±800kV, 6000MW HVDC Raigarh - Pugalur Terminals Raigarh - Pugalur	Document number , revision 1JNL375066 , E		Page 1 (19)
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Title DC disconnectors and earthing switches			

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PROPRIETARY AND SECRET INFORMATION

1 General

This document constitutes the Requirement Specification for the ±800 kV, 6000 MW HVDC Raigarh – Pugalur Terminals Project (RP800). The DC Disconnectors and earthing switches will be installed at Raigarh and Pugalur converter stations.

The equipment will be used for disconnecting and earthing of the pole and neutral buses. The disconnectors and earthing switches for the different items shall, as far as possible, be of identical design.

The equipment shall comply with the requirements in this specification and in General requirements for main circuit apparatus [1]. In case of conflicting information, this specification shall prevail.

The equipment shall also comply with the requirements given in section 6.8, 6.9 and 6.13 of the customer's technical specification. The customer's Technical Specifications are found in the enclosure to this RS. In case of any conflict between this RS and Customer Technical Specification, the supplier shall inform BHEL for a final decision.

Alterations from the Standard requirement specification are printed in italic font.

2 Quantities

2.1 Raigarh Converter station

Pos	Reference designation	Description	Quantity (1 ph units)	Scope of Supply
02	=WN(1,2).Q(11,13)[1] =WN.Q(15,16,31)	DC disconnectors, neutral	7	BHEL
03	=P(1,2,3,4).WN.Q21	DC earthing switch, neutral	4	BHEL
06	=P(1,2,3,4).Z1.Q12 =WN(1,2).Q(12,14)[1] =WN.Q(17,18)[1]	DC disconnector with 1 earthing switch, neutral	10	BHEL

[1] Arcing horns or arcing contacts are required for =WN(1,2).Q(11,13), =WN(1,2).Q(12,14) and =WN.Q(11,12,17,18,32). Similar arcing horns or arcing contacts shall be provided for spares also.
[2] Arcing horns or arcing/whipping contacts are required for =P(1,2,3,4).Z1.Q11. Similar arcing horns or arcing/whipping contacts shall be provided for spares also.

90	Spare[1]	DC disconnector set, neutral, for Pos 02 and 06	1	BHEL
91	Spare	DC earthing switch set, neutral, for Pos 03 and 06	1	BHEL
100	*Spare*	*As per "Annexure DISCON", when not covered by items 90-91*	--	

2.2 Pugalur Converter station

Pos	Reference designation	Description	Quantity (1 ph units)	Scope of Supply
02	=WN(1,2).Q(11,13)[3] =WN.Q(15,16,39[3])	DC disconnector, neutral	7	BHEL
03	=P(1,2,3,4).WN.Q21	DC earthing switch, neutral	4	BHEL
05	=P(1,2,3,4).Z1.Q12 =WN(1,2).Q(12,14)[3] =WN.Q(17,38)[3]	DC disconnector with 1 earthing switch, neutral	10	BHEL

[3] Arcing horns or arcing contacts are required for =WN(1,2).Q(11,13),=WN.Q39,=WN(1,2).Q(12,14) , =WN.Q(17,38) and =WN.Q18. Similar arcing horns or arcing contacts shall be provided for spares also.
[4]Arcing horns or arcing/whipping contacts are required for =P(1,2,3,4).Z1.Q11. Similar arcing horns or arcing/whipping contacts shall be provided for spares also.

07	=WN.Q18[3]	DC disconnectors with 2 earthing switches, neutral	1	BHEL
90	Spare[3]	DC disconnector set, neutral, for Pos 02, 05 and 07	1	BHEL
91	Spare	DC earthing switch set, neutral, for Pos 03, 05 and 07	1	BHEL
100	*Spare*	*As per "Annexure DISCON", when not covered by items 90-91*	--	

3 Standards

The disconnectors and earthing switches shall, except otherwise specified herein, be designed, rated and tested in accordance with IEC 62271-102, High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches [4].

4 Technical data

4.1 Raigarh Station

			Neutral Disconnector	Neutral Earthing switch
	Reference designation as per clause 2.1			
	Position		02/06	03/06
	Location		DC yard	DC yard
1	**Frequencies**			
1.1	Rated frequency		DC	DC
2	**Voltages**			
2.1	Rated DC voltage	kV_{dc}	95	95
2.2	Max temporary DC voltage, 30 min	kV_{dc}	105	105
3	**Currents**			
3.1	Rated current *at 1.1 overload*	A_{dc}	2316	N.A.
3.2	*Rated current, rms*	A	--	--
3.3	Max. temporary current (30 min)	A_{dc}	2425	N.A.
3.4	Rated short time withstand current, 1s	kA_{rms}	7.2	7.2
3.5	Rated peak withstand current	kA_{peak}	18	18
3.6	*Whipping contact current*	*A*	--	--
	-at recovery voltage	*kV*	--	--
4	**Test voltages**			

[5] Only for Pos 07, 08 and 10
[6] Only for Pos 01

			Neutral Disconnector	Neutral Earthing switch
	Reference designation as per clause 2.1			
	Position		02/06	03/06
	Location		DC yard	DC yard
4.1	DC voltage withstand (Ut), 1 hour			
	• Terminal to earth	kV_{dc}	141	N.A.
	• Across open switch	kV_{dc}	141	141
4.2	Radio interference test voltage	kV_{rms}	N.A.	N.A.
5	**Insulation levels**			
5.1	Lightning impulse withstand voltage			
	• Terminal to earth	kV_{peak}	644	N.A.
	• Across open switch	kV_{peak}	644	644
5.2	Switching impulse withstand voltage			
	• Terminal to earth	kV_{peak}	460	N.A.
	• Across open switch	kV_{peak}	460	460
6	**Auxiliary contacts**			
6.1	Signals from disconnectors/ earthing switch			
6.1.1	Open indication	Number of free contacts	5	5
6.1.2	Closed indication	Number of free contacts	5	5
6.1.3	Internal faults alarm	Number of free contacts	1	1
6.1.4	Remote	Number of free contacts	1	1
6.1.5	Local	Number of free contacts	1	1
6.2	Signals to disconnector/earthing switch			
6.2.1	Open order, 2 pole control circuit		1	1
6.2.2	Close order, 2 pole control circuit		1	1

			Neutral Disconnector	Neutral Earthing switch
	Reference designation as per clause 2.1			
	Position		02/06	03/06
	Location		DC yard	DC yard
6.2.3	Permit local control		1	1
7	**Auxiliary voltages**			
7.1	Motor operating voltage		See ref. [1]	See ref. [1]
7.2	Control circuit voltage		See ref. [1]	See ref. [1]
8	**Min creepage distance, terminal to earth**			
8.1	Base voltage for creepage distance, phase-earth	kV_{dc}	95	95
8.2.1	Minimum creepage distance (Polymer/RTV-coated porcelain)	mm	4750	4750
8.2.2	Minimum creepage distance (Porcelain)	mm	5700	5700

4.2 Pugalur Station

			Neutral Disconnector	Neutral Earthing switch
	Reference designation as per clause 2.2			
	Position		02/05/07	03/05/07
	Location		DC yard	DC yard
1	**Frequencies**			
1.1	Rated frequency		DC	DC
2	**Voltages**			
2.1	Rated DC voltage	kV_{dc}	16	16
3	**Currents**			
3.1	Rated current *at 1.1 overload*	A_{dc}	2316/4509[7]	N.A.
3.2	*Rated current, rms*	A	--	--
3.3	Max. temporary current (30 min)	A_{dc}	2425/ 4652[7]	N.A.
3.4	Rated short time withstand current, 1s	kA_{rms}	7.2	7.2
3.5	Rated peak withstand current	kA_{peak}	18	18
3.6	*Whipping contact current*	*A*	--	--
	-at recovery voltage	*kV*	--	--
4	**Test voltages**			
4.1	DC voltage withstand (Ut), 1 hour			
	• Terminal to earth	kV_{dc}	24	N.A.
	• Across open switch	kV_{dc}	24	24

[7] Only for Pos 08 and 09
[8] Only for Pos 01

			Neutral Disconnector	Neutral Earthing switch
	Reference designation as per clause 2.2			
	Position		02/05/07	03/05/07
	Location		DC yard	DC yard
4.2	Radio interference test voltage	kV_{rms}	N.A.	N.A.
5	**Insulation levels**			
5.1	Lightning impulse withstand voltage			
	• Terminal to earth	kV_{peak}	125	N.A.
	• Across open switch	kV_{peak}	125	125
5.2	Switching impulse withstand voltage			
	• Terminal to earth	kV_{peak}	N.A.	N.A.
	• Across open switch	kV_{peak}	N.A.	N.A.
6	**Auxiliary contacts**			
6.1	Signals from disconnectors/ earthing switch			
6.1.1	Open indication	Number of free contacts	5	5
6.1.2	Closed indication	Number of free contacts	5	5
6.1.3	Internal faults alarm	Number of free contacts	1	1
6.1.4	Remote	Number of free contacts	1	1
6.1.5	Local	Number of free contacts	1	1
6.2	Signals to disconnector/earthing switch			
6.2.1	Open order, 2 pole control circuit		1	1
6.2.2	Close order, 2 pole control circuit		1	1
6.2.3	Permit local control		1	1
7	**Auxiliary voltages**			

			Neutral Disconnector	Neutral Earthing switch
	Reference designation as per clause 2.2			
	Position		02/05/07	03/05/07
	Location		DC yard	DC yard
7.1	Motor operating voltage		See ref. [1]	See ref. [1]
7.2	Control circuit voltage		See ref. [1]	See ref. [1]
8	**Min creepage distance, terminal to earth**			
8.1	Base voltage for creepage distance, phase-earth	kV_{dc}	16	16
8.2.1	Minimum creepage distance (Polymer/RTV-coated porcelain)	mm	800	800
8.2.2	Minimum creepage distance (Porcelain)	mm	960	960

4.3 Other data

Maximum allowed operating time is *25 seconds for 800kV apparatus and 16 seconds for others*.

5 Design

5.1 General

The disconnectors and earthing switches shall be of single-phase type. The earthing switches should be mounted on the corresponding disconnector, *whenever feasible*.

The switches shall be capable of withstanding the dynamic and thermal effects of the specified short circuit current in their closed position. They shall be designed such that they do not open under the influence of short circuit current and that they cannot fall to another position if the operating shaft gets disconnected. The operating parts shall not be dislodged from their open or closed positions by short circuit forces, gravity, vibrations, shocks or accidental touching of the connecting rods of the operating mechanism. Lubrication of any part shall be required only at very infrequent intervals.

The disconnectors and earthing switches shall be provided with a weatherproof secondary terminal box fulfilling the requirements in General requirements for main circuit apparatus clause 6.

The frame of the earthing switches shall be provided with two reliable terminals for connection to the earth grid.

The terminals must be capable of bearing the switches which will operate with the total forces including, wind, ice, snow and mechanical and electrodynamic forces on the attached conductor without impairing reliability or current carrying capacity.

The transmission of motion from the operating mechanism shall be by rigid members. In the event of overtorquing of the mechanism no part of the switch shall bend, twist or shear and so allow the auxiliary switch contacts to operate erroneously.

Locking arrangement, e.g. bolts through drilled holes, shall be provided in order to minimise the risk that different parts are displaced in relation to each other. This is to prevent that possible displacements between different parts can lead to faulty “open” or “closed” indications.

The contactor coils must be protected by varistors in order not to damage the relays.

The switchblade shall enter into the counter contact even if it is misaligned by 45mm in any direction.

5.2 RIV design

The disconnectors and earthing switches shall be free of external corona at the maximum rated voltage.

5.3 Contacts

The disconnectors shall be provided with high pressure current carrying copper contacts and all contact surfaces shall be silver plated. The thickness of silver plating should not be less than *25* μm. The contacts shall be accurately machined and self-aligned and of a self-cleaning type.

5.4 Metal parts

Current conducting structural parts shall preferably be made in aluminum or aluminum alloy. Mixing of different materials shall be avoided as far as possible. Other metal parts exposed to the weather shall either be hot dip galvanized or made of non-corroding material. All castings shall be made of malleable cast iron, grey cast iron, cast steel, cast aluminum or aluminum alloy. Bolts, screws and pins shall be provided with lock washers or alternative locking methods approved by ABB AB, HVDC.

The live parts shall be designed to eliminate sharp joints, edges and other corona producing surfaces. Where this is impracticable adequate corona shields shall be provided.

5.5 Operating mechanism

5.5.1 Earthing switches

The earthing swithces shall be provided with electrically operated mechanisms with padlocking arrangements. Emergency operation shall be possible by means of an operating handle.

The front of the mechanism cabinet shall be provided with the following equipment:

– Selector switch for local /off/remote operation *when provided separately, i.e. disconnector with earthing switch only need one selector switch*. The switch shall be lockable in each position

– Selector for open/close operation

The motor shall be suitable for the specified supply voltage according to clause 4.

The mechanisms shall be provided with terminal blocks for connection of external interlocks. They shall also be prepared for the installation of a key interlock system.

Signaling of closed position shall not take place unless it is certain that the movable contacts have reached a position in which nominal current, peak withstand current and short time withstand current can be carried safely. Signaling of open position shall not take place unless the movable contacts have reached a position such that clearance between contacts is at least 80% of the maximum isolating distance.

The operating pipes and rods shall be sufficiently rigid to maintain positive control under the most adverse conditions and when operated in tension or compression. They shall also be capable of withstanding all torsion and bending stresses due to operation of the switch. The rotating operating pipe shall be supported on roller or ball bearings, or other type of support approved by ABB AB, HVDC. Bearing pressure shall be kept low to ensure long life and ease of operation.

After final adjustment has been made it shall not be possible for any part of the mechanism to be displaced enough to allow improper functioning of the switch when it is opened or closed. All holes in cranks, linkages etc. having moving pins shall be drilled to accurate fit so as to maintain the minimum amount of slack and lost motion.

The design of the manual operating mechanism shall be such that maximum force required for manual operation is according to IEC 62271-102. The height of the operating handle above servicing level shall be 1000-1500 mm.

The form of protection shall be as defined in General requirements for main circuit apparatus.

5.5.2 Disconnectors

The disconnectors shall be provided with electrically operated mechanisms with padlocking arrangements. Emergency operation shall be possible by means of an operating handle.

