maximum slenderness ratios for leg members, other stressed members and redundant members for compression force shall be as per IS-802.

26.3.6 Minimum distance from hole center to edge shall be 1.5 x bolt diameter. Minimum distance between center to center of holes shall be 2.5 x bolt diameter.

26.3.7 All bolts shall be M16 or higher as per design requirement.

26.3.8 **Step Bolts:** In order to facilitate inspection and maintenance, the structures shall be provided with climbing devices. Each tower shall be provided with M16 step bolts 175mm long spaced not more than 450mm apart, staggered on faces on one leg extending from about 0.5 meters above plinth level to the top of the tower. The step bolt shall conform to IS: 10238.

26.4.0 Design Parameters

All structures shall be designed for the worst combination of dead loads, live loads, wind loads as per code IS:875, seismic forces as per code IS:1893, loads due to deviation of conductor, load due to unbalanced tension in conductor, torsional load due to unbalanced vertical and horizontal forces, erection loads, short circuit forces including “snatch” in the case of bundled conductors etc. Short circuit forces shall be calculated considering a fault level of 40 kA, 50kA, 63kA or as applicable. IEC-60865 may be followed for evaluation of short circuit forces. Lattice type structures are also accepted, however, AEGCL shall have the right to choose any type structure (lattice/pipe) as per requirement during detailed engineering without any price implication.

All Pipe support structures used for supporting equipments shall be designed for the worst combination of dead loads, erection load. Wind load/seismic forces, short circuit forces and operating forces acting on the equipment and associated bus bars as per IS:806. The material specification shall be as per IS: 1161 read in conjunction with IS: 806.

26.4.1 Switchyard structures such as columns, beams and equipment mounting structures shall be designed as per IS 802 but for loading combinations specified hereunder. Computation of wind loading on structural members, conductors, insulators, etc and other parameters shall be as specified in IS 802 except otherwise specified in this Specification.

26.4.2 The switchyard structures shall be designed for following loads considered acting simultaneously:

(i) Wire tension
(ii) Wind Load
(iii) Short Circuit Forces
(iv) Weight of supported wires, insulators, equipment etc and self-weight of structures.

An additional load of 3000 N shall be considered acting for weight of lineman and tools. For beams this 3000 N load shall be considered acting at middle of the beam.

26.4.1.3 The design shall be checked for following two loading conditions:

26.4.1.4 The design shall be checked for following two loading conditions:

(A) Normal Conditions (all wires intact)

Under this condition, the loads shall be taken as under:

(i) Wire Tension:- Maximum Wire tension as specified in Clause 39.4.3

(ii) Wind Load:- Loads due to 100% Design Wind Pressure (after accounting for drag coefficient and gust factor) on structures,
wires, insulators, equipment etc. Design wind pressure shall be as per Clause 39.4.2

(iii) Short Circuit Forces: Loading due to a 3 phase short circuit current of 63kA, 50kA, 40 kA and 31.5 kA shall be considered
for 400kV, 220 KV,132 kV and 33 kV respectively subject to minimum of 10% of maximum wire tension as considered in
(i) above.

(iv) Dead Weight:- All dead loads mentioned in Clause 39.4.1.2 (iv) shall be considered. Conductor and shield wire weight shall

L B) BROKEN WIRE CONDITION

Under this condition design shall be checked with all wires broken on one side and load shall be as under:

(i) Wire Tension:- Wire tension for intact wires shall be taken as 100% of Clause 39.4.1.4 (A) (i). For broken wires it shall be
taken as zero.

(ii) Wind Load:-Same wind load as calculated in Clause 39.4.1.4 (A) (ii) shall be considered.

(iii) Short Circuit Forces:- Short circuit forces shall be considered only for intact wires.

(i) Dead Weight: - Same dead load as calculated in Clause 39.4.1.4 (A) (iv) shall be considered.cula

26.4.2 **Design Wind Pressure**

The Design Wind pressure for the purpose of this Specification shall be taken as 793 N/m2. This wind pressure corresponds to Terrain

26.4.3 **Wire Tensions**

For design purpose tension in each power and shield wires shall be taken as under

a. For Power Conductors

(i) 400/220 kV Switchyard:	10000 N for each conductor between Line gantry and Dead-End Tower of Transmission Line. 8000 N for each Bus Bar conductor and other jumpers/jack buses.
(ii) 132 kV and 33 kV switchyard.	8000 N for each conductor between Line gantries and Dead-End Tower of Transmission Line. 6000 N for each Bus Bar conductor and other jumpers/jack buses.

b. For Shield Wires

(i) 400kV, 220 KV,132 kV and 33 kV Switchyard.	6000 N for shield wire between Line gantry and Dead End Tower of Transmission Line. 5000 N for shield wires at other Location.

