

# Section **Switchyard Erection**

# SECTION – SE SWITCHYARD ERECTION

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1.0

### GENERAL

The detailed scope of work includes design, engineering, manufacture, testing at works, supply on FOR destination site basis, insurance, handling, storage, erection testing and commissioning of various items and works as detailed herein.

This section covers the description of the following items.

#### A- Supply of

- String insulators and hardware
- ACSR conductor
- Galvanised Steel Earthwire
- Aluminium Tubular Bus Bars
- Spacers
- Bus post insulators
- Earthing & Earthing materials
- Lightning protection materials
- Cabling material
- Other items

#### B. Erection Of all items

##### 1.1 String Insulators & Hardware

The insulators for suspension and tension strings shall conform to IEC383 and long rod insulators shall conform to IEC-433. Insulator hardware shall conform to IS:2486.

##### 1.1.1 Construction Features

- 1.1.1.1 Suspension and tension insulators shall be wet process porcelain with ball and socket connection. Insulators shall be interchangeable and shall be

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suitable for forming either suspension or tension strings. Each insulator shall have rated strength markings on porcelain printed and applied before firing.

- 1.1.1.2 Porcelain used in insulator manufacture shall be homogeneous, free from laminations, cavities and other flaws or imperfections that might affect the mechanical or dielectric quality and shall be thoroughly vitrified, tough and impervious to moisture.
- 1.1.1.3 Glazing of the porcelain shall be uniform brown colour, free from blisters, burrs and other similar defects.
- 1.1.1.4 When operating at normal rated voltage there shall be no electric discharge between conductor and insulator which would cause corrosion or injury to conductors or insulators by the formation of substances due to chemical action. No radio interference shall be caused when operating at normal rated voltage.
- 1.1.1.5 The design of the insulator shall be such that stresses due to expansion and contraction in any part of the insulator shall not lead to deterioration. All ferrous parts shall be hot dip galvanized in accordance with the latest edition of IS: 2629. The zinc used for galvanizing shall be of grade Zn-99.95 as per IS-209. The zinc coating shall be uniform, adherent, smooth, reasonably bright, continuous and free from imperfections such as flux, ash, rust stains bulky white deposits and blisters.
- 1.1.1.6 Bidder shall make available data on all the essential features of design including the method of assembly of discs and metal parts, number of discs per insulator string insulators, the manner in which mechanical stresses are transmitted through discs to adjacent parts, provision for meeting expansion stresses, results of corona and thermal shock tests, recommended working strength and any special design or arrangement employed to increase life under service conditions.
- 1.1.1.7 Clamps for insulator strings and Corona Control rings shall be of aluminium alloy as stipulated for clamps and connectors.
- 1.1.1.8 Insulator hardware shall be of forged steel. Malleable cast Iron shall not be accepted except for insulator disc cap. The surface of hardware must be clean, smooth, without cuts, abrasion or projections. No part shall be subjected to excessive localized pressure. The metal parts shall not produce any noise generating corona under operating conditions.
- 1.1.1.9 The tension Insulator hardware assembly shall be designed for 11500 kg

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tensile load. Earth wire tension clamp shall be designed for 1000 kg tensile load with a factor of safety of two (2).

1.1.1.10 The tension string assemblies shall be supplied alongwith suitable turn buckle. Sag compensation springs if required may also be provided.

1.1.1.11 All hardware shall be bolted type.

**1.2 Long Rod Insulators**

1.2.1 As an alternative to disc insulator , Bidder can offer long rod insulators strings, with suitable hardware. The combination should be suitable for application specified and should offer the identical / equivalent parameters as would be available from insulator string comprising disc insulators and hardware combination.

1.2.2 All constructional features specified at Clause 1.1.1 of this Section shall also apply to the long rod insulator string.

**1.3 Tests**

In accordance with the stipulations of the specification, the suspension and tension strings, insulator and hardware shall be subjected to the following type tests, acceptance tests and routine tests:

1.3.1 **Type Tests on Insulator Strings :** The test reports for following type tests shall be submitted for approval as per clause 9.2 of Section - GTR.

- a) Power frequency voltage withstand test with corona control rings under wet condition as per IEC 383.
- b) Switching surge voltage withstand test [400 kV class only] under wet condition as per IEC-383.
- c) Lightning Impulse voltage withstand test with corona control rings under dry condition as per IEC-383
- d) Voltage distribution test (Dry)

The voltage across each insulator unit shall be measured by sphere gap method. The result obtained shall be converted into percentage. The voltage across any disc shall not exceed 9% and 10% for 400KV suspension string and tension insulator string respectively, 13% for 220KV suspension and tension insulator

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strings, 20% and 22% for 132kV suspension and tension insulator strings respectively.

e) Corona Extinction Voltage test (Dry)

The sample assembly when subjected to power frequency voltage shall have a corona extinction voltage of not less than 320kV(rms) for 400kV and 156kV(rms) for 220kV line to ground under dry condition. There shall be no evidence of Corona on any part of the sample. The atmospheric condition during testing shall be recorded and the test results shall be accordingly corrected with suitable correction factor as stipulated in IEC 383.

f) RIV Test (Dry)

Under the conditions as specified under (e) above the insulator string alongwith complete hardware fittings shall have a radio interference voltage level below 1000 microvolts at 1 MHz when subjected to 50 Hz AC line to ground voltage of 320kV for 400kV and 156kV for 220kV string under dry conditions. The test procedure shall be in accordance with IS 8263/IEC 437.

g) Mechanical strength test

The complete insulator string alongwith its hardware fitting excluding arcing horn, corona control ring, grading ring, tension/suspension clamps shall be subjected to a load equal to 50% of the specified minimum ultimate tensile strength (UTS) which shall be increased at a steady rate to 67% of the minimum UTS specified. The load shall be held for five minutes and then removed. After removal of the load, the string components shall not show any visual deformation and it shall be possible to dismantle them by hand. Hand tools may be used to remove cotter pins and loosen the nuts initially. The string shall then be reassembled and loaded to 50% of UTS and the load shall be further increased at a steady rate till the specified minimum UTS and held for one minute. No fracture should occur during this period. The applied load shall then be increased until the failing load is reached and the value recorded.

### 1.3.2 Type Tests on Insulators

Type test report for Thermal Mechanical Performance tests as per IEC:575, Clause 3 shall be submitted for approval as per clause 9.2

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of Section - GTR.

1.3.3

**Acceptance Tests for Insulators:**

- a) Visual examination as per IEC 383
- b) Verification of Dimensions as per IEC 383.
- c) Temperature cycle test as per IEC 383.
- d) Puncture Test as per IEC 383.
- e) Galvanizing Test as per IEC 383.
- f) Mechanical performance test as per IEC-575 Cl. 4.
- g) Test on locking device for ball and socket coupling as per IEC-372(2)
- h) Porosity test as per IEC 383.

1.3.4

**Acceptance Test on Hardware Fitting**

- a) Visual Examination as per Cl. 5.10 of IS:2486 (Part-I).
- b) Verification of Dimensions as per Cl. 5.8 of IS : 2486 (Part-I)
- c) Galvanising/Electroplating tests as per Cl. 5.9 of IS : 2486 (Part-I).
- d) Slip strength test as per Cl 5.4 of IS-2486 (part-I)
- e) Shore hardness test for the Elastometer (if applicable as per the value guaranteed by the Bidder).
- f) Mechanical strength test for each component (including corona control rings and arcing horns).

The load shall be so applied that the component is stressed in the same way as it would be in actual service and the procedure as given in 1.2.13.1 (g) above should be followed.

- g) Test on locking devices for ball and socket coupling as per IEC:372(2).

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**1.3.5 Routine Test on Insulator**

- a) Visual Inspection as per IEC383
- b) Mechanical Routine Test as per IEC383
- c) Electrical Routine Test as per IEC383

**1.3.6 Routine Test on hardware Fittings**

- a) Visual examination as per Cl 5.10 of IS : 2486 (Part-I).
- b) Mechanical strength Test as per Cl. 5.11 of IS : 2486 (Part-I).

**1.3.7 Test during manufacture on all Components as applicable on insulator**

- a) Chemical analysis of zinc used for galvanising:

Samples taken from the zinc ingot shall be chemically analyzed as per IS : 209. The purity of zinc shall not be less than 99.95%.

- b) Chemical Analysis, mechanical hardness tests and magnetic particle inspection for malleable casting:

The chemical analysis, hardness tests and magnetic particle inspection for malleable casting will be as per the internationally recognized procedures for these tests. The sampling will be based on heat number and heat treatment batch. The details regarding tests will be as discussed and mutually agreed to by the Contractor and Owner in Quality Assurance Program.

**1.3.8 Test during manufacture on all components as applicable on hardware fittings:**

- a) Chemical analysis of zinc used for galvanising:

Samples taken from the zinc ingot shall be chemically analyzed as per IS : 209. The purity of zinc shall not be less than 99.95%

- b) Chemical analysis, hardness tests and magnetic particle for

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forgings:

The chemical analysis, hardness tests and magnetic particle inspection for forgings will be as per the internationally recognized procedures for these tests. The sampling will be based on heat number and heat treatment batch. The details regarding tests will be as discussed and mutually agreed to by the Contractor and Owner in Quality Assurance Programme.

- c) Chemical analysis and mechanical hardness tests and magnetic particle inspection for fabricated hardware:

The chemical analysis, hardness tests and magnetic particle inspection for fabricated hardware will be as per the internationally recognized procedures for these tests. The sampling will be based on heat number and heat treatment batch. The details regarding tests will be as discussed and mutually agreed to by the Contractor and Owner in Quality Assurance programme.

### 1.4 Parameters

#### 1.4.1 Disc Insulators

400/220/132 kV

- |    |   |   |  |
|----|---|---|--|
| a) | Type of insulators  | : | Fog type   |
| b) | Size of insulator units (mm)  | : | 255x145  |
| c) | Electro mechanical strength   | : | 120 kN   |
| d) | Creepage distance of individual insulator units (minimum and as required to meet total creepage distance) | : | 430 mm   |
| e) | Markings  | : | Markings on porcelain shall be printed and applied before firing |
| f) | Power frequency puncture withstand voltage  | : | 1.3 times the actual wet flashover voltage.                      |

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\*Long rod insulators should conform to equivalent electrical and mechanical parameters.