The front of the mechanism cabinet shall be provided with the following equipment:

- Selector switch for local /off/remote operation. The switch shall be lockable in each position
- Selector for open/close operation

The motor shall be suitable for the specified supply voltage according to clause 4. A reduction gearing shall be provided between the motor and the drive shaft with a suitable device to protect the motor and gear against overload when the switch is stopped in the open or close position after an operation.

The mechanisms shall be provided with terminal blocks for connection of external interlocks. They shall also be prepared for the installation of a key interlock system.

Signaling of closed position shall not take place unless it is certain that the movable contacts have reached a position in which nominal current, peak withstand current and short time withstand current can be carried safely. Signaling of open position shall not take place unless the movable contacts have reached a position such that clearance between contacts is at least 80% of the maximum isolating distance.

The circuits for signals to the earthing switch for open order and close shall be suitable for 2-pole operation.

The operating pipes and rods shall be sufficiently rigid to maintain positive control under the most adverse conditions and when operated in tension or compression for closing. They shall also be capable of withstanding all torsion and bending stresses due to operation of the switch. The rotating operating pipe shall be supported on roller or ball bearings, or other type of support approved by ABB AB, HVDC. Bearing pressure shall be kept low to ensure long life and ease of operation.

After final adjustment has been made it shall not be possible for any part of the mechanism to be displaced enough to allow improper functioning of the switch when it is opened or closed. All holes in cranks, linkages etc. having moving pins shall be drilled to accurate fit so as to maintain the minimum amount of slack and lost motion.

The design of the manual operating mechanism shall be such that maximum force required for manual operation is according to IEC 62271-102. The height of the operating handle above servicing level shall be 1000-1500 mm.

The form of protection shall be as defined in General requirements for main circuit apparatus.

The disconnector shall be provided with "over centre" device in the operating mechanism to prevent accidental opening by wind, vibration, short circuit forces or movement of the support structures.

5.6 Insulators

The insulators shall be as specified in General requirements for main circuit apparatus.

The creepage distance is given in the electrical data in clause 4 of this document.

5.7 EMC design

The secondary system shall comply both in terms of emission requirements and immunity requirements as specified in IEC 62271-1 [1], Clause 5.18 and in IEC 61000-6-5 [6].

5.8 Terminals

The high voltage terminals shall be provided with terminal pads in accordance with *Mechanical Requirements on Apparatuses Terminals for HVDC* [2].

The earthing switches shall be connected to the earth grid according to *Mechanical Requirements on Apparatuses Terminals for HVDC*.

5.9 Seismic requirements

Seismic requirements, if any, are specified in General requirements for main circuit apparatus.

5.10 Surface treatment

The surface treatment requirements shall comply with General requirements for main circuit apparatus.

6 Nameplates

General requirements on nameplates are specified in General requirements for main circuit apparatus. The information on the nameplates shall be in accordance with IEC 62271-102 clause 5.10.

7 Environment

The disconnectors and earthing switches will be installed outdoors *in the DC yard*.

The environment conditions are specified in General requirements for main circuit apparatus.

8 Quality program

8.1 Quality program level

The quality program shall be according to General requirements for main circuit apparatus.

9 Routine tests

9.1 Dielectric test on the main circuit

As per IEC 62271-102, clause 7.1.

Not applicable when the insulation is provided only by solid-core insulators and air at ambient pressure if a dimensions check between conductive parts according to IEC 62271-1, clause 7.1 is made.

9.2 Dielectric test on auxiliary and control circuits

As per IEC 62271-102, clause 7.2.

9.3 Measurement of the resistance of the main circuit

As per IEC 62271-102, clause 7.3. Only for disconnectors.

9.4 Design and visual checks

As per IEC 62271-102, clause 7.5

9.5 Mechanical operating tests

As per IEC 62271-102, clause 7.101.

10 Type tests

Certified type tests reports from tests already performed on a similar (or identical) design may be accepted in lieu of performing new type tests*, if performed later than July 28, 2008*. To be applicable, both the design and testing requirements have to comply with this Requirement specification. The justification for compliance shall be made by means of a Type test summary report (TTSR), sufficiently detailed regarding similarities and differences in design and testing, to facilitate and support an approval of reports from previously performed type tests.

The certified type test reports and supporting TTSR shall be referred to in the Inspection and test plan (ITP) and submitted together with the ITP for approval.

10.1 Dielectric tests

As per IEC 62271-102, clause 6.2.

10.1.1 Tests of disconnectors and earthing switches of a rated voltage $U_r \leq 245$ kV

As per IEC 62271-102, clause 6.2.6.

The heading above is not quite applicable for d.c. disconectors and d.c. earthing switches. The decisive parameter Ur ≤ 245 kV is replaced by calculated switching impulse withstand voltage SIWV < 750 kV or N.A. given in the electrical data in clause 4 of this document.

10.1.1.1 Power-frequency voltage test

As per IEC 62271-1, clause 6.

10.1.1.2 Lightning impulse voltage test

As per IEC 62271-1, clause 6.

10.1.2 Tests of disconnectors and earthing switches of a rated voltage above 245 kV

As per IEC 62271-102, clause 6.2.7.

The heading above is not quite applicable for d.c. disconectors and d.c. earthing switches. The decisive parameter Ur > 245 kV is replaced by switching impulse withstand voltage SIWV ≥ 750 kV given in the electrical data in clause 4.

10.1.2.1 Power-frequency voltage test

As per IEC 62271-1, clause 6.

10.1.2.2 Switching impulse voltage test

As per IEC 62271-1, clause 6.

Support structure height during test shall not be more than the actual height of the support structure to be used at the site.

10.1.2.3 Lightning impulse voltage test

As per IEC 62271-1, clause 6.

10.1.3 Partial discharge test

As per IEC 62271-102, clause 6.2.9.

10.1.4 Test on auxiliary and control circuits

As per IEC 62271-102, clause 6.2.10.

10.2 Radio interference voltage (riv) test

As per IEC 62271-102, clause 6.3.

10.3 Measurement of the resistance of the circuits

As per IEC 62271-102, clause 6.4.

The measurements are only applicable for disconnectors.

10.4 Temperature-rise test

As per IEC 62271-102, clause 6.5.

Based on the test, verifications of temperature limits shall be made for the following conditions.

Maximum continuous current as per the electrical data in clause 4 with the temperature taken as the maximum ambient dry bulb temperature as specified in General requirements for main circuit apparatus.

The test shall be performed only for the disconnectors.

10.5 Short-time withstand current and peak withstand current tests

As per IEC 62271-102, clause 6.6.

10.6 Electromagnetic compatibility test on secondary systems

Emission and immunity tests for auxiliary circuits as per IEC 62271-1, and IEC 61000-6-5.

EMC tests on secondary system are only required if it includes any electronic equipment.

10.7 Operating and mechanical endurance tests

As per IEC 62271-102, clause 6.102

10.7.1 Contact zone test

As per IEC 62271-102, clause 6.102.2

10.7.2 Mechanical endurance test

As per IEC 62271-102, clause 6.102.3

10.7.3 Operation during application of the rated static mechanical terminal load

As per IEC 62271-102, clause 6.102.4

10.8 Operation under severe ice conditions

As per IEC 62271-102, clause 6.103. If applicable the ice condition is specified in General requirements for main circuit apparatus.

The thickness of ice shall be not less than 20 mm.

10.9 Wet DC withstand test

The test shall be carried out under wet conditions. The water shall be applied as specified in IEC-60060. The unit shall be open for the test. One terminal shall be grounded and the dc test voltage shall be negative. The test shall be repeated on the other terminal.
The test voltage is given in Clause 4.

10.10 Locked blade tests on both opening and closing cycles

The test shall be performed on one fully equipped unit and shall utilize the maximum supply voltage on the control and motor circuits. The test shall clearly demonstrate that the motor supply MCBs/MCCBs shall operate before any deformation of the mechanism linkages or switch parts has taken place. In all cases the main switch and its auxiliary switches shall remain in their correct relative positions at all times.

11 Verifications

The below design verifications are to be performed by means of verifying reports in lieu of performing corresponding tests. The reports shall be sufficiently detailed in its justification to facilitate and support the approval of each clause to be verified. Additionally mounted equipment shall be duly considered when influence is applicable.

The verification reports and its supporting documents, e.g. reports on previous tests etc., shall be referred to in, and submitted with, the ITP. If verifications are still "to be done" at the submittal of the ITP, the text "To be verified" shall be written in the ITP.

11.1 Seismic requirements

Fulfilment of the seismic requirements shall be verified.

11.2 Verification of degree of protection

Verification of degrees of protection for enclosures according to IEC 60529 shall be submitted.

12 Enclosures

- Customer Technical Specification part II, Volume II, Section 6.8 HVDC Switchgear, 6.9 HVDC Insulators, bushings, buses and hardware and 6.13 HVAC Isolators and Earth switches

- Annexure DISCON

13 References

[1] *1JNL355425*, General requirements for main circuit apparatus

[2] *1JNL 355427, Mechanical Requirements on Apparatuses Terminals for HVDC*

[3] IEC 62271-1, 2011, High-voltage switchgear and controlgear - Part 1: Common specifications

[4] IEC 62271-102, 2012, High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches

[5] IEC 60060-1, 2010, High-voltage test techniques – Part 1: General definitions and test requirements

[6] IEC 61000-6-5, 2015, Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment

14 Revision history

Rev.	Prepared	Approved
C	Rakesh K	

Revision text
- Cover sheet revised into Requirement Specification.

Rev.	Prepared	Approved
D	Björn Djurberg	

Revision text
- Revised as per updated Parts List and Main Circuit Parameters.
- Maximum temporary neutral voltage added for Raigarh-station
- Creepage distance stated in mm.
- Type test validity date updated.

Rev.	Prepared	Approved
E	Björn Djurberg	

Revision text
- Revised as per customer comments
- Arcing horns added for WN.Q(11,12,32) in Raigarh station

6.8 HVDC SWITCHGEAR

6.8.1 GENERAL

The Contractor shall provide all the required switches (circuit breakers),disconnects, isolators and grounding switches to meet the electrical performance requirements of Raigarh – Pugalur bipole.

The switchgear shall be rated for the voltage, current and switching duty required by the application. They along with their appurtenances shall satisfy the general technical requirements and standards. As no Standard exists for such dc equipment, the relevant portion of the corresponding standard for ac equipment shall be applicable to the extent possible.

No re-strikes and re-ignition shall be allowed across the main contacts of the switches. Opening of series main contacts on any pole shall be fully synchronized and shall meet the requirements imposed by the operating conditions. When units with series connected interrupters are supplied, voltage equalization may be done shunting interrupting contacts with suitable resistors and/or capacitors.

The switches which are current interrupting or making devices shall generally comply with the requirements, as specified in Clause 6.12, HVAC Circuit Breakers (as appropriate to DC switches). Further, Neutral Bus Grounding Switches shall have on load switching capabilities. All High voltage HSS (High speed switches) and neutral DC switches (NBS, NBGS, GRTS & MRTB) shall be provided with current measuring devices and all neutral DC switches with suitable auxiliary current commutation Circuit.

The disconnectors, isolators and grounding switches shall also comply with the requirements, as specified in Clauses 6.13, HVAC Isolators & Earth Switches.

6.8.2 REQUIREMENTS

6.8.2.1 TYPE

The disconnectors and isolators shall be vertical type or horizontal centre break or Double break type.
All isolators and grounding switches shall be motor operate with provision to operate manually. Comprehensive interlocking scheme shall be incorporated to prevent false operation

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Special consideration shall be given for corona design of switches, disconnector and isolators to be installed in the valve hall building.

Grounding switches shall normally be locally operated. However, when required due tosequential switching schemes they shall be suitable for remote operation too.

6.8.3 TESTS

The Contractor shall submit a test program which describes the tests and test levels, in accordance with the requirements. Type test shall be carried out on one item of each type & rating being supplied.

6.8.3.1 SWITCHES/BREAKERS

The switches shall be tested in accordance with the requirements of the applicable standards and will include at least the following additional tests(As applicable):

.1 Type tests:

a) Mechanical tests

b) Temperature rise

c) Dielectric tests (dry & wet)

The dielectric tests shall be carried out according to the requirements of the applicable IEC Standards. In addition, the switches shall be subjected to a lightning and switching impulse test across the open contacts whereby the full lightning impulse and switching impulse voltage to ground is applied to one terminal and a dc voltage equal to the maximum rated voltage of neutral bus to ground is applied to the other terminal with opposite polarity to that of the impulse.

d) Test on auxiliary & control circuit

e)Short time current test.

f) Radio interference voltage and corona test

g) Mechanical and thermal tests on porcelain, if used

h) Not used

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i) Sound pressure level test

j) Over pressure test on breaking element

In case, due to limitation on test facility, commutation test can not be performed as a type test in the factory for full rated current, this test may be performed at site during system test.

k) Discharge/operating duty test (for spark gap & capacitor, if provided)

l) **Wet** DC withstand tests

The dc withstands tests shall consist of the application of a test voltage Ut for one hour of:

$U_t = 1.5\ U_s$

where

Us = the maximum rated dc voltage of the switch

Test shall be performed:

i) with the switch contacts open and the test voltage applied to each terminal with the opposite terminal and frame grounded.

ii) with the switch contacts closed and the test voltage applied to one terminal with the frame grounded.

For switches with grading resistors: On a complete switchith all contacts open, a test voltage of 1.1 Us shall be applied for one hour to one terminal, with the opposite terminal and frame grounded.

.2 Routine Tests:

a) Bushing tests

b) Pressure tests

c) Measurement of resistance of main circuit

d) Leakage tests

e) Resistor, heater and coil check tests

f) Control and secondary wiring check tests

g) Clearance and mechanical adjustment check tests

h) Mechanical operation tests

i) Timing tests

j) Stored energy system tests

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k) Conductivity of current path tests

l) Voltage grading element tests

m) Low frequency withstand voltage tests on control and secondary wiring

n) Dielectric tests on main insulating **components including the DC Withstand Test**

o) hydraulic system tests

6.8.3.2 DISCONNECTS, ISOLATORS AND GROUNDING SWITCHES

The disconnects, isolators and grounding switches shall be tested in accordance with the requirements of the applicable standards, with at least the following additional type tests on one item of each type and rating to be supplied:

.1 DC Withstand Tests

The test shall consist of the application of a test voltage U_t as follows:

U_t = 1.5 U_s for one hour

Us = the maximum rated dc voltage of the unit to be tested.