Note: Structures with earth peak shall assume to have two earth wires for design purpose in broken wire condition.

26.4.4 Spans

Following Spans shall be considered in design of all structures as applicable:-

a). Line gantries (structures to terminate lines):

(i) For 400, 220, 132, Switchyard: 200 Meter, wind span

150 Meter, weight span

(ii) For 33 KV Switchyard: 75 Meter, wind & weight span.

b). All other Structures

(i) For 400 KV Switchyard: 75 Meter, wind & weight span

(ii) For 220 KV Switchyard: 75 Meter, wind & weight span

(iii) For 132 KV Switchyard: 50 Meter, wind & weight span

(ii) For 33 KV Switchyard: 20 Meter, wind & weight span.

26.4.5 Deviation Angle

The design of line gantries shall only be checked for a maximum deviation angle of 300 from normal at center of gantries to Dead End Tower.

26.4.6 Conductors and Shield Wires

A) Following sizes of power conductors if not otherwise specified in the drawings, shall be used for design of structures:

a). For 400 kV switchyard:- As indicated in layout drawings.

b). For 220 kV switchyard:-

(i) ACSR 'MOOSE' conductor (two conductors per phase) for Drop Downs, Jumpers and Connection Between Equipments.

c). For 132 kV switchyard:-

(i) ACSR 'MOOSE' conductor (two conductors per phase) for Drop Downs, Jumpers and Connection Between Equipments.

d). For 33 kV switchyard:-

(i) ACSR 'PANTHER' conductor (One conductors per phase) for Connections between equipments and outgoing feeder till
the 33kV Outgoing feeder Gantry.

B) For protection against direct lightning G.I. wires of size 7/3.66 mm conforming to IS 2241 shall be considered for all switch yards.

Terminal/line take off gantries shall be designed for a minimum conductor tension of 4 metric tonnes per phase for 400kV, 2 metric tonnes per phase for 220kV and 1 metric tonne per phase for 132 kV or as per requirements whichever is higher . The distance between terminal gantry and dead end tower shall be taken as 200 metres for 400/220kV and 100m for 132KV. The design of these terminal gantries shall also be checked considering +/- 30 deg deviation of conductor in both vertical and horizontal planes. For other gantries the structural layout requirements shall be adopted in design.

The beams shall be connected with towers/ columns by bolted joints. Wherever luminaries are proposed to be fixed on gantries, the proper loading for the same shall be considered while designing. Also holes for fixing the brackets for luminaries should be provided wherever required.

Foundation bolts shall be designed for the loads for which the structures are designed. Height of Lightning masts shall be as per approved structure layout and designed for diagonal wind

condition. Lightning masts shall be provided with platforms for mounting lighting fixtures and a structural steel ladder within its base up to the level of platform. The ladder shall be provided with protection rings. The platforms shall also have protection railing. The details of lighting fixtures would be as per the approved drawings.

26.5.0 DESIGN DRAWINGS AND DOCUMENTS

As and where asked for the relevant drawings for all the towers, beams and equipment mounting structures shall be furnished by the Contractor to the Employer which shall include structural/erection drawings, shop fabrication drawings, Bill of Materials, foundation working drawings.

The structural/erection drawings, Bill of materials and shop fabrication drawings for all the structures shall be submitted in four copies and will be finally approved by the Employer. The fabrication shall be taken up from the approved shop drawings. The overall responsibility of fabricating structure members correctly lies with the Contractor only and the Contractor shall ensure that all the

members can be fitted while erecting without any undue strain on them.

26.5.1.1 The Contractor shall furnish design, drawing and Bill of Materials and shop manufacturing drawings for every member to the Employer for approval after award of the Contract. The design drawing should indicate not only profile, but section, numbers and sizes of bolts and details of typical joints. In case Employer feels that any design drawing, BOM are to be modified even after its approval, Contractor shall modify the designs & drawings and resubmit the design drawing, BOM as required in the specification.