1.14.2

### INSULATOR STRING

	400kV	220kV	132kV
a) Power frequency withstand voltage of the complete string with Corona Control ring (wet) - kV rms	680	460	275
b) Lightning impulse withstand Voltage of string with corona control rings (dry) - kVp	±1550	±1050	±650
c) Switching surge withstand voltage of string with corona control rings (wet) - kVp	±1050	NA	NA
d) Minimum corona extinction voltage level of string with Corona Control rings (dry) - kV rms	320	156	NA
e) RIV level in micro volts of string with Corona Control rings at 320 kV (rms) for 400 kV string and 156 kV for 220 kV string across 300 Ohms resistor at 1 MHz	1000 (Max.)	1000 (Max.)	NA
f) Total creepage distance of the insulator string (mm)	10500	6125	3625
g) Total no. of discs per strings	25	15 ✓	10 ✓

For tension application, double insulator strings and for suspension purpose single suspension insulator string shall be used for 400 KV, 220 KV and 132KV system.

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2.0      **ACSR 'MOOSE' CONDUCTOR**

2.1      **Details of Conductor**

2.1.1    The Conductor shall conform to IS:355 (Part V) - 1982 except where otherwise specified herein.

2.1.2    The details of the conductor are tabulated below:

a)	Stranding and wire diameter	: 54/3.53 mm Al+7/3.53mm Steel
b)	Number of Strands	:
	Steel centre	: 1
	1st Steel Layer	: 6
	1st Aluminium Layer	: 12
	2nd Aluminium Layer	: 18
	3rd Aluminium Layer	: 24
c)	Sectional area of aluminium	: 528.5 mm <sup>2</sup>
d)	Total sectional area	: 597.00 mm <sup>2</sup>
e)	Overall diameter	: 31.77 mm
f)	Approximate weight	: 2004 kg/km
g)	Calculated d.c. resistance at 20°C:	0.05552 ohm/km
h)	Minimum UTS	: 161.2 kN

2.1.3    **The details of aluminium strand are as follows:**

i)	Minimum breaking load of strand before stranding	: 1.57 kN
ii)	Minimum breaking load of strand after stranding	: 1.49 kN
iii)	Maximum D.C. resistance of strand at 20°C.	: 2.921 Ohms/Km

2.1.4    **The details of steel strand are as follows:**

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- |      |   |   |   |
|------|---|---|---|
| i)   | Minimum breaking load of strand before stranding  | : | 12.86 kN                                      |
| ii)  | Minimum breaking load of strand after stranding   | : | 12.22 kN                                      |
| iii) | Minimum number of twist to be withstood in torsion test when tested on a gauge length of 100 times diameter of wire | : | 18 - before stranding<br>16 - after stranding |

**2.2 Workmanship**

- 2.2.1 The finished conductor shall be smooth, compact, uniform and free from all imperfections including spills and splits, die marks, scratches, abrasions, scuff marks, kinks (protrusion of wires), dents, press marks, cut marks, wire cross over, over riding, looseness (wire being dislocated by finger/hand pressure and/or unusual bangle noise on tapping), material inclusions, white rust, powder formation or black spots (on account of reaction with trapped rain water etc.), dirt, grit etc.
- 2.2.2 All the aluminium and steel strands shall be smooth, uniform and free from all imperfections, such as spills and splits, die marks, scratches, abrasions and kinks after drawing.
- 2.2.3 The steel strands shall be hot dip galvanised and shall have a minimum zinc coating of 260 gm/sq.m. after stranding of the uncoated wire surface. The zinc coating shall be smooth, continuous and of uniform thickness, free from imperfections and shall withstand minimum three dips after stranding in standard Preece test. The finished strands and the individual wires shall be of uniform quality and have the same properties and characteristics as prescribed in ASTM designation : B 498-74.
- 2.2.4 The Steel strands shall be preformed and postformed in order to prevent spreading of strands in the event of cutting of composite core wire. Care shall be taken to avoid damage to galvanisation during preforming and post-forming operation.

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### 2.3 Joints in Wires

#### 2.3.1 Aluminium Wires

No joints shall, be permitted in the individual wires in the outermost layer of the finished conductor. However, joints in the 12 wire and 18 wire inner layers of the conductor shall be allowed but these joints shall be made by cold pressure butt welding and shall be such that no such joints are within 15 metres of each other in the complete stranded conductor.

#### 2.3.2 Steel Wires

There shall be no joint of any kind in the finished wire entering into the manufacture of the strand. There shall also be no strand splices in any length of the completed stranded steel core of the conductor.

### 2.4 Tolerances

The manufacturing tolerances to the extent of the following limits only shall be permitted in the diameter of individual aluminium and steel strands and lay-ratio of the conductor.

#### a) Diameter of Aluminium and steel strands:

	Standard	Maximum	Minimum
Aluminium	3.53 mm	3.55 mm	3.51 mm
Steel	3.53 mm	3.60 mm	3.46 mm

#### b) Lay ratio of Conductor:

		Maximum	Minimum
Steel	6 wire layer	18	16
Aluminium	12 wire layer	14	12
	18 wire layer	13	11
	24 wire layer	12	10

### 2.5 Materials

#### 2.5.1 Aluminium

The aluminium strands shall be hard drawn from electrolytic aluminium rods having purity not less than 99.5% and a copper content not

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exceeding 0.04%.

### 2.5.2 Steel

The steel wire strands shall be drawn from high carbon steel wire rods and shall conform to the following chemical composition:

Element	-	% Composition
Carbon	-	0.50 to 0.85
Manganese	-	0.50 to 1.10
Phosphorous	-	not more than 0.035
Sullphur	-	not more than 0.045
Silicon	-	0.10 to 0.35

### 2.5.3 Zinc

The Zinc used for galvanising shall be electrolytic High Grade Zinc of 99.95% purity. It shall conform to and satisfy all the requirements of IS:209-1979.

### 2.6 Standard Length

2.6.1 The Conductor shall be supplied in standard length of 1500 / 1800 metres as required. No joint shall be allowed within a single span of stringing.

### 2.7 Tests :

2.7.1 The following type, acceptance & routine tests and tests during manufacturing shall be carried out on the conductor.

### 2.7.2 Type Tests

In accordance with the stipulation of specification, the following type tests reports of the conductor shall be submitted for approval as per clause 9.2 of Section - GTR.

- a) UTS test on stranded conductor.

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- |     |  |   |                   |
|-----|--|---|-------------------|
| b)  | Corona extinction voltage test (dry)     | ) | As per Annexure-A |
|     |  | ) |                   |
| (c) | Radio Interference voltage test (dry)    | ) |                   |
|     |  | ) |                   |
| (d) | DC resistance test on stranded conductor | ) |                   |
|     |  | ) |                   |

2.7.3

**Acceptance Tests**

- |    |  |   |                      |
|----|--|---|----------------------|
| a) | Visual check for joints, scratches etc. and lengths of conductor | ) | As per Annexure - A  |
|    |  | ) |                      |
| b) | Dimensional check on steel and aluminium strands                 | ) |                      |
|    |  | ) |                      |
| c) | Check for lay ratios of various layers                           | ) | -do-                 |
|    |  | ) |                      |
| d) | Galvanising test on steel strands                                | ) |                      |
|    |  | ) |                      |
| e) | Torsion and Elongation test on steel strands                     | ) |                      |
|    |  | ) |                      |
| f) | Breaking load test on steel and aluminium strands                | ) |                      |
|    |  | ) |                      |
| g) | Wrap test on steel and aluminium strands                         | ) | IS:398 (Part V) 1982 |
|    |  | ) | Clauses 12.5.2, 12.7 |
|    |  | ) | & 12.8               |
| h) | DC resistance test on aluminium strands                          | ) |                      |
|    |  | ) |                      |
| i) | UTS test on welded joint of aluminium strands                    | ) | As per Annexure - A  |
|    |  | ) |                      |

**NOTE:**

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All the above tests except test mentioned at (a) shall be carried out on aluminium and steel strands after stranding only.

### 2.7.4

#### Routine Tests

- a) Check to ensure that the joints are as per specification.
- b) Check that there are no cuts, fins etc. on the strands.
- c) All acceptance test as mentioned in Clause 2.7.3 above to be carried out on each coil.

### 2.7.5

#### Tests During Manufacture

- a) Chemical analysis of zinc used for galvanising )  
)  
)
- b) Chemical analysis of aluminium used for making aluminium strands ) As per Annexure - A  
)  
)
- c) Chemical analysis of steel used for making steel strands )  
)  
)

### 2.7.6

#### Sample Batch for Type Testing

The Contractor shall offer material for selection of samples for type testing, only after getting quality assurance plans approved from Owner's Quality Assurance Department. The sample shall be manufactured strictly in accordance with the Quality Assurance Plan approved by Owner.

## 3.0

### GALVANISED STEEL EARTHWIRE

### 3.1

#### Details of Earthwire

#### 3.1.1

The galvanised steel earth wire shall generally conform to the specification of ACSR core wire as mentioned in IS : 398 (Part-II)-1976 except where otherwise specified herein.