For outdoor equipment, the test shall be carried out under wet conditions. The water shall be applied as specified in IEC-60060.

The unit shall be open for the test. One terminal shall be grounded and the dc test voltage shall be negative. The test shall be repeated on the other terminal.

.2 Locked Blade Tests on both Opening and Closing Cycles

The test shall be performed on one fully equipped unit and shall utilize the maximum supply voltage on the control and motor circuits. The test shall clearly demonstrate that the motor supply MCBs/ MCCBs shall operate before any deformation of the mechanism linkages or switch parts has taken place. In all cases the main switch and its auxiliary switches shall remain in their correct relative positions at all times.

.3 Mechanical Operation

The test unit shall be subjected to a 2000 mechanical operation test to demonstrate that the switch is capable of 2000 operations without failure of any mechanical part.
For Valve Hall ground switch the test switch unit shall be

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subjected to a 1000 mechanical operation test to demonstrate that the switch is capable of 1000 operations without failure of any mechanical part.

.4 RIV Test

Radio influence voltage shall not exceed 1000 micro-volts at 1000 kHz when tested at voltage levels 30% above the maximum rated dc voltage of the related equipment.

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6.9 HVDC INSULATORS, BUSHINGS, BUSES AND HARDWARE

6.9.1 GENERAL

The Contractor shall furnish all bus work necessary to meet the operational & performance requirement of this Specification.

All HVDC insulators, bushings, buses, conductors, connectors and hardware etc. shall be in accordance with the relevant standards and other relevant publications and as modified herein. All bushings inside valve halls including wall bushings shall be silicone rubber housing.

They shall also conform to the requirements of the Clause 6.15 regarding HVAC equipment. In case of conflict between the Clauses 6.15 & 6.9, the latter shall prevail.

Corona shields shall be provided as required.

6.9.2 BUSHINGS, SUPPORT INSULATORS, STRING INSULATORS & HARDWARE

The support insulators and bushings shall be in accordance with Clauses 6.15.2 & 6.15.3 of this Specification.

The String Insulators for both AC side and DC side shall be polymer insulators. Refer 'Annexure-String Insulators' for further details on String Insulators.

The insulation levels shall be determined by the Contractor in accordance with Section 4 of this Specification.

All bushings shall preferably be one piece only and no joints shall be accepted. However, if joint in insulator, tube or conductor is unavoidable, and then no relaxation in creepage & flash distance shall be acceptable. Joint in condenser core is not acceptable.
Additional type tests to be carried out if joint is provided in bushing as follows:

1. Mechanical Bonding test at Jointed Section
2. Tracking and Erosion Test(IEC-60587)
3. Water diffusion Test(Samples to be taken from jointed area)
4. Gas leakage test followed by Mechanical tests at the Joint area

When wall bushings are used, the Contractor shall provide necessary measures to avoid uneven wetting of the same.
All the bushings inside the valve hall (~~converter transformer valve~~

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~~side bushing &~~ HVDC wall bushing for valve hall) shall be dry type/SF6 gas filled gas-insulated or combination of both (Am.IV, Sl.No.113). Neutral side DC wall bushing for valve hall shall be dry type.

For HVDC Bus post Insulators (Both HV and LV side) and HVDC outdoor equipment (Both HV and LV side) support insulator shall be of silicon rubber. However, porcelain support insulators for HVDC disconnectors (HV Side) and for neutral and dc filter equipments of BIL less than or equal to 650kV shall be acceptable. (~~Am.I, Sl.No.52~~ Am.IV, Sl.No.114)

6.9.3 TUBULAR BUS CONDUCTORS, FLEXIBLE BUS-BARS, EARTHWIRE, CLAMPS, CONNECTORS, SPACERS ETC.

These shall be in accordance with the relevant clauses of Section 6.15 of this Specification. The size of the tubular bus-conductors, number of conductors per pole along with their configuration, etc. shall be determined by the Contractor.

6.9.4 TYPE TESTS

The type tests for HVDC insulators, bushings, busses, conductors etc. shall be in accordance with the applicable IEC Standards. A unit of each type & rating shall be type tested. In addition, the following special type tests shall also be carried out on a unit of each type and rating :

6.9.4.1 LIGHTNING IMPULSE TEST

Standard lightning impulse tests shall be carried out in accordance with the relevant IEC standards at the voltage levels corresponding to the equipment LIWL to ground.

The lightning impulse waves shall be negative polarity for bushings and positive polarity for insulators.

6.9.4.2 SWITCHING SURGE TEST

a) *For self-restoring insulation*, one insulator stack of each type shall be selected at random. Both positive and negative switching surge tests shall be carried out under wet conditions.The subject of these tests is to prove that the insulation has a no more than 2.3% probability of flashover (2 standard deviations below critical flashover) in accordance with IEC publication. The test would be deemed to have been proved if there are no flashovers during the first fifteen applications of voltage. If only one flashover occurs during the application of these 15 shots, the test sequence shall be repeated and, provided no further flashover occurs, only then the object of the test shall be deemed to have been proved. Indoor insulators may be tested dry.

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The switching surge voltage wave form shall be such that the time to crest shall be between 100 and 300 microseconds, and the time to decay to half of crest value between 3000 and 5000 microseconds.
Waveform as per IEC is also acceptable with no negative tolerance.

b) *For non-self restoring insulation*, the switching surge tests shall generally be in accordance with the relevant IEC standard, and shall comprise the application of one reduced and two full voltage levels.

6.9.4.3 DC WITHSTAND TEST

An outdoor bushing or insulator of each type shall be subjected to a wet withstand test as per Clause 10.2.2 of IEC 62199 with water applied according to the requirements of IEC 60060-1.

The bushing shall be considered to have passed the test if no flashover or puncture occurs. If there is a puncture, the bushing shall be considered to have failed the test. If a flashover occurs, the test shall be repeated once only. If during the repetition, flashover or puncture occurs, bushing shall be considered to have failed the test.
For bushings and insulators which are exclusively used indoor, the above test shall be performed dry.

6.9.4.4 RADIO INFLUENCE VOLTAGE

Radio influence voltage shall not exceed the values specified at TS Clause 4.12.13.

6.9.4.5 TEMPERATURE RISE TEST

Temperature rise test shall be conducted as per IEC-60137 corresponding to the overload current level.

6.9.5 ROUTINE TESTS

The routine tests shall be performed as called for in the applicable standards.
For jointed copper conductor bushing, extended heat run test for 24 hours after stabilization shall be conducted.

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6.13 HVAC ISOLATORS AND EARTH SWITCHES

6.13.1 GENERAL

a) The isolators (disconnects), earth (ground) switches and accessories shall conform in general to IEC-62271-102 except to the extent explicitly modified in the Specification.

b) Isolators shall be of double break type. The isolators shall be electrically ganged only. Earth switch(ES) shall be provided on isolators wherever possible, otherwise free standing earth switch shall be provided.

c) Complete isolator with all the necessary items for successful operation shall be supplied including, but not limited to, one central (common) control cabinet for each 3 phase isolator/earth switch and one control cabinet for each pole with all the required electrical devices mounted therein, complete with base frame, linkages, complete operating mechanism etc.
Isolators / Earth Switches shall alternatively have a standard design of master-follower integrated in three boxes only.

6.13.2 DUTY REQUIREMENTS

a) Isolators and earth switches shall be capable of withstanding the dynamic and thermal effects of the maximum possible short circuit current of the systems in their closed position. They shall be constructed such that they do not open under influence of short circuit current.

b) The earth switch shall be capable of discharging trapped charges.

c) The isolators shall be capable of making/breaking normal currents when no significant change in voltage occurs across the terminals of each pole of isolator on account of make/break operation.

d) The isolator shall be capable of making/breaking magnetizing current of at least 0.7A at 0.15 power factor and capacitive current of at least 0.7A at 0.15 power factor.

e) The terminals of the isolator and earth switch(es) shall be able to withstand the total forces including wind loading and electrodynamics forces on the attached conductor without impairing reliability or current carrying capacity in accordance with IEC-62271-102.

f) The earth switch should be able to carry the same fault

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current as the main blades of the isolator and shall withstand dynamic stresses.

6.13.3 CONSTRUCTIONAL FEATURES

The main features and constructional details of isolators with earth switches and other accessories shall be in accordance with requirements stated hereunder:

6.13.3.1 GENERAL

Design of the isolator shall be such as to permit addition of earth switches at a future date. It shall be possible to interchange position of earth switch to either side of pole even at site.

6.13.3.2 CONTACTS

a) The isolator shall be provided with high pressure current carrying contacts made of copper on the hinge and jaw ends and all contact surfaces shall be silver plated. The thickness of silver plating shall not be less than 25 microns. The contacts shall be accurately machined and self aligned.

b) The contacts shall be of sufficient pressure to ensure effective contact and low contact resistance throughout the life of the switch. The contact pressure shall not exceed a safe working value for the materials in contact and shall cause no abrasion or scarring of the contacts.

c) The contacts shall be of self-aligning and self- cleaning type and shall be so designed that binding can not occur after remaining closed for prolonged periods.

d) No undue wear or scuffing shall be evident during the mechanical endurance tests. Contacts and springs shall be designed so that readjustments in contact pressure shall not be necessary throughout the life of the isolator/earth switch. Each contact or pair of contacts shall be independently sprung so that full pressure is maintained on all contacts at all times. Provision shall be made to adjust the contact pressure.

e) Contact springs shall not carry any current and shall not loose their characteristics due to heating effects.

f) The isolator shall be so designed that when operated within their specified rating, the temperature of each part shall be limited to values consistent with a long life for the material used. The temperatures shall not exceed the permissible limits given in IEC-62271-102 under specified ambient conditions.

6.13.3.3 BASE

a) Each single pole of the isolator/earth switch shall be provided

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with a completely galvanized steel base. The base shall be rigid and self supporting and shall require no guying or cross bracing between phases.

b) The frame of each isolator and earthing switch shall be provided with two ground terminals for connection to the ground mat.

6.13.3.4 BLADES

a) All metal parts shall be of non-rusting and non corroding material. All current carrying parts shall be made from high conductivity electrolytic copper/aluminium. Bolts, screws and pins shall be provided with lock washers. Keys or equivalent locking facilities when provided on current carrying parts shall be made of copper silicon alloy or equivalent. The bolts or pins used in current carrying parts shall be made of non-ferrous and non- corroding material. All castings except current carrying parts shall be made of malleable cast iron or cast-steel. No grey iron shall be used in the manufacture of any part of the isolator.

b) The live parts shall be designed to eliminate sharp joints, edges and other corona producing surfaces. Where this is impracticable adequate corona shields shall be provided. Corona shields/rings etc. shall be made up of aluminum / aluminum alloy.

c) The isolator/earth switch shall be so constructed that the switch blade shall be locked in the open/close position and shall not fall to the closed/opened position in case the operating shaft gets disconnected.

d) The isolator/earth switch including their operating parts shall be such that they cannot be dislodged from their open or closed positions by short circuit forces, gravity, wind pressure, vibrations, shocks, or accidental touching of the connecting rods of the operating mechanism.

e) The isolator/earth switch shall be designed such that no lubrication of any part is required except at very infrequent intervals.

f) The switch blade contact shall enter into the counter contact even if it is misaligned by 45 mm in any direction.

6.13.3.5 INSULATOR

a) The insulator shall conform to IS-2544 and/or IEC-60168. The porcelain of the insulator shall have minimum cantilever strength of 800kg. The insulators shall be of solid core type.

b) Pressure due to the contact shall not be transferred to the

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insulators after the main blades are fully closed.

c) The insulators shall be so arranged that leakage current shall pass to earth and not between terminals of same pole or between phases.

6.13.3.6 EARTH SWITCHES

a) Wherever earth switch (es) are specified these shall include the complete operating mechanism and auxiliary contacts.

b) The earth switch shall form an integral part of the isolator and shall be mounted on the base frame of the isolator, whenever possible.

c) The earth switch shall be only locally (motor) operated.

d) The earth switch(es) shall be constructionally interlocked, wherever provided with the isolator, so that the earth switch(es) can be operated only when the isolator is open and vice versa. The constructional interlocks shall be a built in feature in construction of isolator and shall be in addition to the electrical and mechanical interlock provided in the operating mechanism.

e) In addition to the constructional interlock, isolator and earth switch(es) shall have provision to prevent their electrical and manual operation unless the interlocking conditions are met. All these interlocks shall be of fail-safe type. Suitable individual interlocking coil arrangements shall be provided. The interlocking coil shall be suitable for continuous operation from dc supply and within a variation range as stipulated.

f) Each earth switch shall be provided with flexible copper/aluminium braids for connection to earth terminal. These braids shall have the same short time current carrying capacity as the earth blade. The transfer of fault current through switch connection shall not be accepted.

g) The plane of movement and final position of the earth blades shall be such that adequate electrical clearances are obtained from adjacent live parts including in the course of its movement between Close and Open position.

6.13.3.7 OPERATING MECHANISM

a) The isolators and earth switches shall be ac motor operated.

b) Limit switch for control shall be fitted on the isolator/earth switch shaft, within the cabinet to sense and ensure the open and close positions of the isolator and earth switch.

c) After final adjustment has been made it shall not be possible

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for any part of the mechanism to be displaced at any

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point in the travel sufficient enough to allow improper functioning of the isolator/earth switch whenever it is opened or closed at any speed. All holes in cranks, linkage etc. having moving pins shall be drilled to accurately fit so as to maintain the minimum of slack and loose motion in the entire mechanism.

d) A "Local/Remote" selector switch and a set of "Open/Close" push buttons shall be provided in the control cabinet of the isolator to permit its operation. A "Local/Remote" selector switch and "Open/Close" push buttons shall also be provided in central control cabinet to permit simultaneous operation of all three phase.

e) Provision shall be made in the control cabinet to disconnect power supply to prevent local/remote power operation.

f) Suitable reduction gearing shall be provided between the motor and the drive shaft of the isolator. The mechanism shall stop rapidly when motor supplies are switched off.

g) Each motor operated mechanism shall be subjected to blocked rotor test.