26.5.1.2 The fabrication drawings to be prepared and furnished by the Contractor shall be based on the design approved by the Employer. These fabrication drawings shall indicate complete details of fabrication and erection including all erection splicing details and typical fabrication splicing details, lacing details, weld sizes and lengths. Bolt details and all customary details in accordance with standard structural engineering practice whether or not given by the Employer. The fabrication drawings shall be submitted to the Employer. Proto shall be made only after approval of fabrication drawings.

26.5.1.3 Such approval shall, however, not relieve the Contractor of his responsibility for the safety of the structure and good connections and any loss or damage occurring due to defective fabrication, design or workmanship shall be borne by the Contractor.

26.5.1.4 The Mass fabrication work shall start only after the final approval to the proto corrected Fabrication drawing is accorded by the Employer.

26.6.0 ACCESSORIES

26.6.1 Step Bolts

Each column/tower shall be provided with step bolts conforming to IS: 10238 of not less than 16mm diameter and 175mm long spaced not more than 450mm apart and extending from 0.5 meters above the plinth level to the top. Each step bolt shall be provided with two nuts on one end to fasten the bolt securely to the tower and button head at the other end to prevent the feet from slipping away. The step bolts shall be capable of withstanding a vertical load not less than 1.5 KN.

26.6.2 **Insulator Strings and Conductor Clamps Attachments**

(i) Double suspension and tension insulator string assemblies (for 400kV, 220kV and 132kV) and Single suspension and tension insulator string assemblies (for 33kV) shall be used for jumpering and connection between the equipments.For the attachment of Suspension Insulator string, a suitable strain plate of sufficient thickness for transferring the load to the tower body shall be provided. To achieve requisite clearances, if the design calls for providing extra D-shackles, link plate etc. before connecting the insulator string the insulator string the same shall be supplied by the Contractor.

(ii) At tension points strain plates of suitable dimensions placed on the beams, shall be provided for taking the hooks or D-shackles of the tension insulator strings. To achieve requisite clearances, if the design calls for providing extra D-shackles, link plate etc. before connecting the insulator string the same shall be supplied by the Contractor.

26.6.3 **Earthwire Clamps Attachment**
i. Suspension Clamp

The detailed drawing shall be submitted by the Contractor for Employer's approval. The Contractor shall also supply U- bolts, Dshackles wherever required.

i. Tension Clamps

Earth-wire peaks of tension towers shall be provided with suitable plates to accommodate the shackle of tension clamps. The contractor shall also supply the U-bolts wherever required and take Employer's approval for details of the attachments before the mass fabrication.

26.7.0 **FABRICATION**

26.7.1 The fabrication of substation steel structures shall be in conformity with the following:

(i). Except where hereinafter modified, details of fabrication shall conform to IS: 802 (Part-II) or the relevant international standards.

(ii). The tower structures shall be accurately fabricated to connect together easily at site without any undue strain on the bolts.

(iii). No angle member shall have the two leg flanges brought together by closing the angle.

(iv). The diameter of the hole shall be equal to the diameter of bolt plus 1.5mm.

(v). The structure shall be designed so that all parts shall be accessible for inspection and cleaning. Drain holes shall be provided at all points where pockets of depression are likely to hold water.

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

26.7.2 Drilling and Punching

(i). Before any cutting work is started, all steel sections shall be carefully strengthened and trued by pressure and not by hammering. They shall again be trued after being punched and drilled.

(ii). Holes for bolts shall be' drilled or punched with a jig but drilled holes shall he preferred. The punching may be adopted for thickness up to 16mm. Tolerances regarding punch holes are as follows:

(iii). Holes must be perfectly circular and no tolerances in this respect are permissible.

(iv). The maximum allowable difference in diameter of the holes on the two sides of plates or angle is 0.8mm. i.e. the allowable taper in a punched hole should not exceed 0.8 mm on diameter.

(v). Holes must be square with the plates or angles and have their walls parallel.

(vi). All burrs left by drills or punch shall be removed completely. When the tower members are in position the holes shall be truly opposite to each other. Drilling or reaming to enlarge holes shall not be permitted.

26.7.3 Erection mark

Each individual member shall have erection mark conforming to the component number given to it in the fabrication drawings. The mark shall be marked with marking dies of 16mm size before galvanizing and shall be legible after galvanizing.