#### 3.1.2

The details of the earth wire are tabulated below:

- a) Stranding and wire diameter : 7/3.66 mm steel

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- b) Number of strands
  - Steel core : 1
  - Outer Steel Layer : 6
- c) Total sectional area : 73.65 mm<sup>2</sup>
- d) Overall diameter : 10.98 mm
- e) Approximate weight : 583 kg/km
- f) Calculated d.c. resistance at 20°C : 2.5 ohms/km
- g) Minimum ultimate tensile strength : 68.4 kN
- h) Direction of lay of outer layer : Right hand

3.2 **WORKMANSHIP**

- 3.2.1 All steel strands shall be smooth, uniform and free from all imperfections, such as spills and splits, die marks, scratches, abrasions and kinks after drawing and also after stranding.
- 3.2.2 The finished material shall have minimum brittleness as it will be subjected to appreciable vibration while in use.
- 3.2.3 The steel strands shall be hot dip galvanised (and shall have a minimum zinc coating of 275 gms/sq.m.) after stranding of the uncoated wire surface. The zinc coating shall be smooth, continuous, of uniform thickness, free from imperfections and shall withstand three and a half dips after stranding in standard Preece test. The steel wire rod shall be of such quality and purity that, when drawn to the size of the strands specified and coated with zinc, the finished strands shall be of uniform quality and have the same properties and characteristics in ASTM designation B498-74.
- 3.2.4 The steel strands shall be preformed and postformed in order to prevent spreading of strands while cutting of composite earthwire. Care shall be taken to avoid damage to galvanisation during preforming and

7/9  
Strands of 3.66 dia  
9 gauge  
— 10.98 mm dia  
9 gauge

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postforming operation.

- 3.2.5 To avoid susceptibility towards wet storage stains (white rust), the finished material shall be provided with a protective coating of boiled linseed oil.

### 3.3 JOINTS IN WIRES

There shall be no joint of any kind in the finished steel wire strand entering into the manufacture of the earth wire. There shall be no strand joints or strand splices in any length of the completed stranded earth wire.

### 3.4 TOLERANCES

The manufacturing tolerances to the extent of the following limits only shall be permitted in the Diameter of the individual steel strands and lay length of the earth wire:

	Standard	Maximum	Minimum
Diameter	3.66 mm	3.75 mm	3.57 mm
Lay length	181 mm	198 mm	165 mm

### 3.5 MATERIALS

#### 3.5.1 Steel

The steel wire strands shall be drawn from high carbon steel rods and shall conform to the following requirements as to the chemical composition :

Element	% Composition
Carbon	Not more than 0.55
Manganese	0.4 to 0.9
Phosphorous	Not more than 0.04
Sulphur	Not more than 0.04
Silicon	0.15 to 0.35

#### 3.5.2 Zinc

The zinc used for galvanising shall be electrolytic High Grade Zinc of

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99.95% purity. It shall conform to and satisfy all the requirements of IS:209-1979.

**3.6 STANDARD LENGTH**

3.6.1 The earthwire shall be supplied in standard drum length of manufacturer.

**3.7 TESTS**

3.7.1 The following type, routine & acceptance tests and tests during manufacturing shall be carried out on the earthwire.

**3.7.2 TYPE TESTS**

In accordance with the stipulation of specification, the following type tests reports of the earthwire shall be submitted for approval as per clause 9.2 of Section - GTR.

- |    |                    |   |                     |
|----|--------------------|---|---------------------|
| a) | UTS test           | ) |                     |
|    |                    | ) |                     |
| b) | DC resistance test | ) | As per Annexure - B |

**3.7.3 ACCEPTANCE TESTS**

- |    |   |   |                        |
|----|---|---|------------------------|
| a) | Visual check for joints, scratches etc. and length of Earthwire | ) |                        |
|    |   | ) |                        |
|    |   | ) |                        |
| b) | Dimensional check   | ) | As per Annexure - B    |
|    |   | ) |                        |
| c) | Galvanising test  | ) |                        |
|    |   | ) |                        |
| d) | Lay length check  | ) |                        |
|    |   | ) |                        |
| e) | Torsion test  | ) |                        |
|    |   | ) |                        |
| f) | Elongation test   | ) |                        |
|    |   | ) |                        |
| g) | Wrap test   | ) |                        |
|    |   | ) |                        |
| h) | DC resistance test  | ) |                        |
|    |   | ) | IS:398 (Part-III) 1976 |
| i) | Breaking load test  | ) |                        |
|    |   | ) |                        |

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- j) Chemical Analysis of steel )

3.7.4

**ROUTINE TESTS**

- a) Check that there are no cuts, fins etc. on the strands.  
b) Check for correctness of stranding.

3.7.5

**TESTS DURING MANUFACTURE**

- a) Chemical analysis of zinc used for galvanising ) As per Annexure - B  
b) Chemical analysis of steel )

3.7.6

**SAMPLE BATCH FOR TYPE TESTING**

The Contractor shall offer material for sample selection for type testing, only after getting quality assurance programme approved by the Owner. The samples for type testing shall be manufactured strictly in accordance with the Quality Assurance Programme approved by the Owner.

4.0

**TUBULAR BUS CONDUCTORS**

4.1

**General**

Aluminium used shall be grade 63401 WP(range 2) conforming to IS:5082.

4.2

**Constructional Features**

4.2.1

For outside diameter (OD) & thickness of the tube there shall be no minus tolerance, other requirements being as per IS : 2678 and IS: 2673.

4.2.2

The aluminium tube shall be supplied in suitable cut length to minimize wastage.

4.2.3

The welding of aluminium tube shall be done by the qualified welders duly approved by the owner.

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### 4.3

#### Tests

In accordance with stipulations of the specification, Routine tests shall be conducted on tubular bus conductors as per IS : 5082. Also the wall thickness and ovality of the tube shall be measured by the ultrasonic method. In addition to the above tests, 0.2% proof tests on both parent metal and Aluminium tube after welding shall be conducted.

### 4.4

#### Parameters

a)	Size	4"IPS (EH Type)
b)	Outer diameter(mm)	114.2
c)	Thickness (mm)	8.51
d)	Cross-sectional area (sq.mm)	2825.61
e)	Weight (kg/m)	7.7

### 5.0

#### EARTHING CONDUCTORS

### 5.1

#### General

All conductors buried in earth and concrete shall be of mild steel. All conductors above ground level and earthing leads shall be of galvanised steel, except for cable trench earthing. The minimum sizes of earthing conductor to be used are as indicated in clause 8.4 of this Section.

### 5.2

#### Constructional Features

### 5.2.1

#### Galvanised Steel

- Steel conductors above ground level shall be galvanised according to IS:2629.
- The minimum weight of the zinc coating shall be 618 gm/sq. m. and minimum thickness shall be 85 microns.
- The galvanised surfaces shall consist of a continuous and uniformly thick coating of zinc, firmly adhering to the surfaces of steel. The finished surface shall be clean and smooth and shall be free from defects like discoloured patches, bare spots, unevenness of

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coating, spelter which is loosely attached to the steel globules, spiky deposits, blistered surfaces, flaking or peeling off etc. The presence of any of these defects noticed on visual or microscopic inspection shall render the material liable to rejection.

### 5.3 Tests

In accordance with stipulations of the specifications galvanised steel shall be subjected to four one minute dips in copper sulphate solution as per IS : 2633.

## 6.0 SPACERS

### 6.1 General

Spacers shall conform to IS : 10162. The spacers are to be located at a suitable spacing to limit the short circuit forces as per IEC 865. Wherever Owner's 400 kV & 220 kV standard gantry structures are being used, the spacer span(s) for different conductor / span configurations and corresponding short circuit forces shall be as per Annexure-D.

Wherever Owner's 400 kV & 220 kV standard gantry structures are not being used, necessary spacer span calculation shall be provided by the contractor during detailed engineering for the approval of Owner.

### 6.2 Constructional Features

6.2.1 No magnetic material shall be used in the fabrication of spacers except for GI bolts and nuts.

6.2.2 Spacer design shall be made to take care of fixing and removing during installation and maintenance.

6.2.3 The design of the spacers shall be such that the conductor does not come in contact with any sharp edge.

### 6.3 Tests

Each type of spacers shall be subjected to the following type tests, acceptance tests and routine tests:

6.3.1 Type Tests : Following type test reports shall be submitted for approval as per clause 9.2 of Section - GTR.

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**a) Clamp slip tests**

The sample shall be installed on test span of twin conductor bundle string or quadruple conductor bundle string (as applicable) at a tension of 44.2 kN. One of the clamps of the sample when subjected to a longitudinal pull of 2.5 kN parallel to the axis of the conductor shall not slip on the conductor. The permanent displacement between the conductor and the clamp of sample measured after removal of the load shall not exceed 1.0 mm. Similar tests shall be performed on the other clamps of the same sample.

**b) Fault current test as per CI 5.14.2 of IS : 10162**

**c) Corona Extinction Voltage Test (Dry).**

This test shall be performed on 400 kV and 220 kV equipment as per procedure mentioned at Annexure - C, Minimum Corona Extinction voltage shall be 320 kV (rms) line to ground and 156 kV (rms) line to ground for 400 kV and 220 kV spacers respectively.

**d) RIV Test (Dry)**

This test shall be performed as per procedure mentioned at Annexure - C, Maximum RIV level at 305 kV (rms) line to ground and 156 kV (rms) line to ground for 400 kV and 220 kV spacers respectively shall be 1000 micro volts, across 300 ohm resistor at 1 MHz

**e) Resilience test (if applicable)**

**f) Tension Test**

**g) Log decrement test (if applicable)**

**h) Compression test**

**i) Galvanising test**

**6.3.2**

**Acceptance Test (As per IS : 10162 )**

**a) Visual examination**

**b) Dimensional verification**

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- c) Movement test
- d) Clamp slip test
- e) Clamp bolt torque test (if applicable)
- f) Assembly torque test
- g) Compression test
- h) Tension test
- i) Galvanising test
- j) Hardness test for neoprene (if applicable)

The shore hardness of different points on the elastometer surface of cushion grip clamp shall be measured by shore hardness meter. It shall be between 65 to 80.

- k) Ultimate Tensile Strength Test

The UTS of the retaining rods shall be measured. It shall not be less than 35 kg/Sq. mm.

### 6.3.3

#### Routine test

- a) Visual examination
- b) Dimensional verification

### 7.0

#### BUS POST INSULATORS

The post insulators shall conform in general to latest IS : 2544, IEC-168 and IEC-815.