6.13.3.8 OPERATION

a) Each pole of the isolator and each earth switch shall have individual drives for main blades. The operating mechanism of the three poles shall be well synchronized and interlocked.

b) The design shall be such as to provide maximum reliability under all service conditions. All operating linkages carrying mechanical loads shall be designed for negligible deflection. The length of operating rods shall be capable of adjustments, by means of screw thread which can be locked with a lock nut after an adjustment has been made. The isolator & earth switches shall be provided with "over centre" device in the operating mechanism to prevent accidental opening by wind or vibration or short circuit forces or movement of the support structures.

c) Each isolator and earth switch shall be provided with a manual operating handle enabling one man to open or close the isolator or earth switch with ease in one movement while standing at ground level. The manual operating handle shall have provision for padlocking. The operating handle shall be located at 1000 mm from the base of isolator support structure.

d) The isolator/earth switch shall be provided with positive

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continuous control throughout the entire cycle of

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operation. The operating rods shall be sufficiently rigid to maintain positive control under the most adverse conditions and when operated in tension or compression for closing. They shall also be capable of withstanding all torsional and bending stresses due to operation of the isolator/earth switch. Wherever supported the operating rods shall be provided with bearings on either ends. The operating rods shall be provided with suitable universal couplings to account for any angular misalignment.

e) The transmission of motion from the electrical operating mechanism shall be by rigid members. It is required that, in the event of over torque of the switch mechanism, no part of the main switch mechanism shall bend, twist or shear and so allow the auxiliary switch contacts to operate erroneously.

f) All rotating parts shall be provided with grease packed roller or ball bearings in sealed housings designed to prevent the ingress of moisture, dirt or other foreign matter. Bearings pressure shall be kept low to ensure long life and ease of operation. Locking pins wherever used shall be rustproof.

g) The position of movable contact system (main blades) of each of the isolators and earth switches shall be indicated by a mechanical indicator at the lower end of the vertical rod of shaft for the isolators and earth switch. The indicator shall be of metal and shall be visible from operating level.

h) Signalling of closed position shall not take place unless it is certain that the movable contacts shall reach a position in which rated normal current, peak withstand current and short time withstand current can be carried safely. Signalling of open position shall not take place unless movable contacts have reached a position such that clearance between contacts is at least 80% of the isolating distance.

i) Counter balance spring if required shall be provided for counter balancing the isolator and earth switch to prevent impact at the end of the travel both on opening and closing. The spring shall be made of non rusting type alloy.

6.13.4 TESTS

6.13.4.1 FACTORY TESTS

Each type of isolator and earth switch alongwith their operating mechanism shall be subjected to the type tests and routine tests in accordance with IEC-62271-102.The radio interference voltage and corona extinction voltage test shall also be conducted as type test.

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The insulators shall be routine and type tested as per IEC-168. In addition,the following additional type tests shall be performed:

i) Bending load test in four directions at 50% minimum bending load guaranteed in all insulators.

ii) Bending load test in four directions at 100% minimum bending load guarantee on sample insulators in a lot.

iii) Torsional test on sample insulators of a lot.

6.13.5 TECHNICAL PARAMETERS

The Contractor shall determine the technical parameters of the isolators/earth switches. The following table lists the technical parameters of the isolators/Earthing switch generally used by the Employer and are given for the information of the Contractor

400 kV Isolator & Earth Switch

a)	Rated short time with-stand current of isolator and earth switch		40 kA for 1 second
b)	Rated dynamic short circuit withstand current of isolator and earth switch		100 kA (Peak)
c)	Rated insulation levels		
	1.2/50 micro sec lightning impulse withstand voltage (+ve or -ve polarity)	250/2500 micro sec switching impulse with-stand voltage (+ve or -ve polarity)	one minute power fre-quency withstand voltage
To earth	1425 kV(peak)	1050kV(peak)	520kV(rms)
Across isolating distance	1425 kV peak impulse on one terminal with240 kV peak power frequency of opposite polarity	on other terminal	900 kV peak switching impulse on one terminal with345 kV peak power frequency of opposite

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	polarity on other terminal	
	610kV (rms)	
d)	Corona extinction voltage	320 kV (rms)
e)	Rated mechanical terminal load	As per table III of IEC-60129
f)	Operating mechanism of isolator / earth switch	AC motor operated
g)	Rating of auxiliary contacts	10 A at 220 V DC with breaking capacity of 2A DC with time constant not less than 20 ms.
h)	Creepage distance (total)	10500 mm
i)	Radio interference level for Maximum RIV level should be 0.5 MHz to 2.0 MHz	**Refer TS Cl 4.12.13**
j)	Operating time	12 sec or less

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220 kV Isolator & Earth Switch

a)	Rated short time with-stand current of isolator and earth switch		40 kA for 1 second
b)	Rated dynamic short circuit withstand current of isolator and earth switch		100 kA (Peak)
c)	Rated insulation levels		
	1.2/50 micro sec lightning impulse withstand voltage (+ve or -ve polarity)	250/2500 micro sec switching impulse with-stand voltage (+ve or -ve polarity)	one minute power fre-quency withstand voltage
To earth	1050 kV(peak)	NA	460kV(rms)
Across isolating distance	1200 kV peak		530kV (rms)
d)	Rated mechanical terminal load		As per table III of IEC-60129
e)	Operating mechanism of isolator / earth switch		AC motor operated
f)	Creepage distance (total)		6125 mm
g)	Radio interference level for 0.5 MHz to 2.0 MHz		**Refer TS Clause 4.12.13**
h)	Operating time		12 sec or less

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145 kV Isolator & Earth Switch

a)	Rated short time with-stand current of isolator and earth switch		31.5 kA for 1 second
b)	Rated dynamic short circuit withstand current of isolator and earth switch		80 kA (Peak)
c)	Rated insulation levels		
	1.2/50 micro sec lightning impulse withstand voltage (+ve or -ve polarity)	250/2500 micro sec switching impulse with-stand voltage (+ve or -ve polarity)	one minute power fre-quency withstand voltage
To earth	650 kV(peak)	NA	275 kV(rms)
Across isolating distance	750 kV peak		315 kV (rms)
d)	Rated mechanical terminal load		As per table III of IEC-60129
e)	Operating mechanism of isolator / earth switch		AC motor operated
f)	Creepage distance (total)		3625 mm
	g)Radio interference level for 0.5 MHz to 2.0 MHz		**Refer TS Clause 4.12.13**
h)	Operating time		12 sec or less

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Annexure DISCON

1	**Disconnector**		**Quantity at Raigarh**	**Quantity at Pugalur**
2	Copper contact fingers for female& male contacts for one pole of each rating	Sets	2	2
3	Relays, power contactors, MCBs, switch fuses, push buttons and resistors.Interlocking coils, timers, key interlock for electrical control circuit as per approved schematic. (one no. of each type)	Set	1	1
4	Limit switches & aux. contact (contact for one MOM box of isolator).	Set	1	1
5	Rotor housing bearing assembly(one no. of each type)	Set	1	1
6	Motor with gear assembly and bevel gear assembly	Set	1	1
7	Corona Shield rings	Set.	3	3
8	Bearings	Set	1	1
9	Current Carrying assembly	Nos.	3	3
10	Interlocking coils, timer key interlock of each type with resistor	Set	1	1
11	Terminal pad/stud with connectors for one pole of Isolator	Set	2	2
12	Hinge Pins	Nos.	3	3

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पावर ग्रिड कॉरपोरेशन ऑफ इंडिया लिमिटेड
POWER GRID CORPORATION OF INDIA LIMITED

± 600KV, 6000MW HVDC Terminals Associated With HVDC Bipole Link Between Western Region (Raigarh, Chhattisgarh) and Southern Region (Pugalur, Tamil Nadu) - North Trichur (Kerala)

Approved in Category :	I	II	III	IV
	Checked by	Verified by	Reviewed by	
Signature :				
Date :	25/4/17			

1 General information

This Specification gives the general requirements on equipment deliveries for the converter stations for the ±800kV, 6000MW HVDC Raigarh and Pugalur Terminals.

In case of conflicting requirements, the supplier shall bring those to the notice for a discussion/ decision and decision of ABB AB HVDC shall be final.

Alterations from the Standard requirement specification are printed in *italic* font.

Changes compared to the NEA800-project requirement specification are highlighted in yellow.

2 Lifetime

The design of apparatus including readable nameplates shall enable the Project to be in operation under rated conditions for at least ***40*** years.

3 Environment

The converter stations environment is defined as sub-tropical with a preponderance of high temperature and high humidity.

3.1 Seismic requirements

All structures shall be designed for seismic forces in accordance with IS-1893.

The seismic design of electrical equipment shall be performed using estimated actual earth/ground motion, defined by a response spectrum, rather than the equivalent loads specified in typical Building Codes.

*For brittle materials like glass, porcelain and glass fiber reinforced plastic the maximum calculated load should not exceed 2/3 of the guaranteed minimum rupture (breaking) strength (safety factor 1.5) as defined by the manufacturer/supplier of the material used. The minimum rupture value is defined as (X - 2*sigma), where X is the mean value and 'sigma' is the standard deviation. For load combinations in porcelain insulators and similar the following expressions shall be fulfilled:*

$$\{Ft / (Ft)b\} + \{Mb / (Mb)b\} < 2/3$$

and

$$\{Fc / (Fc)b\} + \{Mb / (Mb)b\} < 2/3$$

Where:

Ft, Fc, Mb = calculated maximum tensile force; compressive force and bending respectively

(Ft), (Fc), (Mb)b = corresponding guaranteed strength values (For normal operating loads, a higher safety factor more than 1.5 shall be used, normally 2.0-2.5 depending on type of load as per recommendations of manufacturer).

3.1.1 Seismic Coefficient

Raigarh and Pugalur converter stations are located in zone II according to IS-1893, Criteria for Earthquake Resistant Design of Structures (see table below).

Seismic Zone	*II*	*III*	*IV*	*V*
Seismic intensity	*Low*	*Moderate*	*Severe*	*Very severe*
Zone factor (Z)	*0.1*	*0.16*	*0.24*	*0.36*

(Extracted from IS 1893: 2002)

Importance factor for the stations is 1.5 as per table no. 6 of IS-1893.

3.1.2 Seismic design requirement verification

The fulfillment of the seismic requirement shall be verified according to the procedure given in "Seismic Qualification Procedures for Electrical Equipment", [31].

3.2 Outdoor conditions

		Raigarh	Pugalur
Maximum temperature one hour average (dry bulb)	°C	50	50
Maximum temperature 24 hour average (dry bulb)	°C	40	40
Annual mean temperature (dry bulb)	°C	30	30
Minimum temperature (dry bulb)	°C	0	0
Temperature for low ambient condition (dry bulb)	°C	33	33
Maximum temperature one hour average (wet bulb)	°C	33	33
Temperature for low ambient condition (wet bulb)	°C	23	23
Relative humidity	%	100	100
Ice loading (thickness)	mm	--	--
Elevation above sea level	m	<1000	<1000
Isokeraunic level of thunderstorms	days/year	50	50
Rain fall intensity	mm/hr	80	50
Solar radiation per hour	Cal/cm^2	83	83
Wind*)	m/s	39	47

**) All structures shall be designed for Wind forces in accordance with IS-875 (Part III)-1987, Code of Practice for Design Loads (other than earthquake) for Buildings and Structures. Both Raigarh and Pugalur converter stations lies in Zone II with basic wind speed of 39m/s and 47 m/s respectively at 10 m height above mean ground level. The risk level coefficient/factor shall be taken as 1.07. If terrain, height, structure size factor is less than 1.0, then these shall be neglected, otherwise they shall be considered.*

3.3 Design parameters for indoor equipment

3.3.1 Indoor with humidity controlled environment

For normal operating conditions the relative humidity is 50% in the valve hall. During the non-operation state of the station, the temperatures may be as specified for outdoor application during shorter times and then the maximum relative humidity may increase above 60%.

		Valve area	Other areas
Maximum temperature	°C	60	40
Minimum temperature[1]	°C	5	5
Maximum relative humidity[1]	%	60	60
Minimum relative humidity	%	10	-
ESDD[2] per year	mg/cm^2	< 0.003	-

3.3.2 Control cabinets in control room

During the non-operation state of the station, the temperatures may be as specified for outdoor application during shorter times, and then the maximum relative humidity may increase above 60%.

Maximum temperature	°C	55
Minimum temperature	°C	5
Maximum relative humidity	%	60
Minimum relative humidity	%	10
ESDD per year	mg/cm^2	< 0.003

3.3.3 Indoor without controlled environment

Maximum temperature (dry bulb)	°C	60
Maximum 24 h average temperature (dry bulb)	°C	60
Minimum temperature (dry bulb)	°C	5

3.4 Pollution level

Pollution level *d - **heavy***[3] for both Raighar and Pugalur as per IEC/TS 60815-1 [6] shall be considered.

[1] *This requirement is not valid for the Thyristor valve.*
[2] *ESDD = Equivalent Salt Deposit Density*
[3] *Minimum creepage shall regardless be as per clause 11.3*

3.5 Surface treatment

The equipment shall have sufficient corrosion resistance by the use of corrosion resistant materials or by using coatings. The choice of protection shall be based on the environmental classification given in ISO 12944-2 [15].

The environmental classes for the different areas in the station are:

	Raighar / Pugalur
Area	**Class**
Outdoor	**C3**
Indoor with humidity controlled environment	**C1**
Indoor without controlled environment	**C2**

Hot dip galvanized coating on fabricated iron and steel articles shall be according to ISO 1461(1999).

A special moisture and fungus resistant varnish shall be applied to parts, which may be subject or predisposed to the formation of fungi due to the presence or deposit of nutrient substances. The varnish shall not be applied to any surface or part where the treatment shall interfere with the operation or performance of the equipment. Such surfaces or parts shall be protected against the application of the varnish, see clause 3.5, Appendix 2.

3.6 EMC environment

The requirements stated below shall be met for secondary equipment.