26.8 FOUNDATION BOLTS

26.8.1 Foundation bolts for the towers and equipment supporting structures and elsewhere shall be embedded in first stage concrete while the foundation is cast. The Contractor shall ensure the proper alignment of these bolts to match the holes in the base plate.
26.8.2 The Contractor shall be responsible for the correct alignment and levelling of all steel work on site to ensure that the towers/structures are plumb.
26.8.3 All foundation bolts for lattice structure, pipe structure is to be supplied by the Contractor.
26.8.4 All foundation bolts shall be fully galvanised so as to achieve 0.61 kg. per Sq.m. of Zinc Coating as per specifications.
26.8.5 All foundation bolts shall conform to IS 5624 but the material, however shall be MS conforming to IS: 2062.

26.9.0 **GALVANIZING AND PAINTING**
26.9.1 Galvanising of the various members of the structures shall be done only after all works of sawing, shearing, drilling, filing, bending and matching are completed. Galvanising shall be done by the hot dip process as recommended in IS: 2629 or other such authoritative international standards and shall produce a smooth, clean and uniform coating of not less than 610 gm per square meter. The preparation for galvanising and the galvanising process itself must not affect adversely the mechanical properties of the treated materials.

26.9.2 All assembly bolts shall be thoroughly hot dip galvanized after threading. Threads shall be of a depth sufficient to allow for the galvanized coating, which must not be excessive at the root of the threads, so that the nut shall turn easily on the completed bolts without excessive looseness. The nut threads shall not be galvanized, but oiled only.
26.9.3 The outside surface shall be galvanised. Sample of galvanised materials shall be supplied to the galvanising test set out in IS 729 or other such authoritative international standards.

26.10 **EARTHING**
39.10.1 To keep provision in the structures for earthing, holes shall be drilled on two diagonally opposite legs of the towers/columns/mounting structures. The holes shall be suitable for bolting GI strips of size mentioned elsewhere in this specification (Vol II) and shall be such that the lower hole is about 350 mm above the ground level, clear of the concrete muffing, for connecting the earthing strip.

26.11 TEST AND TEST CERTIFICATE
26.11.1 Each consignment ready for transportation shall be offered to AEGCL for inspection before dispatch giving a minimum time of not less than 30 days. Samples of fabricated structure materials shall be subjected to following tests: -
a. Steel: The structural steel shall conform to IS 226 and IS 8500, BS 4360-1068 or ISO / R 630 other such authoritative international standards. Manufacturer's test certificate shall be submitted for all used steel.
b. Galvanising: The galvanising shall be as per IS 2633 or BS 729 other such authoritative international standards. Zinc coating over the galvanised surfaces shall not be less than 610 gm per square meter.
c. Bolts and nuts: Manufacturer's test certificate as per standard practice shall be submitted.
26.11.2 Test at Contractor's Premises
26.11.2.1 The contractor shall fabricate one specimen structure of each type as soon as possible after placement of order and before starting the bulk fabrication of the structures ordered. It shall be assembled on a foundation as nearly similar as practicable to site and tested with suitable test loads as per specified broken wire condition, multiplied by the corresponding factor of safety to ensure that the design and fabrication complies with the

requirements. Each structure shall be capable of withstanding the above-mentioned tests without any injury or any permanent deflection at any part. If any member is found to be weak or damaged the design should be suitably modified and the tower re-tested.
26.11.2.2 After the first lot of the structures manufactured, the members forming one structure of each type shall be selected at random from the lots of similar member and assembled in exactly the same manner as to be done at site. The structure then shall be set on foundation as nearly similar as practicable to site and tested with equivalent test load for which the structure has been designed.

26.11.2.3 No structure or any member thereof, which failed under the test shall be supplied.

26.12 MODE OF MEASUREMENT

26.12.1.1 The measurement of all lattice and pipe structures for towers, beams, equipment support structure etc. shall be made in numbers for each type of structures. This will include foundation bolts and nuts and therefore no separate payment shall be made for the same. The unit rate quoted for each type of structure shall be inclusive of supply, fabrication, galvanizing, erection, nuts, bolts, wastages etc. complete. Nothing extra shall be payable for substitution necessitated due to non-availability of section. Nothing extra shall be payable for modifications or steel added to suit the contractors fixing arrangements for accessories etc.