### 7.1

#### Constructional Features

#### 7.1.1

Post type insulators shall consist of a porcelain part permanently secured in a metal base to be mounted on the supporting structures. They shall be capable of being mounted upright. They shall be designed to withstand any shocks to which they may be subjected to by the operation of the associated equipment. Only solid core insulators will be acceptable.

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- 7.1.2 Porcelain used shall be homogeneous, free from lamination, cavities and other flaws or imperfections that might affect the mechanical or dielectric quality and shall be thoroughly vitrified, tough and impervious to moisture.
- 7.1.3 Glazing of the porcelain shall be of uniform brown in colour, free from blisters, burrs and other similar defects.
- 7.1.4 The insulator shall have alternate long and short sheds with aerodynamic profile, The shed profile shall also meet the requirements of IEC-815 for the specified pollution level.
- 7.1.5 When operating at normal rated voltage there shall be no electric discharge between conductor and insulators which would cause corrosion or injury to conductors or insulators by the formation of substance produced by chemical action.
- 7.1.6 The design of the insulators shall be such that stresses due to expansion and contraction in any part of the insulator shall not lead to deterioration.
- 7.1.7 All ferrous parts shall be hot dip galvanised in accordance with the latest edition of IS: 2633, & IS: 4579. The zinc used for galvanising shall be grade Zn 99.95 as per IS : 209. The zinc coating shall be uniform, adherent, smooth, reasonably bright, continuous and free from imperfections such as flux ash, rust stains, bulky white deposits and blisters. The metal parts shall not produce any noise generating corona under the operating conditions.
- 7.1.8
- a) Every bolt shall be provided with a steel washer under the nut so that part of the threaded portion of the bolts is within the thickness of the parts bolted together.
  - b) Flat washer shall be circular of a diameter 2.5 times that of bolt and of suitable thickness. Where bolt heads/nuts bear upon the beveled surfaces they shall be provided with square tapered washers of suitable thickness to afford a seating square with the axis of the bolt.
  - c) All bolts and nuts shall be of steel with well formed hexagonal heads forged from the solid and shall be hot dip galvanised. The nuts shall be good fit on the bolts and two clear threads shall show through the nut when it has been finally tightened up.

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- 7.1.9 Bidder shall make available data on all the essential features of design including the method of assembly of shells and metals parts, number of shells per insulator, the manner in which mechanical stresses are transmitted through shells to adjacent parts, provision for meeting expansion stresses, results of corona and thermal shock tests, recommended working strength and any special design or arrangement employed to increase life under service conditions.

### 7.2 Tests

In accordance with the stipulations of the specification, the post insulators shall be subject to type, acceptance, sample and routine tests as per IS : 2544 and IEC-168.

- 7.2.1 In addition to acceptance/sample/routine tests as per IS : 2544 and IEC-168, the following tests shall also be carried out.

- a) Ultrasonic test as an acceptance test
- b) Soundness test, metallurgical tests and magnetic test on MCI caps and pedestal tests as acceptance test.
- c) All hot dip galvanised components shall be subject to check for uniformity of thickness and weight of zinc coating on sample basis.
- d) The bending test shall be carried out at 50% minimum failing load in four directions as a routine test and at 100% minimum failing load in four directions as an acceptance test.
- e) Acceptance norms for visual defects allowed at site and also at works shall be agreed in the Quality plan.

- 7.2.2 In accordance with the stipulation of specification, the following type tests reports of the post insulators shall be submitted for approval as per clause 9.2 of Section - GTR.

- a) Power frequency withstand test (dry & wet)
- b) Lightning impulse test (dry)
- c) Switching impulse test (wet) (For 420 kV Insulator only)
- d) Measurement of R.I.V (Dry) (As per Annexure - C)

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- e) Corona extinction voltage test (Dry) (As per Annexure – C)
- f) Test for deflection under load
- g) Test for mechanical strength.

7.3

**Technical Parameters of Bus Post Insulators.**

a) Type	Solid Core	Solid Core	Solid Core
b) Voltage class (kV)	420	245	145
c) Dry and wet one minute power frequency withstand voltage (kV rms)	680	460	275
d) Dry lightning impulse withstand Voltage (kVp)	±1425	± 1050	±650
e) Wet switching surge withstand voltage (kVp)	±1050	—	—
f) Max. radio interference voltage (in microvolts) at voltage of 305 kV (rms) and 156 (rms) for 400 kV & 220 kV respectively between phase to ground.	500	500	500
g) Corona extinction voltage (kV rms)	320 (Min.)	156 (Min.)	105 (Min)
h) Total minimum cantilever strength (Kg)	800	800	600
i) Minimum torsional moment	-----	As per IEC-273	-----
j) Total height of insulator (mm)	3650	2300	---
k) P.C.D			
Top (mm)	127	127	---

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	Bottom (mm)	300	254	---
l)	No. of bolts			
	Top	4	4	---
	Bottom	8	8	---
m)	Diameter of bolt/holes (mm)			
	Top	M16	M16	---
	Bottom dia	18	18	---
n)	Pollution level as per IEC-815	Heavy(III)	Heavy(III)	Heavy(III)
o)	Minimum total creepage distance for Heavy Pollution (mm)	10500	6125	3165

7.3.1 If corona extinction voltage is to be achieved with the help of corona ring or any other similar device, the same shall be deemed to be included in the scope of the Contractor.

## 8.0 EARTHING

8.1 The earthing shall be done in accordance with requirements given hereunder and drawing titled 'Earthing Details' enclosed with the specification. The earthmat design shall be done by the Contractor as per IEEE-80. The soil resistivity measurement shall also be done by the Contractor. The main earthmat shall be laid in the switchyard area in accordance with the approved design requirements.

8.2 Neutral points of systems of different voltages, metallic enclosures and frame works associated with all current carrying equipments and extraneous metalworks associated with electric system shall be connected to a single earthing system unless stipulated otherwise.

8.3 Earthing and lightning protection system installation shall be in strict accordance with the latest editions of Indian Electricity Rules, relevant Indian Standards and Codes of practice and Regulations existing in the locality where the system is installed.

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- a) Code of practice for Earthing IS:3043
- b) Code of practice for the protection of Building and allied structures against lightning IS:2309.
- c) Indian Electricity Rules 1956 with latest amendments.
- d) National Electricity Safety code IEEE-80.

8.4

**Details of Earthing System**

Item	Size	Material
a) Main Earthing Conductor to be buried in ground	40mm dia	Mild Steel rod
b) Conductor above ground & earthing leads (for equipment)	75x12mm G.S. flat	Galvanised Steel
c) Conductor above ground & earthing leads (for columns & aux. structures)	75x12mm G.S. flat	Galvanised Steel
d) Earthing of indoor LT panels, Control panels and out door marshalling boxes, MOM boxes, Junction boxes & Lighting Panels etc.	50x6 mm G.S. flat	Galvanised Steel
e) Rod Earth Electrode	40mm dia, 3000mm long	Mild Steel
f) Pipe Earth Electrode (in treated earth pit) as per IS.	40mm dia, 3000mm long	Galvanised steel
g) Earthing for motors	25x3mm GS flat	Galvanised steel
h) Earthing conductor	50x6mm MS	Mild steel

along outdoor cable trenches flat

- The sizes of the earthing conductor indicated above are the minimum sizes.

## 8.5

- 8.5.1

- 8.5.2

- ### 8.5.3

- 8.5.4

- 8.5.5

- 8.5.6

- 8.5.7

## 8.6

- ### 8.6.1

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shall be made by two short earthing leads (one direct and another through the support structure) free from kinks and splices. In case earthing pads are not provided on the item to be earthed, same shall be provided in consultation with Owner.

- 8.6.2 Whether specifically shown in drawings or not, steel/RCC columns, metallic stairs etc. shall be connected to the nearby earthing grid conductor by two earthing leads. Electrical continuity shall be ensured by bonding different sections of hand-rails and metallic stairs.
- 8.6.3 Metallic pipes, conduits and cable tray sections for cable installation shall be bonded to ensure electrical continuity and connected to earthing conductors at regular interval. Apart from intermediate connections, beginning points shall also be connected to earthing system.
- 8.6.4 Metallic conduits shall not be used as earth continuity conductor.
- 8.6.5 Wherever earthing conductor crosses or runs along metallic structures such as gas, water, steam conduits, etc. and steel reinforcement in concrete it shall be bonded to the same.
- 8.6.6 Light poles, junction boxes on the poles, cable and cable boxes/glands, lockout switches etc. shall be connected to the earthing conductor running alongwith the supply cable which inturn shall be connected to earthing grid conductor at a minimum two points whether specifically shown or not.
- 8.6.7 Railway tracks within switchyard area shall be earthed at a spacing of 30m and also at both ends.
- 8.6.8 Earthing conductor shall be buried 2000 mm outside the switchyard fence. All the gates and every alternate post of the fence shall be connected to earthing grid.
- The stone spreading shall also be done 2000 mm outside switchyard fence. The criterion for stone spreading shall be followed in line with requirement specified elsewhere in the specification
- 8.6.9 Flexible earthing connectors shall be provided for the moving parts.
- 8.6.10 All lighting panels, junction boxes, receptacles fixtures, conduits etc. shall be grounded in compliance with the provision of I.E. rules
- 8.6.11 A continuous ground conductor of 16 SWG GI wire shall be run all along

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each conduit run. The conductor shall be connected to each panel ground bus. All junction boxes, receptacles, switches, lighting fixtures etc. shall be connected to this 16 SWG ground conductor.