Location	Immunity requirements	Emission requirements
1. In the switchyards	• Section 5.18 and 6.9.2 of IEC 62271-1 [14]. • Area H in Tables 1 to 5 of IEC/TS 6100-6-5 [11].	• Section 6.9.1 of IEC 62271-1. • IEC 61000-6-4 [10].
2. Inside valve hall or converter enclosure as applicable	• Section 5.18 and 6.9.2 of IEC 62271-1. • Area H in Tables 1 to 5 of IEC/TS 61000-6-5 [11]. • Additional immunity requirements inside valve hall or converter enclosure. See table and figure below	• Section 6.9.1 of IEC 62271-1. • IEC 61000-6-4. (Emission requirements are not applicable for the valves.)
3. Kiosks etc. in the switchyard, non-protected areas	• Section 5.18 and 6.9.2 of IEC 62271-1 • Area H in Tables 1 to 5 of IEC/TS 61000-6-5	• Section 6.9.1 of IEC 62271-1 • IEC 61000-6-4
4. Partly shielded areas inside enclosures and kiosks (control building etc.)	• Area H in Tables 1 to 5 of IEC/TS 61000-6-5	• IEC 61000-6-4
5. Other areas inside service buildings etc.	• IEC 61000-6-2 [9]	• IEC 61000-6-4

The selection of the immunity specifications for the apparatus is based on Figure 4, as applicable, of IEC/TS 61000-6-5.

The electromagnetic field strength inside valve hall or converter enclosure shall be taken to be as shown in the table and figure below. The equipment inside these areas shall withstand this field strength applied to their enclosure port(s)[4], in addition to the requirements stated earlier. However, proper screening measures will significantly reduce the field impact on ports/equipment and the withstand requirement is valid for ports/equipment in combination with screening measures.

Table Additional immunity requirements inside valve hall or converter enclosure, as applicable.

Frequency (Hz)	dB (1μV/m)
$1.0 * 10^3$	210
$1.0 * 10^4$	190

[4] Enclosure port is defined in IEC/TS 61000-6-5 as physical boundary of the apparatus through which electromagnetic fields may radiate or impinge on.

$3.0 * 10^5$	140
$\geq 3.0 * 10^5$	As per IEC/TS 61000-6-5

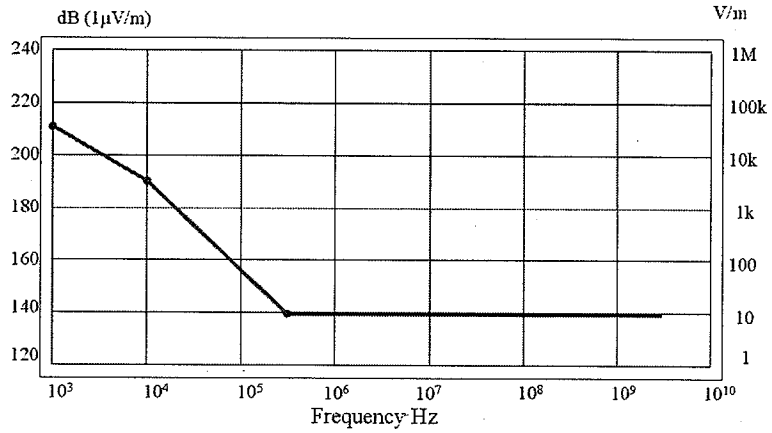

Figure Additional immunity requirements inside valve hall or converter enclosure, as applicable.

4 Materials and workmanship

4.1 General requirements

Equipment, materials and components shall be new, of high grade and be to the best engineering practice. The material and workmanship throughout shall be in accordance with the purpose for which they are intended. Each component shall be designed to be consistent with its duty.

Screw threads shall be standard metric threads. The Supplier shall furnish locking devices for threaded fasteners.

All components exposed to rain shall be designed with sloped upper surfaces to avoid water pools and if this is not possible suitable drainage shall be arranged.

Outdoor equipment shall be suitable for service and storage under tropical conditions of high temperature, high humidity, heavy rainfall and environment favourable to the growth of fungi and mildew. The indoor equipment located in non air-conditioned areas shall also be of the same type.

4.2 Welding

Welding shall be performed as per Customer's Technical Specification clause 3.9, Appendix 2.

5 Auxiliary power

5.1 Selection of supply

Control signals and supply is d.c. according to clause 5.3.1 below.

Supply to motors intended for continuous operation (e.g. fans) is three-phase a.c. according to clause 5.2 below.

Supply to motors intended for intermittent operation (e.g. motors for disconnectors, spring charging motor for breakers) is a.c. single phase according to clause 5.2 below, except for Valve hall earthing switches (RS-054) and DC disconnectors and earthing switches (RS-058) where the supply to motors is d.c. according to clause 5.3 below.

Supply to equipment heaters is single-phase a.c. according to clause 5.2 below.

5.2 AC Supply

5.2.1 415 V 50 Hz

Nominal voltage (solidly grounded), rms value	V	*415*
Voltage variations, steady-state	%	±10
Minimum voltage at motor during start, rms value	V	340
Nominal frequency	Hz	50
Frequency variations	%	±5

All voltages in section 5.2.1 are phase-to-phase voltages.

5.3 DC Supply

5.3.1 220 V DC

Nominal voltage, d.c. value	V	220
Maximum/Normal operating voltage, d.c. value	V	242
Minimum voltage at motor during start, d.c. value	V	187
Maximum ripple, peak-to-peak	V	11

The midpoint of the voltage source will be impedance grounded.

5.3.2 48 V DC

Nominal voltage, d.c. value	*V*	*48*
Maximum/Normal operating voltage, d.c. value	*V*	*52.8*
Minimum voltage at motor during start, d.c. value	*V*	*41*
Maximum ripple, peak-to-peak	*V*	*2.5*

6 Terminal boxes and control cabinets

6.1 Design

The control cabinets, terminal boxes, junction boxes terminal boxes and marshalling boxes shall comply and tested in accordance with IS-5039 [27], IS-8623[28], IEC-60439 [29] where applicable, and Customer's Technical Specification clause 3.6 and 3.7, Appendix 2.

All types of outdoor enclosures shall be tested and approved for IP55 according to IEC 60529 [5].

All openings *in cabinets and boxes for equipment* shall be properly provided with gaskets made of *EPDM / XLPE foam. Indoor control cubicles* shall be provided with Neoprene / EPDM gaskets. Equivalent material may be proposed for approval by ABB AB HVDC. Suitable ventilation and drainage devices or other similar arrangement shall be provided to maintain the inside of the enclosure dry.

All equipment in or on an enclosure shall be completely wired to terminal blocks or connectors ready for external connection.

All external connections shall enter the cabinet from below through weather proof and dust proof connections and be terminated on terminal blocks or connectors as adequate. There shall be a clearance of at least 120 mm between the first/bottom row of terminal blocks and the associated cable gland. The clearance between two adjacent rows of terminal blocks shall be at least 150 mm. The ABB AB HVDC may accept other terminal block arrangements after approval.

6.2 Equipment heaters

Heating elements shall be provided by the Supplier and mounted in all outdoor and "indoor without controlled environment" enclosures containing equipment with movable parts, i.e. switches and relays, or electronic equipment. At least one heater in each cabinet shall always be energized.

The heaters shall be suitable for continuous operation at 240 V ac supply voltage and shall be connected to the supply through a fuse.

Control cubicles installed in air-conditioned area need not be provided with space heaters. These cubicles shall, however, have space heaters in case of storage of cubicles for long duration.

One or more heaters shall be provided, with thermostats or hygrostat, to prevent condensation in any compartment. The heaters shall be suitable to maintain the compartment temperature at approximately 10°C, above the outside air temperature to prevent condensation.

7 Motors

All motors shall be delivered as standard motors conforming to IEC 60034-5 [1] */IS Standard* and with the principal dimensions in accordance with IEC 60072-1 [2], IEC 60072-2 [3] and IEC 60072-3 [4].

All motors shall conform as specified herein:

1 *Motors rated 0.5 kW and above, and reversing motors, shall be rated 415 V, three phase, grounded neutral;*

2 *Motors rated below 0.5 kW shall be rated 240 V one phase;*

3 *All motors shall be designed to operate at full load dynamic conditions with a voltage range of variation of +10%, -20% and a frequency range variation of +5%, -10%. Motors shall also be designed to operate at 125% of the rated speed without mechanical damage, and to start with 80% of their rated voltage;*

4 *All motors shall be designed and rated for continuous operation at maximum ambient temperature of 50°C. The class of insulation shall be at least one class higher than used for defining the temperature rise of the motor;*

5 *Vertical motors rated 60 kW and above shall be provided with oil-lubricated self-cooled pivoted shoe-type thrust bearing. Vertical motors below 60 kW shall be provided with re-greasable antifriction ball or roller bearings;*

6 *All antifriction bearings shall be guaranteed to operate successfully for a minimum of 131,000 hours;*

7 *All bearings shall be quiet operating and statically and dynamically balanced;*

8 *All belts to be used shall be "V" type and designed for the maximum power to be transmitted and for the maximum speed. The selection of the "V" belt drive for any application shall also be based on the nature of the load and the type of the driving unit. Belts installed outdoors shall be suitably protected.*

8 Terminal blocks

The terminal blocks shall be tested with at least 2.0 kVrms, 50 Hz/60 Hz, during 1 minute. They shall be made of moulded, nonflammable thermosetting plastic. The material of the terminal block moulding shall not deteriorate because of varied conditions of heat, cold, humidity, dryness etc., that would be expected at the location the equipment is proposed to be installed.

The terminal shall be such that maximum contact area is achieved when a cable is terminated. The terminal shall have locking characteristic to prevent the cable from escaping from the terminal clamp unless it is done intentionally. The conducting part in contact with the cable shall be tinned or silver plated.

The terminal blocks shall be of extensible design.

The terminal blocks shall have a locking arrangement to prevent its escape from the mounting rails.

The terminals shall be rated to carry the maximum current continuously that is expected to be carried by the terminals.

The terminals shall be provided with marking tags for positioning identification.

All internal wiring to be connected to external equipment shall terminate on terminal blocks. Terminal blocks shall be 650 V grade and have 10 Amperes continuous rating. All terminal blocks shall have shrouding with transparent unbreakable material.

At least 20% spare terminals shall be provided on each panel and these spare terminals shall be uniformly distributed on all terminal blocks.

The terminal blocks shall be suitable for connecting the conductors of external cable on each side.

Terminal blocks shall be moulded, complete with insulated barriers, stud type terminals, complete with washers, nuts and lock nuts. Screw clamp, overall insulated, insertion type, rail mounted terminals can be used in place of stud terminals with locking type. The terminal blocks shall be of reputed make subject to Employer's acceptance.

Terminal block design shall include a white fiber marking strip with clear plastic, /clip-on terminal covers. Markings on the terminal strips shall correspond to wire numbers on the wiring diagrams.

Terminal blocks for current transformer and voltage transformer secondary leads shall be provided with test links and isolating facilities. The current transformer secondary leads shall also be provided with short-circuiting and earthing facilities.

The conducting part in contact with the cable shall preferably be tinned or silver-plated however; nickel-plated copper shall also be acceptable. Insulating barriers shall be provided between the terminal blocks.

Supplier's standard practice for internal wiring of cubicles shall be acceptable. However all external cabling requirements shall be strictly as per project technical specification.

The supplier shall furnish all wire, conduits and terminals for the necessary inter-phase electrical connections (where applicable) as well as between phases and common terminal boxes or control cabinets.

9 Quality program

As per [17].

9.1 Type test

Thyristor valves, converter transformers, 800 kV wall bushings, auto-transformer, shunt reactors, DC smoothing reactors and LT Transformers(except dynamic short circuit test) must be type tested specifically for this project.

Previous type test for Converter transformer bushings, other bushings, DC switchgear, DC measurement device, AC/DC harmonic filter components, PLC/RI or other high frequency filter components, fundamental frequency blocking filter component, DC surge arrester and AC filter arresters with the same design,

insulation class and rating shall be acceptable, in-lieu of performing new tests, if such tests were performed after July 28, 2008.

Previous type test for LT transformers(only dynamic short circuit test), fibre-optic communication equipments, power/control/FO cables, HVAC equipments and switchgear, main ACDB, AC side surge arresters (excluding those used in AC filters), ventilation system and any other equipments not covered above, with the same design, insulation class and rating shall be acceptable, in-lieu of performing new tests, if such tests were performed after July 28, 2005.

Type tests shall be performed as per relevant IEC/ IS standard or other significant specifications as given in the Requirement Specifications (RS) document for equipment.

10 Name plates and markings

Name plate and marking shall be complied with an applicable IEC standard for each piece of equipment and Customer's Technical Specification clause 3.3.4, Appendix 2.

11 Insulators

Only composite insulators that have a surface of HTM can be used for outdoor applications. For indoor application, composite insulators of other surface materials may be used.

While specifying the requirements, the terms composite/Polymer/HTM are used interchangeably. These shall be considered to refer to HTM insulators requirements.

While specifying the requirements, the terms Porcelain/non-HTM are used interchangeably. These shall be considered to refer to non-HTM insulators requirements.

In case of conflicting information between this Requirement Specification and the standards referred to, this Requirement Specification shall prevail.

11.1 Definitions

Composite insulator:

A composite insulator is an insulator that is made, partly or completely, of polymeric materials of one or more types. More rigorous definitions are given in references [12], [19], [20] and [21].

HTM and non-HTM Material:

Polymer materials exhibit hydrophobicity and the capability to transfer hydrophobicity to the layer of pollution are referred to in this Requirement Specification as Hydrophobic property Transferable Material (HTM). Material with silicone rubber as base material is the most common HTM. Other materials,

such as porcelain or other type of polymer materials, which do not exhibit hydrophobicity transfer, are referred to as non-HTM.

Installation angle:

Vertical: the center axis of the insulator is within 90 ±15° to the horizontal plane

Angled: The insulator is at other positions than vertical.

Average diameter:

The average diameter of the insulator is calculated from the core diameter and sheds diameter as per the rules given in reference [6].

11.2 External surface materials of insulators

Insulators with HTM surface shall be examined and qualified by relevant tests and the test reports shall be sent to ABB AB HVDC for approval. Insulators without accepted test reports to qualify the hydrophobic characteristics shall be treated as insulators with non-HTM.

11.2.1 Qualification of HTM

Insulators with HTM surface are characterized by three criteria: exhibit hydrophobicity on the clean surface, the capability to transfer hydrophobicity to the layer of pollution, and the capability to recovery its hydrophobicity after temporarily loss of the hydrophobicity. All these three characteristics shall be examined and qualified in type tests with relevant test methods as described in [21]. For an English version of the relevant parts of [21], see Appendix 1.