- 8.6.12 50mm x 6mm MS flat shall run on the top tier and all along the cable trenches and the same shall be welded to each of the racks. Further this flat shall be earthed at both ends and at an interval of 30 mtrs. The M.S. flat shall be finally painted with two coats of Red oxide primer and two coats of Post Office red enamel paint.
- 8.6.13 ✓ A 40 mm dia, 3000 mm long MS earth electrode with test link, CI frame and cover shall be provided to connect down conductor of lightning mast and towers with peak.
- 8.7 **Jointing**
- 8.7.1 Earthing connections with equipment earthing pads shall be bolted type. Contact surfaces shall be free from scale, paint, enamel, grease, rust or dirt. Two bolts shall be provided for making each connection. Equipment bolted connections, after being checked and tested, shall be painted with anti corrosive paint/compound.
- 8.7.2 Connection between equipment earthing lead and main earthing conductors and between main earthing conductors shall be welded type. For rust protections, the welds should be treated with red lead and afterwards coated with two layers bitumen compound to prevent corrosion.
- 8.7.3 Steel to copper connections shall be brazed type and shall be treated to prevent moisture ingress.
- 8.7.4 Resistance of the joint shall not be more than the resistance of the equivalent length of the conductor.
- 8.7.5 All ground connections shall be made by electric arc welding. All welded joints shall be allowed to cool down gradually to atmospheric temperature before putting any load on it. Artificial cooling shall not be allowed.
- 8.7.6 Bending of earthing rod shall be done preferably by gas heating.
- 8.7.7 All arc welding with large dia. conductors shall be done with low hydrogen content electrodes.
- 8.7.8 The 75x12mm GS flat shall be clamped with the equipment support

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structures at 1000mm interval.

**8.8 Power Cable Earthing**

Metallic sheaths and armour of all multi core power cables shall be earthed at both equipment and switchgear end. Sheath and armour of single core power cables shall be earthed at switchgear end only.

**8.9 Specific Requirement for Earthing Systems**

8.9.1 Each earthing lead from the neutral of the power transformer/Reactor shall be directly connected to two pipe electrodes in treated earth pit (as per IS) which in turn, shall be buried in Cement Concrete pit with a cast iron cover hinged to a cast iron frame to have an access to the joints. All accessories associated with transformer/reactor like cooling banks, radiators etc. shall be connected to the earthing grid at minimum two points.

8.9.2 Earthing terminal of each lightning arrester & capacitor voltage transformer shall be directly connected to rod earth electrode which in turn, shall be connected to station earthing grid.

8.9.3 Auxiliary earthing mat comprising of 40mm dia M.S. rods closely spaced (300 mm x 300 mm) conductors shall be provided at depth of 300mm from ground level below the operating handles of the M.O.M. Box of the isolators. M.O.M. boxes shall be directly connected to the auxiliary earthing mat.

**9.0 Main Bus Bars**

The brief description of the bus switching scheme, bus bar layout and equipment connection to be adopted are indicated elsewhere in the specification. The bus bar arrangements are shown in drgs enclosed with the bid documents.

9.1 The Contractor shall furnish supporting calculations for the bus bars/conductors to show adequacy of design parameters for:

- a) Fibre-stress
- b) Cantilever strength of post insulators
- c) Aeolian vibrations

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- d) Vertical deflection of bus bars
  - e) Short circuit forces in bundle conductor and spacer location for each span of ACSR conductor stringing as per layout drawings.
- 9.1.1 The welds in the aluminium tubes shall be kept to the minimum and there shall not be more than one weld per span. The procedure and details of welding shall be subject to Owner's approval. Material for welding sleeve shall be same as that of Aluminium tube. Welding sleeve shall be of 600mm length
- 9.1.2 Corona bells shall be provided wherever the bus extends beyond the clamps and on free ends, for sealing the ends of the tubular conductor against rain and moisture and to reduce the electrostatic discharge loss at the end points. There shall be a small drain hole in the corona bell. The material of Corona bell shall be Aluminium alloy similar to that of clamps & connectors.
- 9.1.3 To minimise the vibrations in the aluminium tubes, damping conductor shall be provided inside the aluminium tubes. For this purpose, the cut pieces of ACSR conductor which otherwise are considered wastages, shall be used as damping conductor.
- 9.1.4 Details of past experience of the persons proposed to be employed for Aluminium tube welding and the test reports of the welded pieces to prove the electrical and mechanical characteristics shall also be furnished along with the bid. Welding at site shall be done by adopting a qualified procedure and employing qualified welders as per ASME-Section IX.
- 10.0 **BAY EQUIPMENT**
- 10.1 The disposition of various bay equipments shall be as per single line diagrams and layout drawings.
- 10.2 Bay Marshalling Kiosk:-
- One no. of bay marshalling kiosk shall be provided for each bay. In addition to the requirements specified elsewhere in the specification, the bay marshalling kiosk shall have three distinct compartments for the following purpose:-
- (i) To receive two incoming 415V, 3 phase, 63Amps, AC supply with auto changeover and MCB unit and distribute minimum six (four in case of S/S having highest voltage 132kV) outgoing 415V, 3 phase,

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16 Amps AC supplies controlled by MCB.

- (ii) To distribute minimum ten (six in case of S/S having highest voltage 132kV) outgoing 240V, 10 Amps single phase supplies to be controlled by MCB to be drawn from above 3 phase incomers
- (iii) 200 (100 in case of S/S having highest voltage 132kV) nos. terminal blocks in vertical formation for interlocking facilities.

Additional marshalling Kiosk shall be provided incase the existing marshalling kiosks in a Diametre do not have adequate spare feeders.

### 11.0 LIGHTNING PROTECTION

- 11.1 Direct stroke lightning protection (DSLIP) shall be provided in the EHV switchyard by lightning masts and shield wires. The layout drawings enclosed indicate the tentative arrangement. The final arrangement shall be decided after approval of the DSLIP calculations.
- 11.2 The lightning protection system shall not be in direct contact with underground metallic service ducts and cab.
- 11.3 Conductors of the lightning protection system shall not be connected with the conductors of the safety earthing system above ground level.
- 11.4 Down conductors shall be cleated on the structures at 2000 mm interval.
- 11.5 Connection between each down conductor and rod electrodes shall be made via test joint (pad type compression clamp) located approximately 1500 mm above ground level. The rod electrode shall be further joined with the main earthmat.
- 11.6 Lightning conductors shall not pass through or run inside G.I. conduits.

### 12.0 EQUIPMENT ERECTION DETAILS

- 12.1 For equipment interconnection, the surfaces of equipment terminal pads, Aluminium tube, conductor & terminal clamps and connectors shall be properly cleaned. After cleaning, contact grease shall be applied on the contact surfaces of equipment terminal pad, Aluminium tube/conductor and terminal clamps to avoid any air gap in between. Subsequently bolts of the terminal pad/terminal connectors shall be tightened and the surfaces shall be cleaned properly after equipment interconnection.

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- 12.2 Muslin or leather cloth shall be used for cleaning the inside and outside of hollow insulators .
- 12.3 All support insulators, circuit breaker interrupters and other fragile equipment shall preferably be handled with cranes having suitable booms and handling capacity.
- 12.4 Bending of Aluminium tube and compressed air piping if any should be done by a bending machine and through cold bending only. Bending shall be such that inner diameter of pipe is not reduced.
- 12.5 Cutting of the pipes wherever required shall be such as to avoid flaring of the ends. Hence only a proper pipe cutting tool shall be used. Hack saw shall not be used.
- 12.6 Handling of equipment shall be done strictly as per manufacturer's/supplier's instructions/instruction manual.
- 12.7 Handling equipment, sling ropes etc. should be tested periodically before erection for strength.
- 12.8 The slings shall be of sufficient length to avoid any damage to insulator due to excessive swing, scratching by sling ropes etc.
- 13.0 **STORAGE**
- 13.1 The Contractor shall provide and construct adequate storage shed for proper storage of equipments, where sensitive equipments shall be stored indoors. All equipments during storage shall be protected against damage due to acts of nature or accidents. The storage instructions of the equipment manufacturer/Owner shall be strictly adhered to.
- 14.0 **CABLING MATERIAL**
- 14.1 **CABLE TAGS AND MARKERS**
- 14.1.1 Each cable and conduit run shall be tagged with numbers that appear in the cable and conduit schedule.
- 14.1.2 The tag shall be of aluminium with the number punched on it and securely attached to the cable conduit by not less than two turns of 20 SWG GI wire conforming to IS:280. Cable tags shall be of rectangular shape for power cables and of circular shape for control cables.

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- 14.1.3 Location of cables laid directly underground shall be clearly indicated with cable marker made of galvanised iron plate.
- 14.1.4 Location of underground cable joints shall be indicated with cable marker with an additional inscription "Cable joints".
- 14.1.5 The marker shall project 150 mm above ground and shall be spaced at an interval of 30 meters and at every change in direction. They shall be located on both sides of road and drain crossings.
- 14.1.6 Cable tags shall be provided on all cables at each end (just before entering the equipment enclosure), on both sides of a wall or floor crossing, on each duct/conduit entry and at each end & turning point in cable tray/trench runs. Cable tags shall be provided inside the switchgear, motor control centres, control and relay panels etc., wherever required for cable identification, where a number of cables enter together through a gland plate.
- 14.2 Cable Supports and Cable Tray Mounting Arrangements**
- 14.2.1 The Contractor shall provide embedded steel inserts on concrete floors/walls to secure supports by welding to these inserts or available building steel structures.
- 14.2.2 The supports shall be fabricated from standard structural steel members.
- 14.2.3 Insert plates will be provided at an interval of 750 mm wherever cables are to be supported without the use of cable trays, such as in trenches, while at all other places these will be at an interval of 2000 mm.
- 14.3 Cable Termination and Connections**
- 14.3.1 The termination and connection of cables shall be done strictly in accordance with cable and termination kit manufacturer's instructions, drawing and/or as directed by the Owner.
- 14.3.2 The work shall include all clamping, fittings, fixing, plumbing, soldering, drilling, cutting, taping, heat shrinking (where applicable), connecting to cable terminal, shorting and grounding as required to complete the job.
- 14.3.3 Supply of all consumable material shall be in the scope of Contractor.
- 14.3.4 The equipment will be generally provided with undrilled gland plates for cables/conduit entry. The Contractor shall be responsible for drilling of-

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gland plates, painting and touching up. Holes shall not be made by gas cutting.