11.2.2 Resistance to tracking and erosion

All the composite insulators to be used under DC shall have a good ability to prevent tracking and erosion caused by discharges and leakage current.

For insulators used outdoors, this ability shall be examined and qualified in type tests with relevant test methods as described in [12], [19], [20] and [21], see Appendix 1.

For insulators used indoors, this ability, classified as Comparative Tracking Index (CTI), should be examined and qualified in type tests with relevant test methods as described in [22] and [23] and fulfil CTI≥600.

11.2.3 Other parameters of the surface material

Other dielectric parameters that the surface material shall fulfill include those given [12], [19], [20], [21] and also the Appendix 1:

- *DC dielectric strength: ≥ 30kV/mm*

11.3 Creepage distance

11.3.1 General

The unified specific creepage distance (USCD), as per IEC/TS60815-1 [6], shall be used.

USCD is the creepage distance of an insulator divided by the rms value of the highest operating voltage across the insulator, given in mm/kV. This voltage is evaluated by:

$U_{rms} = \sqrt{U_{DC}^2 + \sum_n U_n^2}$, where U_n is the fundamental voltage including possible harmonics 'n' added across the insulator in rms.

U_{rms} for 400 kV, 220 kV and 132 kV AC equipment shall be considered as 420/√3 kV, 245/√3 kV and 145/√3 kV, respectively.

11.3.2 Corrections

11.3.2.1 Diameter

For ac application, the correction factor due to diameter of insulator is taken in account according to IEC/TS 60815-2 (2008) for porcelain insulators and non-HTM insulators. For HTM insulators it is taken in account according to IEC/TS 60815-3.

For dc application, the correction factor due to diameter of insulator is taken in account according to formula below for porcelain insulator and non-HTM insulators. For HTM insulators it is supposed to be 1.

$\frac{l_2}{l_1} = \left(\frac{D_2}{300}\right)^{0.23}$, where l_1 is the required creepage distance for insulators with an average diameter equal or smaller than 300 mm; D_2 is the average diameter (in mm) of the insulator for which creepage distance l_2 is sought.

11.3.2.2 Air density

When applicable, correction will be applied for the change of air density from reference conditions due to a higher temperature or/and a higher altitude for insulators with non-HTM. For insulators with HTM, correction for air density is not required.

11.3.3 Outdoor insulators

Outdoor DC wall bushings and support insulators for DC-equipment shall be only of Silicone rubber type i.e. HTM-type.

Exceptions to this requirement:

- *DC Disconnectors, where RTV-coated porcelain is permitted.*

- *DC-Neutral equipment, where RTV-coated porcelain or porcelain is permitted as long as BIL requirement on the insulator is below or equal to 650kV.*
- *DC-Filter equipment, where RTV-coated porcelain or porcelain is permitted as long as BIL requirement on the insulator is below or equal to 650kV.*

AC equipment connected to the 400 kV bus, the creepage distances shall not be less than 10500 mm.

For outdoor insulators, unless specifically approval by ABB, the minimum nominal creepage distance shall be as below:

11.3.3.1 HTM

- *Raigarh / Pugalur station*:
  For ac application: 43 mm/kV, based on U_{rms} defined above
  For dc application: 50 mm/kV, based on U_{rms} defined above

11.3.3.2 Non-HTM

- *Raigarh / Pugalur station*:
  For ac application: 43 mm/kV, based on U_{rms} defined above
  For dc application, RTV-coated porcelain: 50 mm/kV, based on U_{rms} defined above
  For dc application, porcelain: 60mm/kV, based on U_{rms} defined above

11.3.4 Indoor with humidity controlled environment

For indoor insulators with controlled environment the minimum nominal creepage distance shall be

HTM/Non HTM:

Valve hall

- *Raigarh / Pugalur station*:

  For dc application *maximum of:*

  14 mm/kV, based on U_{rms} defined above

  or

  20mm/kV, based on U_{dmax}.

11.4 Insulator shed profile

11.4.1 General

The insulator shed profile (form) shall be according to the requirement by ABB AB HVDC. For profiles deviating from the requirement, drawing and justification of function shall be sent to ABB for approval.

At the following conditions, deviations from the profile requirement may be accepted after approval by ABB AB, HVDC:

1. No profile requirement for insulators used at the indoor conditions that maximum relative humidity is always lower than or equal to 60%.
2. No profile requirements for insulators at d.c. neutral voltage.
3. No profile requirements for insulators with an average diameter smaller than 100 mm.
4. No profile requirements for insulators at a near horizontal position
5. Profiles with smaller shed spacing than required may be accepted for the insulators used at the indoor conditions where maximum relative humidity may become higher than 60%.
6. Profiles that deviating from the requirement may be accepted for clean outdoor conditions (verified by systematic pollution measurement or by the satisfactory operational experience for more than 5 years of an existing project of the same voltage level).

Parameters of insulator sheds are given in the figure below.

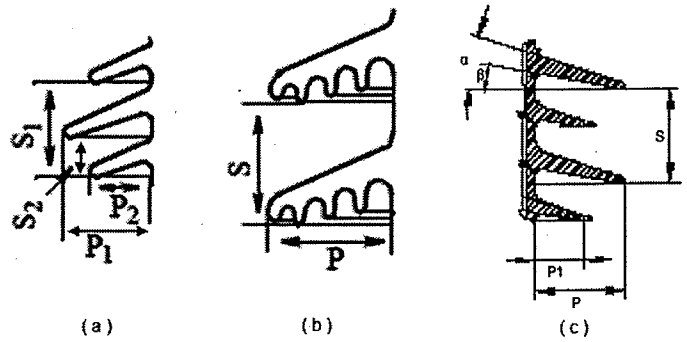

Figure Parameters of insulator sheds: (a) alternating profile of a porcelain insulator; (b) deep under-rib profile of a porcelain insulator; (c) alternating profile of a polymer insulator

11.4.2 Porcelain insulators, AC

The shed form (profile) for porcelain ac insulators shall be according to IEC/TS 60815-2.

11.4.3 Polymer insulators, AC

The shed form (profile) for polymer ac insulators shall be according to IEC/TS 60815-3.

11.4.4 Porcelain insulators, DC

Requirements for dc porcelain insulators:

- Shed spacing of alternating profile: $S_1 \geq 70$ mm.
- Shed spacing of deep under-rib profile: $S = 95$ mm.
- The ratio between shed spacing and overhang for both alternating and deep under-rib profiles: S_1/P_1 or $S/P \geq 1$.
- For alternating profile, the overhang difference between big and small shed $(P_1 - P_2) \geq 20$mm.
- For alternating profile, the inclination of sheds should be within the range: 10°~ 25°.

11.4.5 Polymer insulators, DC

The polymer shed should have excellent electrical and mechanical characteristics. In addition, the polymer shed should be homogenous, free from laminations, cavities or other flaws affecting its mechanical strength or dielectric quality.

For polymer insulators with non-HTM, the shed profile requirement shall be the same as that for porcelain insulators.

Requirements for dc polymer insulators with HTM:

- Spacing for nominal DC voltage up to 525 kV: $S \geq 60$ mm.
- Spacing for nominal DC voltage higher than 525 kV: $S \geq 65$ mm
- The ratio between shed spacing and overhang: $S/P \geq 0.9$.
- The overhang difference between big shed and small shed: 15 mm $< (P-P1) \leq 20$ mm.
- Upper inclination angle $\alpha > 10°$
- Lower inclination angle $\beta > 3°$.

Note: A too large value of β will result in an area with high pollution accumulation and therefore is not recommended.
Note: If helicoidal shed profile is used in vertically mounted insulators, the combination of pitch and α shall be such that the lip inclination shall be at least 4° less than α, so that rain water will run off the shed, rather than along it.

11.5 Other requirements

Insulators shall conform to customer's Technical Specification clause 6.9 and 6.15.2, where applicable, see Appendix 2.

12 Colors

12.1 Porcelain insulators

Color of porcelain insulators shall comply with requirements as per IEC 62155 [13]. The color shall preferably be brown glazed, according to RAL8016 or similar. Other colors may be used after approval from ABB AB HVDC.

12.2 Polymer insulators

Color of polymer insulators shall comply with requirements as per IEC61462. The color shall preferably be grey, RAL 7035 or similar. Other colors may be used after approval from ABB AB HVDC.

12.3 Panel and cubicles

The furnishing for the indoor panel and cubicles shall be RAL 7035, and for outdoor shall be RAL 7032.

12.4 Converter Transformer

The converter transformer furnishing shall be RAL 7042.

13 Enclosure

-

14 References

[1] IEC 60034-5 — Rotating electrical machines-Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) -Classification

[2] IEC 60072-1 (1991) — Dimensions and output series for rotating electrical machines - Part 1: frame numbers 56 to 400 and flange numbers 55 to 1080

[3] IEC 60072-2 (1990) — Dimensions and output series for rotating electrical machines - Part 2: frame numbers 355 to 1000 and flange numbers 1180 to 2360

[4] IEC 60072-3 (1994) — Dimensions and output series for rotating electrical machines - Part 3: Small built-in motors - flange numbers BF10 to BF50

[5] IEC 60529 (2001) — Degrees of protection provided by enclosures (IP code)

[6] IEC/TS 60815-1 (2008) — Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 1: Definitions, information and general principles

[7] IEC/TS 60815-2 (2008) — Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 2: Ceramic and glass insulators for a.c. systems

[8] IEC/TS 60815-3 (2008) — Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 3: Polymer insulators for a.c. systems

[9] IEC 61000-6-2 (2005) — Electromagnetic Compatibility (EMC) – Part 6-2: Generic

		standards. – Immunity for industrial environment.
[10]	IEC 61000-6-4 (2011)	Electromagnetic Compatibility - Generic Emission Standard. Part 2: Industrial environment.
[11]	IEC/TS 61000-6-5 (2001)	Electromagnetic Compatibility (EMC) - Part 6-5: Generic standards – Immunity for power station and substation environments.
[12]	IEC 61462 (2007)	Composite hollow insulators - Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V - Definitions, test methods, acceptance criteria and design recommendations
[13]	IEC 62155 (2003)	Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V
[14]	IEC 62271-1 (2011)	Common specifications for high-voltage switchgear and control gear standards
[15]	ISO 12944-2 (1998)	Paints and varnishes -- Corrosion protection of steel structures by protective paint systems -- Part 2: Classification of environments
[16]	ISO 1461 (2009)	Hot dip galvanized coatings on fabricated iron and steel articles -- Specifications and test methods
[17]	1JNL364609	General Quality Assurance Requirements for Sub-Suppliers to HVDC
[18]	COUNCIL DIRECTIVE 93/68/EEC	Rules for the affixing and use of the CE conformity marking
[19]	IEC 61109 (2008)	Insulators for overhead lines – Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1000 V - Definitions, test methods and acceptance criteria
[20]	IEC 62231 (2006)	Composite station post insulators for substations with a.c. voltages greater than 1000 V up to 245 kV – Definitions, test methods and acceptance criteria
[21]	DL/T 810-2002	Electric Power Industry Standard of the People's Republic of China: Technical specification for ±500 kV D.C. long rod composite insulators
[22]	IEC 60664-1 (2007)	Insulation coordination for equipment within low-voltage systems. Part 1: Principles, requirements and tests
[23]	IEC 60112 (2009)	Method for the determination of the proof and the comparative tracking indices of solid insulating materials
[24]	*IS-1893 (2002)*	*Criteria earthquake resistant design of structures*

[25]	*IS-875 Part-III (1987)*	*Code of Practice for Design Loads (other than earthquake) for Building and Structures*
[26]	*IS-2147*	*Degrees of protection provided by enclosures for low voltage switchgear and controlgear*
[27]	*IS-5039*	*Distribution pillars for Voltages not Exceeding 1000 Vac /1200V dc*
[28]	*IS-8623*	*Specification for Switchgear & Control Assemblies*
[29]	*IEC-60439*	*Rotating Electrical Machines*
[30]	*IS-325*	*Three Phase Induction Motors*
[31]	*1JNL355430*	*Seismic Qualification Procedures for Electrical Equipment*

15 Revision history

Rev.	Prepared	Approved
-	Björn Djurberg	Rodrigo Borquez

Revision text

Rev.	Prepared	Approved
A	Björn Djurberg	Rodrigo Borquez

Revision text

- §1: Project name revised.
- §9: Reference removed.

Rev.	Prepared	Approved
B	Björn Djurberg	Rodrigo Borquez

Revision text

- §3.1.1: Seismic Zone for both converter stations changed to Zone II.
- §3.2: Wind speed updated to 44m/s for both converter stations.
- §3.2: Rain fall intensity updated for Pugalur station.
- §9.1: Previous type tests for LT transformers are not acceptable (except dynamic short circuit test).

Rev.	Prepared	Approved
C	Björn Djurberg	

Revision text

- §11.3.3: RTV-coated porcelain and porcelain acceptable for DC-neutral and DC-filter equipment.
- §16: Welding requirements updated as per customer amendment.

Rev.	Prepared	Approved
D	Björn Djurberg	

Revision text
- §9.1: Type test validity date updated. - §11.3: Clarified usage of material for insulators.

Rev.	Prepared	Approved
E	Björn Djurberg	

Revision text
- Revised as per customer comments. - Type test validity date updated.

Rev.	Prepared	Approved
F	Björn Djurberg	

Revision text
- Revised as per customer comments. - Wind speed updated for Raigarh-station.

Rev.	Prepared	Approved
G	Nils Englund	

Revision text
- Wind speed updated for both stations

16 Appendix 1

16.1 Qualification of HTM

The following text is an excerpt from translated English text of clause 5.6 of Ref. [21].

5.6 Hydrophobicity test

This test is to evaluate the hydrophobicity performance of the insulator, including hydrophobicity of housing/shed, transference of after polluted, loss and recovery of hydrophobicity under specified conditions.

The hydrophobicity is described with Contact Angle (θ) and Hydrophobicity Class (HC).