- 14.3.5 Control cable cores entering control panel/switch-gear/MCCB/MCC/miscellaneous panels shall be neatly bunched, clamped and tied with nylon strap or PVC perforated strap to keep them in position.
- 14.3.6 The Contractor shall tag/ferrule control cable cores at all terminations, as instructed by the Owner. In panels where a large number of cables are to be terminated and cable identification may be difficult, each core ferrule may include the complete cable number as well.
- 14.3.7 Spare cores shall be similarly tagged with cable numbers and coiled up.
- 14.3.8 All cable entry points shall be sealed and made vermin and dust proof. Unused openings shall be effectively closed.
- 14.3.9 Double compression type nickel plated (coating thickness not less than 10 microns) brass cable glands shall be provided by the Contractor for all power and control cables to provide dust and weather proof terminations.
- 14.3.10 The cable glands shall conform to BIS:6121. They shall comprise of heavy duty brass casting, machine finished and nickel plated, to avoid corrosion and oxidation. Rubber components used in cable glands shall be neoprene and of tested quality. Cable glands shall be of approved make.
- 14.3.11 The cable glands shall also be suitable for dust proof and weather proof termination. The test procedure, if required, has to be discussed and agreed to between Owner and cable gland manufacturer.
- 14.3.12 If the cable-end box or terminal enclosure provided on the equipment is found unsuitable and requires modification, the same shall be carried out by the Contractor, as directed by the Owner.
- 14.3.13 Crimping tool used shall be of approved design and make.
- 14.3.14 Cable lugs shall be tinned copper solderless crimping type conforming to IS-8309 & 8394. Bimetallic lugs shall be used depending upon type of cables used.
- 14.3.15 Solderless crimping of terminals shall be done by using corrosion inhibitory compound. The cable lugs shall suit the type of terminals provided.

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**14.4 Storage and handling of Cable Drums**

- 14.4.1 Cable drums shall be unloaded, handled and stored in an approved manner and rolling of drums shall be avoided as far as possible. For short distances, the drums may be rolled provided they are rolled slowly and in proper direction as marked on the drum.

**15.0 DIRECTLY BURIED CABLES**

- 15.1 The Contractor shall construct the cable trenches required for directly buried cables. The scope of work shall include excavation, preparation of sand bedding, soil cover, supply and installation of brick or concrete protective covers, back filling and ramming, supply and installation of route markers and joint markers. The Bidder shall ascertain the soil conditions prevailing at site, before submitting the bid.
- 15.2 The cable (power and control) between LT station, control room, DG set building and fire lighting pump house shall be laid in the buried cable trenches. In addition to the above, for lighting purpose also, buried cable trench can be used in outdoor area.
- 15.3 Cable route and joint markers and RCC warning covers shall be provided wherever required. The voltage grade of cables shall be engraved on the marker.

**16.0 INSTALLATION OF CABLES**

- 16.1 Cabling in the control room shall be done on ladder type cable trays while cabling in switchyard area shall be done on angles in the trench.
- 16.2 All cables from bay cable trench to equipments including and all interpole cables (both power and control) for all equipment, shall be laid in PVC pipes of minimum 50 mm nominal outside diameter of class 4 as per IS 4985 which shall be buried in the ground at a depth of 250mm below finish formation level. Separate PVC pipes shall be laid for control and power cables.
- 16.3 Cables shall be generally located adjoining the electrical equipment through the pipe insert embedded in the floor. In the case of equipments located away from cable trench either pipe inserts shall be embedded in the floor connecting the cable trench and the equipment or in case the distance is small, notch/opening on the wall shall be provided. In all these cases necessary bending radius as recommended by the cable

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manufacturer shall be maintained.

- 16.4 Cable racks and supports shall be painted after installation with two coats of metal primer (comprising of red oxide and zinc chromate in a synthetic medium) followed by two finishing coats of aluminium paint. The red oxide and zinc chromate shall conform to IS:2074.
- 16.5 Suitable arrangement should be used between fixed pipe / cable trays and equipment terminal boxes, where vibration is anticipated.
- 16.6 Power and control cables in the cable trench shall be laid in separate tiers. The order of laying of various cables shall be as follows, for cables other than directly buried.
- a) Power cables on top tiers.
  - b) Control instrumentation and other service cables in bottom tiers.
- 16.7 Single core cables in trefoil formation shall be laid with a distance of three times the diameter of cable between trefoil centre lines. All power cables shall be laid with a minimum centre to centre distance equal to twice the diameter of the cable of higher size of cables.
- 16.8 Trefoil clamps for single core cables shall be of pressure die cast aluminium (LM-6), Nylon -6 or fibre glass and shall include necessary fixing GI nuts, bolts, washer etc. These are required at every 2 metre of cable runs.
- 16.9 Power and control cables shall be securely fixed to the trays/supports with self locking type nylon ties with deinterlocking facility at every 5 metre interval for horizontal run. Vertical and inclined cable runs shall be secured with 25 mm wide and 2 mm thick aluminium strip clamps at every 2m.
- 16.10 Cables shall not be bent below the minimum permissible limit. The permissible limits are as follows :
- | Table of Cable and | Minimum bending radius |
|--------------------|------------------------|
| Power cable        | 12 D                   |
| Control cable      | 10 D                   |
- D is overall diameter of cable

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- 16.11 Where cables cross roads, drains and rail tracks, these shall be laid in reinforced spun concrete or steel pipes buried at not less than one metre depth.
- 16.12 In each cable run some extra length shall be kept at a suitable point to enable one (for LT cables)/two (for H.T. cables) straight through joints to be made in case the cable develop fault at a later date.
- 16.13 Selection of cable drums for each run shall be so planned as to avoid using straight through joints. Cable splices will not be permitted except where called for by the drawings, unavoidable or where permitted by the Owner. If straight through joints are unavoidable, the Contractor shall use the straight through joints kit of reputed make.
- 16.14 Control cable terminations inside equipment enclosures shall have sufficient lengths so that changing of termination in terminal blocks can be done without requiring any splicing.
- 16.15 Metal screen and armour of the cable shall be bonded to the earthing system of the station, wherever required by the Owner.
- 16.16 Rollers shall be used at intervals of about two metres while pulling cables.
- 16.17 All due care shall be taken during unreeling, laying and termination of cable to avoid damage due to twist, kinks, sharp bends, etc.
- 16.18 Cable ends shall be kept sealed to prevent damage. In cable vault, fire resistant seal shall be provided underneath the panels.
- 16.19 Inspection on receipt, unloading and handling of cables shall generally be in accordance with IS:1255 and other Indian Standard Codes of practices.
- 16.20 Wherever cable pass through floor or through wall openings or other partitions, GI/PVC wall sleeves with bushes having a smooth curved internal surface so as not to damage the cable, shall be supplied, installed and properly sealed by the Contractor at no extra charges.
- 16.21 Contractor shall remove the RCC/Steel trench covers before taking up the work and shall replace all the trench covers after the erection-work in that particular area is completed or when further work is not likely to be taken up for some time.
- 16.22 Contractor shall furnish three copies of the report on work carried out in a

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particular week, indicating cable numbers, date on which laid, actual length and route, testing carried out, terminations carried out, along with the marked up copy of the cable schedule and interconnection drawing wherever any modifications are made.

- 16.23 Contractor shall paint the tray identification number on each run of trays at an interval of 10 m.
- 16.24 In case the outer sheath of a cable is damaged during handling/installation, the Contractor shall repair it at his own cost to the satisfaction of the Owner. In case any other part of a cable is damaged, the same shall be replaced by a healthy cable at no extra cost to the Owner, i.e. the Contractor shall not be paid for installation and removal of the damaged cable.
- 16.25 All cable terminations shall be appropriately tightened to ensure secure and reliable connections. The Contractor shall cover the exposed part of all cable lugs whether supplied by him or not with insulating tape, sleeve or paint.
- 16.26 **Cable trays**
- i) The cable trays shall be of G.S.sheet and minimum thickness of sheet shall be 2mm.
  - ii) The Contractor shall perform all tests and inspection to ensure that material and workmanship are according to the relevant standards. Contractor shall have to demonstrate all tests as per specification and equipment shall comply with all requirements of the specification.
- a) Test for galvanising (Acceptance Test)  
The test shall be done as per approved standards.
  - b) Deflection Test : (Type Test)  
A 2.5 metre straight section of 300mm, 600mm wide cable tray shall be simply supported at two ends. A uniform distributed load of 76 kg/m shall be applied along the length of the tray. The maximum deflection at the mid-span shall not exceed 7mm.
- 16.27 **Conduits, Pipes and Duct Installation**
- 16.27.1 Contractor shall supply and install all rigid conduits, mild steel pipes, flexible conduits, hume pipes etc. including all necessary sundry

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materials such as tees, elbows, check nuts, bushing, reducers, enlargers, coupling cap, nipples, gland sealing fittings, pull boxes etc as specified and to be shown in detailed drawing. The size of the conduit/pipe shall be selected on the basis of 40% fill criterion.

- 16.27.2 Contractor shall have his own facility for bending, cutting and threading the conduits at site. Cold bending should be used. All cuts & threaded ends shall be made smooth without leaving any sharp edges. Anticorrosive paint shall be applied at all field threaded portions.
- 16.27.3 All conduit/pipes shall be extended on both sides of wall/floor openings. The fabrication and installation of supports and the clamping shall be included in the scope of work by Contractor.
- 16.27.4 When two lengths of conduits are joined together through a coupling, running threads equal to twice the length of coupling shall be provided on each conduit to facilitate easy dismantling of two conduits.
- 16.27.5 Conduit installation shall be permanently connected to earth by means of special approved type of earthing clamps. GI pull wire of adequate size shall be laid in all conduits before installation.
- 16.27.6 Each conduit run shall be painted with its designation as indicated on the drawings such that it can be identified at each end.
- 16.27.7 Embedded conduits shall have a minimum concrete cover of 50 mm.
- 16.27.8 Conduit run sleeves shall be provided with the bushings at each end.
- 16.27.9 Metallic conduit runs at termination shall have two locknuts and a bushing for connection. Flexible conduits shall also be suitably clamped at each end with the help of bushings. Bushings shall have rounded edges so as not to damage the cables.
- 16.27.10 Where embedded conduits turn upwards from a slab or fill, the termination dimensions shown on the drawings, if any, shall be taken to represent the position of the straight extension of the conduit external to and immediately following the bend. At least one half of the arc length of the bend shall be embedded.
- 16.27.11 All conduits/pipes shall have their ends closed by caps until cables are pulled. After cables are pulled, the ends of conduits/pipes shall be sealed in an approved manner to prevent damage to threaded portions and entrance of moisture and foreign material.

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- 16.27.12 For underground runs, Contractor shall excavate and back fill as necessary.
- 16.27.13 Contractor shall supply, unload, store and install conduits required for the lighting installation as specified. All accessories/fittings required for making the installation complete, including but not limited to pull out boxes, ordinary and inspection tees and elbow, checknuts, male and female bushings (brass or galvanised steel), caps, square headed male plugs, nipples, gland sealing fittings, pull boxes, conduits terminal boxes, gaskets and box covers, saddle terminal boxes, and all steel supporting work shall be supplied by the Contractor. The conduit fittings shall be of the same material as conduits.
- 16.27.14 All unarmoured cables shall run within the conduits from lighting panels to lighting fixtures, receptacles etc.
- 16.27.15 Size of conduit for lighting shall be selected by the Contractor during detailed engineering.
- 16.27.16 Exposed conduits shall be run in straight lines parallel to building columns, beams and walls. Unnecessary bends and crossings shall be avoided to present a neat appearance.
- 16.27.17 Conduit supports shall be provided at an interval of 750mm for horizontal runs and 1000mm for vertical runs.
- 16.27.18 Conduit supports shall be clamped on the approved type spacer plates or brackets by saddles or U- bolts. The spacer plates or brackets in turn, shall be securely fixed to the building steel by welding and to concrete or brick work by grouting or by nylon rawl plugs. Wooden plug inserted in the masonry or concrete for conduit support is not acceptable.
- 16.27.19 Embedded conduits shall be securely fixed in position to preclude any movement. In fixing embedded conduit, if welding or brazing is used, extreme care should be taken to avoid any injury to the inner surface of the conduit.
- 16.27.20 Spacing of embedded conduits shall be such as to permit flow of concrete between them.
- 16.27.21 Where conduits are placed alongwith cable trays, they shall be clamped to supporting steel at an interval of 600mm.

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- 16.27.22 For directly embedding in soil, the conduits shall be coated with an asphalt-base compound. Concrete pier or anchor shall be provided wherever necessary to support the conduit rigidly and to hold it in place.
- 16.27.23 Conduit shall be installed in such a way as to ensure against trouble from trapped condensation.
- 16.27.24 Conduits shall be kept, wherever possible, at least 300mm away from hot pipes, heating devices etc. when it is evident that such proximity may reduce the service life of cables.
- 16.27.25 Slip joints shall be provided when conduits cross structural expansion joints or where long run of exposed conduits are installed, so that temperature change will cause no distortion due to expansion or contraction of conduit run.
- 16.27.26 For long conduit run, pull boxes shall be provided at suitable intervals to facilitate wiring.
- 16.27.27 Conduit shall be securely fastened to junction boxes or cabinets, each with a lock nut inside and outside the box.
- 16.27.28 Conduits joints and connections shall be made thoroughly water-tight and rust proof by application of a thread compound which insulates the joints. White lead issuitable for application on embedded conduit and red lead for exposed conduit.
- 16.27.29 Field bends shall have a minimum radius of four (4) times the conduit diameter. All bends shall be free of kinks, indentations or flattened surfaces. Heat shall not be applied in making any conduit bend. Separate bends may be used for this purpose.
- 16.27.30 The entire metallic conduit system, whether embedded or exposed, shall be electrically continuous and thoroughly grounded. Where slip joints are used, suitable bonding shall be provided around the joint to ensure a continuous ground circuit.
- 16.27.31 After installation, the conduits shall be thoroughly cleaned by compressed air before pulling in the wire.
- 16.27.32 Lighting fixtures shall not be suspended directly from the junction box in the main conduit run.

**17.0 JUNCTION BOX**

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- a) The Contractor shall supply and install junction boxes complete with terminals as required. The brackets, bolts, nuts, screws etc required for erection are also included in the scope of the Contractor.
- b) Junction boxes having volume less than 1600 cubic centimeters may be installed without any support other than that resulting from connecting conduits where two or more rigid metallic conduits enter and accurately position the box. Boxes shall be installed so that they are level, plumb and properly aligned to present a pleasing appearance.
- c) Boxes with volumes equal to or greater than 1600 cubic cm, and smaller boxes terminating on less than two rigid metallic conduits or for other reasons not rigidly held, shall be adequately supported by auxiliary steel of standard steel shapes or plates to be fabricated and installed. The Contractor shall perform all drilling, cutting, welding, shimming and bolting required for attachment of supports.

### 18.0 TESTING AND COMMISSIONING

18.1 An indicative list of tests for testing and commissioning is given below. Contractor shall perform any additional test based on specialities of the items as per the field Q.P./instructions of the equipment Contractor or Owner without any extra cost to the Owner. The Contractor shall arrange all equipments instruments and auxiliaries required for testing and commissioning of equipments alongwith calibration certificates and shall furnish the list of instruments to the Owner for approval.

### 18.2 GENERAL CHECKS

- (a) Check for physical damage.
- (b) Visual examination of zinc coating/plating.
- (c) Check from name plate that all items are as per order/specification.
- (d) Check tightness of all bolts, clamps and connecting terminals using torque wrenches.
- (e) For oil filled equipment, check for oil leakage, if any. Also check oil level and top up wherever necessary.

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- (f) Check ground connections for quality of weld and application of zinc rich paint over weld joint of galvanised surfaces.
- (g) Check cleanliness of insulator and bushings.
- (h) All checks and tests specified by the manufacturers in their drawings and manuals as well as all tests specified in the relevant code of erection.
- (i) Check for surface finish of grading rings (Corona control ring).
- (j) Pressure test on all pneumatic lines at 18.5 times the rated pressure shall be conducted.

**18.3 STATION EARTHING**

- a) Check soil resistivity
- b) Check continuity of grid wires
- c) Check earth resistance of the entire grid as well as various sections of the same.
- d) Check for weld joint and application of zinc rich paint on galvanised surfaces.
- e) Dip test on earth conductor prior to use.

**18.4 'MOOSE' ACSR STRINGING WORK, TUBULAR BUS WORK AND POWER CONNECTORS**

- a) Physical check for finish
- b) Electrical clearance check
- c) Testing of torque by torque wrenches on all bus bar power connectors and other accessories.
- d) Millivolt drop test on all power connectors.
- e) Sag and tension check on conductors.

**18.5 ALUMINIUM TUBE WELDING**

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- a) Physical check
- b) Millivolt drop test on all joints.
- c) Dye penetration test & Radiography test on 10% sample basis on weld joints.
- c) Test check on 5% sample joints after cutting the weld piece to observe any voids etc.

**18.6 INSULATOR**

Visual examination for finish, damage, creepage distance etc.

- 18.7** All pre/commissioning activities and works work for substation equipment shall be carried out in accordance with owner's "Pre-Commissioning procedures and formats for substation bay equipments" by the contractor. This document shall be provided to the successful contractor during detailed engineering stage.

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**ANNEXURE "A"**

**(Testing Procedure for ACSR 'MOOSE' Conductor)**

**1.0        UTS Test on Stranded Conductor**

Circles perpendicular to the axis of the conductor shall be marked at two places on a sample of conductor of minimum 5 m length suitably compressed with dead end clamps at either end. The load shall be increased at a steady rate upto 80 kN and held for one minute. The circles drawn shall not be distorted due to Relative movement of strands. Thereafter the load shall be increased at a steady rate to 161.2 kN and held for one minute. The applied load shall then be increased until the failing load is reached and the value recorded.

**2.0        Corona Extinction Voltage Test**

Two samples of conductor of 5m length shall be strung with a spacing of 450 mm between them at a height not exceeding 8.0 m above ground. This assembly shall be tested as per Annexure-C, Corona extinction voltage shall not be less than 320 KV (RMS) Line to ground.

**3.0        Radio Interference Voltage Test**

The sample assembly similar to that specified under (2.0) above shall be tested as per Annexure - C. Maximum RIV level (across 300 ohm resistor at 1 MHz) at 305 KV (RMS) line to ground voltage shall be 1000 micro volts.

**4.0        D.C Resistance Test on Stranded Conductor**

On a conductor sample of minimum 5 m length two contact clamps shall be fixed with a pre-determined bolt torque. The resistance shall be measured by a Kelvin double bridge by placing the clamps initially zero metre and subsequently one metre apart. The test shall be repeated at least five times and the average value recorded. The value obtained shall be corrected to the value at 20°C as per clause no. 12.8 of IS:398 (Part V)-1982. The resistance corrected at 20°C shall conform to the requirements of this specification.

**5.0        Chemical Analysis of Zinc**

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Samples taken from the zinc ingots shall be chemically/spectrographically analysed. The same shall be in conformity to the requirements stated in this specification.

### 6.0 Chemical Analysis of Aluminium and Steel

Samples taken from the Aluminium ingots/coils/strands shall be chemically/spectrographically analysed. The same shall be in conformity to the requirements stated in this specification.

### 7.0 Visual Check for Joints, Scratches etc.

Conductor drums shall be rewound in the presence of the inspector. The inspector shall visually check for scratches, joints, etc. and that the conductor generally conform to the requirements of this specification. The length of conductor wound on the drum shall be measured with the help of counter meter during rewinding.

### 8.0 Dimensional Check for Steel and Aluminium Strands.

The individual strands shall be dimensionally checked to ensure that they conform to the requirements of this specification.

### 9.0 Check for Lay-ratios of various Layers.

The lay-ratios of various layers shall be checked to ensure that they conform to the requirements of this specification and clause no. 9.4 and 9.5 of IS-398 (Part - V) 1982.