5.6.1 Test specimens

The formula and vulcanized formation process of the specimens should be identical to the insulator shed/housing assembled on product line. In case of difference of formula and vulcanized formation process between the insulator housing and shed, this test should be conducted on materials of housing and shed respectively.

a. Contact Angle (CA) method: three flat-type specimens, each with area of (30~50) cm^2, thickness of (3~6)mm.

b. Hydrophobicity Class (HC) method: five flat-type specimens, each with area of (50~100) cm^2.

c. Surface cleaning prior to test: Use Ethanol absolute to clean the surface and then rinse the surface with deionized water (or distilled water). After dried, place the specimens in a dust-proof container and keep them under standard laboratory conditions for at least 24 hours.

d. Specimen polluting and transference of hydrophobicity: after the specimens are pre-cleaned, spray the specimens with methods specified in B2.2 and B2.3 of Annex B, with salt density of 0.1mg/cm^2, ash density of 0.5mg/cm^2. After polluted, place the specimens in a dust-proof container under standard laboratory ambient conditions for transference of hydrophobicity over 4 days.

5.6.2 Method of hydrophobicity measurement

a. Contact Angle (CA) method: This method has the purpose of revealing the hydrophobicity state on surface by directly measuring the static contact angle of [water] droplets on a solid surface. The contact angle (θ) may be measured with a CA meter, measuring microscope or photography. The volume of each droplet is about (4~7) μl (i.e. each droplet weighs 4~7mg). For each specimen, the θ of five droplets will be measured (the average of the 15 measurements on the three specimens is denoted in θ_{av}, minimum denoted in θ_{min}).

b. Hydrophobicity class (HC) method: This method has the purpose of revealing the hydrophobicity state on a solid surface so as to classify it into hydrophobicity classes. Seven classes of hydrophobicity (HC 1~ HC7) have

been defined. HC 1 corresponds to a completely hydrophobic (water-repellent) surface and HC 7 to a completely hydrophilic (easily wetted) surface. See Annex E for description and typical condition of different classes of hydrophobicity.

(1) HC measurement procedure: Spray [water] 1 time per second from a distance of 25cm. The spraying shall continue for 25 seconds. There should be runnels flowing down from the surface after the sprays. The spraying direction should be perpendicular to the surface of the specimen if possible. The judgment of the hydrophobicity class shall be performed within 30 seconds after the spraying has been finished. The specimen should be placed 20^0~30^0 from the plane surface.

(2) Sprayer: a spray bottle may be used. The volume of each spray should be 0.7~1 ml, dispersion angle 50^0~70^0. Verification of the spray dispersion angle may be measured with the following method: erect a newspaper 25cm away from the spray nozzle, with the spraying direction perpendicular to the newspaper. After 10~15 sprays, a wet area with diameter of 25~35cm will be formed.

5.6.3 Test procedure and passing criteria

Measure both the θ and HC for the specimen, which shall comply with the following criteria:

a. Hydrophobicity: Measure the θ and HC of the clean surface of the specimen with the methods specified in 5.6.2. See 5.6.1 for the test specimens. For housing and shed of composite insulators, the following criteria apply:

   (1) $\theta_{av} \geq 100^0$, $\theta_{min} \geq 90^0$;

   (2) Generally HC1~HC2, no more than 1 specimen measured to HC3.

b. Loss of hydrophobicity: Immerse 5 clean specimens into a glass vessel containing distilled water, for 96 hours, under standard lab ambient conditions. The distilled water should be enough to completely immerse the specimens, whose conductivity is less than 10μS/cm. See 5.6.1 for test specimens.

After taking the specimens out of the vessel, dry the surface with filter paper. Then randomly select three of the specimens and measure their Contact Angle and Hydrophobicity Class. For the other two specimens, only HC is measured. The measurement on each specimen should be finished in 10 minutes. The conformance criteria are as follows:

(1) $\theta_{av} \geq 90^0$, $\theta_{min} \geq 80^0$;

(2) Generally HC3~HC4, no more than 1 specimen measured to HC5.

a. Recovery of hydrophobicity: After completing the measurement in 5.6.3 b, place the specimens under standard lab ambient conditions for 48 hours. Then randomly select three of the specimens and measure their Contact Angle and Hydrophobicity Class. For the other two specimens, only HC is measured. The conformance criteria are as follows:

   (1) $\theta_{av} \geq 95^0$, $\theta_{min} \geq 90^0$;

   (2) Generally HC2~HC3, no more than 1 specimen measured to HC4.

b. Transference of hydrophobicity: Randomly select three of the five specimens that have been polluted and hydrophobicity transferred for 4 days with the method specified in 5.6.1 d. Then, randomly select three of the specimens and measure their Contact Angle and Hydrophobicity Class. For the other two specimens, only HC is measured. The conformance criteria are as follows:

   (1) $\theta_{av} \geq 110^0$, $\theta_{min} \geq 100^0$;

   (2) Generally HC2~HC3, no more than 1 specimen measured to HC4.

16.2 Tracking and erosion test

The following text is an excerpt from translated text of clause 5.5.1 of Ref. [21].

5.5.1 Tracking and erosion test on housing/shed

a. Test specimens: five specimens shall be tested in a group. The dimension of each specimen should be 120mm*50mm*6mm. The formula and vulcanized formation process of the specimens shall be identical to the insulator shed/housing assembled on product line. In case of difference of formula and vulcanized formation process between the insulator housing and shed, this test should be conducted on materials of housing and shed respectively.

b. Test system: inclined plane method as stipulated in GB 6553 will be used in this test. The test system should provide +4.5kV D.C. voltage. During the test, in case of 60mA current flowing at the high-voltage side for 0.5s, the output voltage drop should not be greater than 5%. The polluting liquid flowing through the surface shall be (0.2±0.05)ml/min.

c. Test procedure: mount the specimens and supply polluting liquid to the specimens as per stipulations in GB 6553. Apply +4.5kV voltage to the specimens and record the time. The test will last 6 hours. Before and after the test, measure the polluting liquid volume flowing through each specimen, record the test duration of each specimen as well as the aggregate volume of the polluting liquid used. The polluting liquid should not be reused.

d. Evaluation of the test: The test is regarded as passed if, after the 6h test, no tracking occurs and the erosion depth is no more than 2.5mm. In such case, it will be deemed that the specimens have come up to Class 4.5.

16.3 DC dielectric strength test

The following text is an excerpt from translated text of clause 5.5.2 of Ref. [21].

5.5.2 D.C. dielectric strength test on housing/shed

a. Test specimens: The thickness of the specimen should be (2±0.1) mm, other dimension indexes should comply with stipulations of GB/T 1408.

b. Test system and procedure: This test is conducted as per GB/T 1408. D.C. voltage is used as the test voltage, with voltage ripple factor no greater than 5%. D.C. dielectric strength test is made on each of the five specimens.

c. Compliance criterion: the D.C. dielectric strength of the specimens should not be smaller than 30kV/mm

17 Appendix 2

(Extracted applicable sections from the Customer's Technical Specification).
The following applicable sections are extracted from the customer's technical specifications.

3.3.4 NAME PLATES AND MARKINGS

1) *All equipment mounted on front and rear side as well as equipment mounted inside the panels shall be provided with individual nameplates with equipment designation engraved. Also on the top of each panel on front as well as rear side, large and bold nameplates shall be provided for circuit/ feeder designation.*
2) *All front mounted equipment shall also be provided at the rear with individual name plates engraved with tag numbers corresponding to the one shown in the panel internal wiring to facilitate easy tracing of the wiring.*
3) *All relays and other devices shall be clearly marked with manufacturer's name, manufacturer's type, serial number and electrical rating data.*
4) *Name Plates shall be made of non-rusting metal or 3-ply lamicoid. Nameplates shall be black with white engraving lettering.*

All the panels shall be provided with nameplate mounted inside the panel. Stainless steel nameplates shall be installed on all apparatus and on all major equipment components. For indoor cubicles, nameplates made of aluminium shall also be acceptable. Name plates shall be white with black engraved lettering and shall carry all the applicable information specified in the applicable items of the Standards, together with any other relevant information which may be required. For groups of smaller items for which this is not possible e.g. switch bays etc. a common nameplate with the title and special instructions on it shall be provided. No scratching, corrections or changes shall be allowed on nameplates. Main equipments like converter transformer, CBs, Reactor, Filter gates etc shall have nameplates in Hindi also.
All equipment mounted on front and rear sides as well as equipment mounted inside the panels shall be provided with individual name plates with equipment designation engraved. Also on the top of each panel on front as well as rear sides large nameplates with bold size lettering shall be provided for circuit / feeder / cubicle / box designation.
All front mounted equipment shall also be provided at the rear with individual name plates engraved with tag numbers corresponding to the one shown in the panel internal wiring to facilitate tracing of the wiring. The nameplates shall be mounted directly by the side of the respective equipment and shall not be hidden by the equipment wiring.
The nameplate inscription and size of nameplates and letters shall be submitted to the Employer for approval.

The nameplates of the apparatus shall include, at least, the information listed below, together with any other relevant information specified in the applicable standards:

a. *A concise descriptive title of the equipment*
b. *Rating and circuit diagram reference numbers*
c. *Manufacturer's name, trade-mark, model type, serial number*
d. *Instruction book number*
e. *Year of manufacture*
f. *Total weight (for capacitor racks indicate weight, for capacitors indicate quantity of liquid)*
g. *Special instructions, if any, about storage, transportation, handling etc.*

Each measuring instrument and meter shall be prominently marked with the quantity measured e.g. kV, A, MW etc. All relays and other devices shall be clearly marked with manufacturer's name, manufacturer's type, serial number and electrical rating data.
Danger plates and plates for phase colours shall be provided as per requirement. The Contractor shall devise a system to designate equipment and sub-systems. The nameplates/ labels displaying these designations shall be installed at appropriate locations.
Wherever motion/ flow of fluids are involved, plates/ marks showing direction of motion/ flow shall also be provided.

3.5 *PAINTING AND FINISHING OF METAL SURFACES*

All sheet steel work shall be phosphated in accordance with the IS: 6005 "Code of practice for phosphating iron and steel".
Oil, grease, dirt and swarf shall be thoroughly removed by emulsion cleaning.
Rust and scale shall be removed by pickling with dilute acid followed by washing with running water rinsing with a slightly alkaline hot water and drying.
After phosphating, thorough rinsing shall be carried out with clean water followed by final rinsing with dilute dichromate solution and oven drying.
The phosphate coating shall be sealed with application of two coats of ready mixed, stoved type zinc chromate primer. The first coat may be "flash dried" while the second coat shall be stoved.
After application of the primer, two coats of finishing synthetic enamel paint shall be applied, each coat followed by stoving. The second finishing coat shall be applied after inspection of first coat of painting. The exterior colour of paint shall be of a slightly different shade to enable inspection of the painting.
A small quantity of finished paint shall be supplied for minor touching up required at site after installation of the panels.

In case the Bidder proposes to follow his own standard surface finish and protection procedures any other established painting procedures, like electrostatic painting etc., the procedure shall be submitted along with the Bids for Employer's review & approval. The Contractor shall use procedures for painting approved by the Employer during detailed Engineering.
Contractor's standard practice shall be acceptable to the Employer subject to approval during detailed engineering and meeting all functional requirements of the TS.

3.5.1 HOT DIP GALVANIZING

The minimum weight of the zinc coating shall be 615 gm/ sq.m and minimum thickness of coating shall be 85 microns for all items thicker than 6 mm. For items less than 6 mm, requirements of coating thickness shall be as per relevant ASTM. For surfaces, which shall be embedded in concrete, the zinc coating shall be 900-gm/ sq.m.
Zinc coating in coastal area, if applicable, shall not be less than 900-gm/ sq.m.

The galvanized surfaces shall consist of a continuous and uniform thick coating of zinc, firmly adhering to the steel. The finished surface shall be clean and smooth and shall be free from defects like discoloured patches, bare spots, unevenness of coating, 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 inspection shall render the material liable to rejection.
After galvanizing, no drilling or welding shall be performed on the galvanized parts of the equipment except the nuts may be rethreaded after galvanizing. Sodium dichromate treatment shall be provided to avoid formation of white rust after hot dip galvanization.

The galvanized steel shall be subjected to six one-minute dips in copper sulphate solution as per IS-2633.
Sharp edges with radius less than 2.5 mm shall be able to withstand four immersions of the Standard Preece test. All other coatings shall withstand six immersions. The following galvanizing tests should be performed as per relevant Indian Standards.

- *Coating thickness*
- *Uniformity of zinc*
- *Adhesion test*
- *Mass of zinc coating*

3.6 *CONTROL CABINETS, JUNCTION BOXES, TERMINAL BOXES & MARSHALLING BOXES FOR EQUIPMENT*

All types of boxes, cabinets etc. shall generally conform to & be tested in accordance with IS-5039/IS-8623, IEC-60439, as applicable, and the clauses given below:

1. *Enclosure for control cabinets, junction boxes, Marshalling boxes & terminal boxes shall be made of stainless steel or aluminium and shall be dust, water and vermin proof. The box shall be properly braced to prevent wobbling. There shall be sufficient reinforcement to provide level surfaces, resistance to vibrations and rigidity during transportation and installation.*
2. *The enclosures of the control cabinets, junction boxes, terminal boxes & marshalling boxes located outdoor shall provide a degree of protection of not less than IP 55 as per IS-13947, one control cabinet, junction box, terminal box & marshalling box of each type shall be tested for the same.*
3. *Cabinets/boxes shall be freestanding floor-mounting type, wall mounting type, or pedestal mounting type as required. Equipments such as telephone exchange, Public address systems etc shall be kept inside cubicles.*
4. *Cabinets/ boxes shall be provided with double-hinged doors with padlocking arrangements. The distance between two hinges shall be adequate to ensure uniform sealing pressure against atmosphere. The quality of the gasket shall be such that it does not get damaged / cracked during the operation of the equipment.*
5. *All doors, removable covers and plates shall be gasketed all around with suitably profiled EPDM gaskets. The gasket shall be tested in accordance with approved Quality Plan. Ventilating louvers, if provided, shall have screen and filters. The screen shall be fine wire mesh made of brass.*
6. *All boxes/cabinets shall be designed for the entry of cables from the bottom by means of weatherproof and dust-proof connections. Boxes and cabinets shall be designed with generous clearances to avoid interference between the wiring entering from below and any terminal blocks or accessories mounted within the box or cabinet. A suitable horizontal cable gland plate positioned at least 150 mm above the base of the marshalling kiosk/box shall be provided for this purpose along with the proper blanking plates. Necessary number of cable glands shall be supplied and fitted on this gland plate. The gland shall project at least 25mm above gland plate to prevent entry of moisture in cable crutch. Gland plate shall have provision for some future glands to be provided later, if required. The glands shall be dust proof, screw on & double compression type and made of brass. The gland shall have provision for securing armour of the cable separately and shall be provided with earthing tag. The glands shall conform to BS: 6121 and shall be nickel-plated.*

Boxes / cabinets to be located inside a building in a non air-conditioned area may be designed for the entry of cables from the bottom or from the top.