### 10.0 Galvanising Test

The test procedure shall be as specified in IS:4826-1968. The material shall conform to the requirements of this specification.

### 11.0 Torsion and Elongation Tests on Steel Strands

The test procedures shall be as per relevant clause of IS:398 (Part V), 1982. In torsion test, the number of complete twists before fracture shall not be less than 18 on a length equal to 100 times the standard diameter of the strand before stranding & 16 after stranding. In case test sample length of less or more than 100 times the standard diameter of the strand, the minimum number of twist will be proportionate to the length and if number comes in the fraction then it will be rounded off to next

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higher whole number. In elongation test, the elongation of the strand shall not be less than 4% for a gauge length of 200 mm.

12.0

**Breaking load test on welded Aluminium strand:**

Two Aluminium wires, shall be welded as per the approved quality plan and shall be subjected to tensile load. The welded point of the wire shall be able to withstand the minimum breaking load of the individual strand guaranteed by the bidder.

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ANNEXURE "B"

(Testing procedure for Galvanised Steel Earthwire)

1. **UTS TEST**

Circles perpendicular to the axis of the earthwire shall be marked at two places on a sample of earthwire of minimum 5m length, suitably compressed with dead end clamps at either end. The load shall be increased at steady rate upto 34 KN and held for one minute. The circles drawn shall not be distorted due to relative movement of strands. Thereafter, the load shall be increased at a steady rate of 68.4 KN and held for one minute. The earthwire sample shall not fail during this period. The applied load shall then be increased until the failing load is reached and value recorded.

2. **D.C. RESISTANCE TEST**

On an earthwire sample of minimum 5m length, two contact clamps shall be fixed with a predetermined Bolt torque. The resistance shall be measured by a Kelvin double-bridge by placing the clamps initially zero meter and subsequently one meter apart. the test shall be repeated at least five times and the average value recorded. The value obtained shall be corrected to the value at 20°C shall conform to the requirements of this specification.

3. **Visual check for joints, scratches etc. and length of earthwire**

Earthwire drums shall be rewound in the presence of the inspector. The inspector shall visually check for joints, scratches etc. and see that the earthwire generally conforms to the requirements of this specification. The length of earthwire wound on the drum shall be measured with the help of counter meter during rewinding.

4. **TORSION AND ELONGATION TESTS**

The test procedure shall be as per relevant clause of IS:398 (Part-V). The minimum number of twists which a single steel strand shall withstand during torsion test shall be eighteen for a length equal to 100 times the standard diameter of the strand. In case the test sample length is less or more than 100 times the standard diameter of the strand, the minimum number of twists will be proportionate to the length and if number comes in the fraction then it will be rounded off to next higher whole number. In

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elongation test, the elongation of the strand shall not be less than 64% or a gauge length of 200 mm.

**5. DIMENSIONAL CHECK**

The individual strands shall be dimensionally checked to ensure that they conform to the requirements of this specification.

**6. LAY LENGTH CHECK**

The lay length shall be checked to ensure that they conform to the requirements of this specification.

**7. GALVANISING TEST**

The test procedure shall as specified in IS:4826-1968. The material shall conform to the requirements of this specification.

**8. CHEMICAL ANALYSIS OF ZINC USED FOR GALVANIZING**

Samples taken from zinc ingots shall be chemically/spectrographically analysed. The same shall be in conformity to the requirements stated in this specification.

**9. CHEMICAL ANALYSIS OF STEEL**

Samples taken from steel ingots/coils/strands shall be chemically/spectrographically analysed. The same shall be in conformity to the requirements stated in this specification.

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ANNEXURE-C

**CORONA AND RADIO INTERFERENCE VOLTAGE (RIV) TEST**

1. General

Unless otherwise stipulated, all equipment together with its associated connectors, where applicable, shall be tested for external corona both by observing the voltage level for the extinction of visible corona under falling power frequency voltage and by measurement of radio interference voltage (RIV).

2. Test Levels:

The test voltage levels for measurement of external RIV and for corona extinction voltage are listed under the relevant clauses of the specification.

3. Test Methods for RIV:

3.1 RIV tests shall be made according to measuring circuit as per International Special-Committee on Radio Interference (CISPR) Publication 16-1(1993) Part -1. The measuring circuit shall preferably be tuned to frequency with 10% of 0.5 Mhz but other frequencies in the range of 0.5 MHz to 2 MHz may be used, the measuring frequency being recorded. The results shall be in microvolts.

3.2 Alternatively, RIV tests shall be in accordance with NEMA standard Publication No. 107-1964, except otherwise noted herein.

3.3 In measurement of, RIV, temporary additional external corona shielding may be provided. In measurements of RIV only standard fittings of identical type supplied with the equipment and a simulation of the connections as used in the actual installation will be permitted in the vicinity within 3.5 meters of terminals.

3.4 Ambient noise shall be measured before and after each series of tests to ensure that there is no variation in ambient noise level. If variation is present, the lowest ambient noise level will form basis for the measurements. RIV levels shall be measured at increasing and decreasing voltages of 85%, 100%, 115% and 130% of the specified RIV test voltage for all equipment unless otherwise specified. The specified RIV test voltage for 400 kV, 220 KV is listed in the detailed specification together with maximum permissible RIV level in microvolts.

3.5 The metering instruments shall be as per CISPR recommendation or equivalent device so long as it has been used by other testing authorities.

3.6 The RIV measurement may be made with a noise meter. A calibration.

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procedure of the frequency to which noise meter shall be tuned shall establish the ratio of voltage at the high voltage terminal to voltage read by noise meter.

### 4. Test Methods for Visible Corona

The purpose of this test is to determine the corona extinction voltage of apparatus, connectors etc. The test shall be carried out in the same manner as RIV test described above with the exception that RIV measurements are not required during test and a search technique shall be used near the onset and extinction voltage, when the test voltage is raised and lowered to determine their precise values. The test voltage shall be raised to 130% of RIV test voltage and maintained there for five minutes. In case corona inception does not take place at 130%, test shall be stopped, otherwise test shall be continued and the voltage will then be decreased slowly until all visible corona disappears. The procedure shall be repeated at least 4 times with corona inception and extinction voltage recorded each time. The corona extinction voltage for purposes of determining compliance with the specification shall be the lowest of the four values at which visible corona (negative or positive polarity) disappears. Photographs with laboratory in complete darkness shall be taken under test conditions, at all voltage steps i.e. 85%, 100%, 115% and 130%. Additional photographs shall be taken at corona inception and extinction voltages. At least two views shall be photographed in each case using Panchromatic film with an ASA daylight rating of 400 with an exposure of two minutes at a lens aperture of f/5.6 or equivalent. The photographic process shall be such that prints are available for inspection and comparison with conditions as determined from direct observation. Photographs shall be taken from above and below the level of connector so as to show corona on bushing, insulators and all parts of energised connectors. The photographs shall be framed such that test object essentially, fills the frame with no cut-off.

In case corona inception does not take place at 130%, voltage shall not be increased further and corona extinction voltage shall be considered adequate.

- 4.1 The test shall be recorded on each photograph. Additional photograph shall be taken from each camera position with lights on to show the relative position of test object to facilitate precise corona location from the photographic evidence.
- 4.2 In addition to photographs of the test object preferably four photographs shall be taken of the complete test assembly showing relative positions of all the test equipment and test objects. These four photographs shall be taken from four points equally spaced around the test arrangement to show its features from all sides. Drawings of the laboratory and test set up locations

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shall be provided to indicate camera positions and angles. The precise location of camera shall be approved by Purchaser's Inspector, after determining the best camera locations by trial energisation of test object at a voltage which results in corona.

4.3 The test to determine the visible corona extinction voltage need not be carried out simultaneously with test to determine RIV levels.

4.4 However, both test shall be carried out with the same test set up and as little time duration between tests as possible. No modification on treatment of the sample between tests will be allowed. Simultaneous RIV and visible corona extinction voltage testing may be permitted at the discretion of Purchaser's Inspector if, in his opinion, it will not prejudice other test.

### 5. Test Records:

In addition to the information previously mentioned and the requirements specified as per CISPR or NEMA 107-1964 the following data shall be included in test report:

- a) Background noise before and after test.
- b) Detailed procedure of application of test voltage.
- c) Measurements of RIV levels expressed in micro volts at each level.
- d) Results and observations with regard to location and type of interference sources detected at each step.
- e) Test voltage shall be recorded when measured RIV passes through 100 microvolts in each direction.
- f) Onset and extinction of visual corona for each of the four tests required shall be recorded.

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## ANNEXURE - D

### SHORT CIRCUIT FORCES AND SPACER SPAN FOR 400KV GANTRY STRUCTURE

Sl.No.	Max. Span	Conductor Configuration	Ph-Ph Spacing	Normal Tension	Short circuit force per Phase	Spacer Span
1.	54 Mtr	QUAD	7 mtr	4 T	5.64 T	6 mtr
2.	54 Mtr	QUAD	6 mtr	4 T	5.1 T	5 mtr
3.	70 Mtr	TWIN	7 mtr	4 T	5.64 T	5 mtr
4.	70 Mtr	TWIN	6 mtr	4 T	5.1 T	5 mtr

### SHORT CIRCUIT FORCES AND SPACER SPAN FOR 220 kV GANTRY STRUCTURE

Sl.No.	Max. Span	Conductor Configuration	Ph-Ph Spacing	Normal Tension	Short circuit force per Phase	Spacer Span
1.	54 Mtr	QUAD	4.5 mtr	4 T	5 T	2.5 mtr
2.	54 Mtr	QUAD	4.0 mtr	4 T	5.7 T	2.5 mtr
3.	54 Mtr	TWIN	4.5 mtr	2 T	3.5 T	2.5 mtr
4.	54 Mtr	TWIN	4.0 mtr	2 T	3.5 T	2.5 mtr
5.	74 Mtr	TWIN	4.5 mtr	4 T	5 T	2.5 mtr
6.	74 Mtr	TWIN	4.0 mtr	4 T	5.7 T	2.5 mtr