7. *Earthing*

The provision for earthing shall be generally as per requirements given in Clause 3.7.2.1.

8. *Tests*

a) The Marshalling Kiosks shall be subject to routine tests as per IS: 5039

b) The following routine tests shall also be conducted:

i) Check for wiring

ii) Visual and dimension check

Marshalling kiosk shall be provided with danger plate and a diagram showing the numbering/ connection/ ferruling by pasting the same on the inside of the door.
Marshalling kiosk shall also be provided with incoming MCB and one 15 Amp interlocked switched socket in addition to the MCB required

3.7 INDOOR CONTROL CUBICLES

The control panel, cubicles and desks shall be in accordance with the relevant IEC standards and shall be installed in air-conditioned space. Indoor electronic cubicles shall not generally require fans for cooling in order to operate successfully and correctly at the maximum ambient temperature. However, if it is absolutely necessary to install fans etc. in cubicles for cooling then these shall be driven by the same dc supply as used for control, and necessary redundancy, failure alarm etc. shall be incorporated. Louvers in the doors and side panels shall be permitted, if required.
The control and relay panels shall be suitable for numerical relays of modular type mounted in standard 19 inch racks located on the vertical front panel with rear doors for access or located on the front doors for front access type panels. Panels Cubicles shall be completely metal enclosed and shall be dust, moisture and vermin proof. The enclosure shall provide a degree of protection not less than IP 32 in accordance with IS-2147 for cubicles located in air-conditioned areas. IP 31 may also be acceptable for these areas if the layout is arranged such that there is no possibility at all of any liquid entering the area. However, for ventilation reasons the cubicles may be provided with a ventilation hood at the top with a protection class of IP21.

Panels shall be free standing, floor mounting type and shall comprise structural frames enclosed completely with specially selected smooth finished, cold rolled sheet steel of thickness not less than 2.5 mm for weight bearing members of the cubicles such as base frame, front sheet and door frames, and 1.5 mm for sides, door top and bottom portions. There shall be sufficient reinforcement to provide level surfaces, resistance to vibration and rigidity during transportation and installation. The cubicles shall be provided with lifting lugs.

All doors, removable covers and plates shall be gasketed all around with neoprene gaskets. Ventilation louvers, if provided, shall have screens and filters. The screens shall be made of either brass or GI wire mesh with a graduation of 1 mm or less.

Design, material selection and workmanship shall be such as to result in a neat appearance, inside and outside with no welds rivets or bolt heads apparent from outside, with all exterior surfaces true and smooth. All cubicles located in any room shall be matched in appearance.

The Contractor along with anchor bolts and necessary hardware for mounting the cubicles shall furnish metal sills in the form of metal channels properly drilled. Panels shall have an additional rolled channel plinth at the bottom with a smooth bearing surface. The panels shall be fixed on channels with intervening layers of anti-vibration strips made of shock absorbing material, which shall be supplied by the Contractor.

Contractor's standard practice for control panels shall be acceptable to the Employer subject to approval during detailed engineering and meeting all functional requirements of the TS.

3.7.1 MOUNTING

All equipment on and in panels shall be mounted and completely wired to the terminal blocks ready for external connections. The equipment on front of panel shall be mounted flush. No equipment shall be mounted on the doors.

Equipment shall be mounted such that removal and replacement can be accomplished individually without interruption of service to adjacent devices and are readily accessible without use of special tools. Terminal marking on the equipment shall be clearly visible.

The Contractor shall carry out cut out, mounting and wiring of the free issue items supplied by others, which are to be mounted in his panel in accordance with the corresponding equipment manufacturer's drawings.

Cut outs if any, provided for future mounting of equipment shall be properly blanked off with blanking plate.

The centre lines of switches, push buttons and indicating lamps shall be not less than 750mm from the bottom of the panel. The centre lines of relays, meters and recorders shall be not less than 450mm from the bottom of the

panel
The centre lines of switches, push buttons and indicating lamps shall be matched to give a neat and uniform appearance. Like wise the top lines of all meters, relays and recorders etc. shall be matched.
No equipment shall be mounted on the doors.
At existing station, panels shall be matched with other panels in the control room in respect of dimensions, colour, appearance and arrangement of equipment (centre lines of switches, push buttons and other equipment) on the front of the panel.

3.7.2 EARTHING

1) *All panels shall be equipped with an earth bus securely fixed. Location of earth bus shall ensure no radiation interference for earth systems under various switching conditions of isolators and breakers. The material and the sizes of the bus bar shall be at least 25×6 sq. mm perforated copper with threaded holes at a gap of 50mm with a provision of bolts and nuts for connection with cable armours and mounted equipment etc for effective earthing. When several panels are mounted adjoining each other, the earth bus shall be made continuous and necessary connectors and clamps for this purpose shall be included in the scope of supply of Contractor. Provision shall be made for extending the earth bus bars to future adjoining panels on either side.*

2) *Provision shall be made on each bus bar of the end panels for connecting Substation earthing grid. Necessary terminal clamps and connectors for this purpose shall be included in the scope of supply of Contractor.*

3) *All metallic cases of relays, instruments and other panel mounted equipment including gland plate, shall be connected to the earth bus by copper wires of size not less than 2.5 sq. mm. The colour code of earthing wires shall be green.*

4) *Looping of earth connections, which would result in loss of earth connection to other devices when the loop is broken, shall not be permitted. Earthing may be done in such a manner that no circulating current shall flow in the panel.*

5) *VT and CT secondary neutral or common lead shall be earthed at one place only at the terminal blocks where they enter the panel. Such earthing shall be made through links so that earthing may be removed from one group without disturbing continuity of earthing system for other groups.*

6) *An electrostatic discharge point shall be provided in each panel connected to earth bus via 1 Mega Ohm resistor.*

3.7.3 INSTRUMENTS, METERS AND RECORDERS

For HVDC station and associated AC yards only digital displays and systems shall be provided. The requirements in this section are applicable to auxiliary systems only. All instruments, meters and recorders shall be enclosed in dust proof, moisture resistant, black finished cases and shall be suitable for tropical use. They shall be calibrated to read directly the primary quantities. They shall be accurately adjusted and calibrated at the factory and shall have means of calibration, checking and adjustment at site.

3.7.4 MISCELLANEOUS

1) *The Contractor shall submit all type and routine test certificates to the Employer for approval before dispatching the equipment. Control and relay panels shall also be subjected to the following tests:*
   - *Mechanical operation test*
   - *Verification of degree of protection as per IS-2147*
   - *High voltage test*
   - *Electrical control, Interlock and sequential operation test*
   - *Verification of wiring as per approved schematic.*

2) *Plug Point: 240V, Single phase 50Hz, AC socket with switch suitable to accept 5 Amps and 15 Amps pin round standard Indian plug, shall be provided in the interior of each cubicle with ON-OFF switch.*

3) *Interior Lighting: Each panel shall be provided with a CFL lighting fixture rated for 240 Volts, single phase, 50 Hz supply for the interior illumination of the panel controlled by the respective panel door switch. Adequate lighting shall also be provided for the corridor in Duplex panels.*

4) *MCB's: Each panel shall be provided with necessary arrangements for receiving, distributing and isolating of DC and AC supplies for various control, signalling, lighting and space heater circuits. The incoming and sub-circuits shall be separately provided with miniature circuit breakers (MCB).*

5) *Space Heater: Panels wherever required shall be provided with a space heater rated for 240V single phase, 50 Hz Ac supply for the internal heating of the panel to prevent condensation of moisture. The fittings shall be complete with thermostat and switch fuse /MCB unit.*

3.9 WELDING AND WELDERS QUALIFICATIONS

All welding shall be in accordance with the corresponding standards of the American Welding Society or the American Society of Mechanical Engineers / DIN / International standards.

Other standards to determine the quality of welding processes and qualifications of welders may be considered, provided that sufficient information is first submitted for the approval of the Employer.
Prior to the start of fabrication, the Contractor shall submit to the Employer for approval, a description of each of the welding procedures which he proposes to adopt, together with certified copies of reports of the results from tests made in accordance with these procedures.

The Contractor shall be responsible for the quality of the work performed by his welding organization. All welding operators shall be assigned to the work, including for repair of castings, shall pass the required tests for qualification of welding procedures. The Employer reserves the right to witness the qualification tests for welding procedures and operators and the mechanical tests of the samples. If the Inspector so requires, the Contractor shall furnish to the Inspector certified copies of reports of the mechanical test results of the samples.
The Contractor shall bear all his own expenses in connection with the qualification tests. If the work of any operator at any time appears questionable, such operator shall be required to pass appropriate re-qualification tests as specified by the Inspector and at the expense of the Contractor.
Strict measures for quality control shall be exercised throughout the Equipment/Works. The Engineer may call for an adequate NDT test of the work of any operator, who, in his opinion, is not maintaining the required standard of workmanship. Should this NDT test prove defective, all work done by that operator, since his last test shall be tested at the Contractor's expense. If three or more of these tests prove defective, the operator shall be removed from the project.
A procedure for the repair of defects shall be submitted to the Employer for his approval prior to any repairs being made.

6.9 HVDC INSULATORS, BUSHINGS, BUSES AND HARDWARE

6.9.1 GENERAL

The Contractor shall furnish all bus work necessary to meet the operational & performance requirement of this Specification.
All HVDC insulators, bushings, buses, conductors, connectors and hardware etc. shall be in accordance with the relevant standards and other relevant publications and as modified herein. All bushings inside valve halls including wall bushings shall be silicone rubber housing.
They shall also conform to the requirements of the Clause 6.15 regarding HVAC equipment. In case of conflict between the Clauses 6.15 & 6.9, the latter shall prevail.

Corona shields shall be provided as required.

6.9.2 BUSHINGS, SUPPORT INSULATORS, STRING INSULATORS & HARDWARE

The support insulators and bushings shall be in accordance with Clauses 6.15.2 & 6.15.3 of this Specification.
The String Insulators for both AC side and DC side shall be polymer insulators. Refer 'Annexure-String Insulators' for further details on String Insulators.
The insulation levels shall be determined by the Contractor in accordance with Section 4 of this Specification.
All bushings shall preferably be one piece only and no joints shall be accepted. However, if joint in insulator, tube or conductor is unavoidable, and then no relaxation in creepage & flash distance shall be acceptable. Joint in condenser core is not acceptable.
Additional type tests to be carried out if joint is provided in bushing as follows:
1. Mechanical Bonding test at Jointed Section
2. Tracking and Erosion Test (IEC-60587)
3. Water diffusion Test (Samples to be taken from jointed area)
4. Gas leakage test followed by Mechanical tests at the Joint area
When wall bushings are used, the Contractor shall provide necessary measures to avoid uneven wetting of the same.

All the bushings inside the valve hall (converter transformer valve side bushing & HVDC wall bushing for valve hall) shall be dry type/SF6 gas filled gas-insulated or combination of both. Neutral side DC wall bushing for valve hall shall be dry type.
For HVDC Bus post Insulators (Both HV and LV side) and HVDC outdoor equipment (Both HV and LV side) support insulator shall be of silicon rubber. However, porcelain support insulators for HVDC disconnectors (HV Side) and for neutral and dc filter equipment of BIL less than or equal to 650kV shall be acceptable.

6.9.3 TUBULAR BUS CONDUCTORS, FLEXIBLE BUS-BARS, EARTHWIRE, CLAMPS, CONNECTORS, SPACERS ETC.

These shall be in accordance with the relevant clauses of Section 6.15 of this Specification. The size of the tubular bus-conductors, number of conductors per pole along with their configuration, etc. shall be determined by the Contractor.

6.9.4 TYPE TESTS

The type tests for HVDC insulators, bushings, busses, conductors etc. shall be in accordance with the applicable IEC Standards. A unit of each type & rating shall be type tested. In addition, the following special type tests shall also be carried out on a unit of
each type and rating :

6.9.4.1 LIGHTNING IMPULSE TEST

Standard lightning impulse tests shall be carried out in accordance with the relevant IEC standards at the voltage levels corresponding to the equipment LIWL to ground.
The lightning impulse waves shall be negative polarity for bushings and positive polarity for insulators.

6.9.4.2 SWITCHING SURGE TEST

a) For self-restoring insulation, one insulator stack of each type shall be selected at random. Both positive and negative switching surge tests shall be carried out under wet conditions.The subject of these tests is to prove that the insulation has a no more than 2.3% probability of flashover (2 standard deviations below critical flashover) in accordance with IEC publication. The test would be deemed to have been proved if there are no flashovers during the first fifteen applications of voltage. If only one flashover occurs during the application of these 15 shots, the test sequence shall be repeated and, provided no further flashover occurs, only then the object of the test shall be deemed to have been proved. Indoor insulators may be tested dry.

The switching surge voltage wave form shall be such that the time to crest shall be between 100 and 300 microseconds, and the time to decay to half of crest value between 3000 and
5000 microseconds.
Waveform as per IEC is also acceptable with no negative tolerance.
b) For non-self restoring insulation, the switching surge tests shall generally be in accordance with the relevant IEC standard, and shall comprise the application of one reduced and two full voltage levels.

6.9.4.3 DC WITHSTAND TEST

An outdoor bushing or insulator of each type shall be subjected to a wet withstand test as per Clause 10.2.2 of IEC 62199 with water applied according to the requirements of IEC 60060-1.
The bushing shall be considered to have passed the test if no flashover or puncture occurs. If there is a puncture, the bushing shall be considered to have failed the test. If a flashover occurs, the test shall be repeated once only. If during the repetition, flashover or puncture occurs, bushing shall be considered to have failed the test.
For bushings and insulators which are exclusively used indoor, the above test shall be performed dry.

6.9.4.4 RADIO INFLUENCE VOLTAGE

Radio influence voltage shall not exceed the values specified at TS Clause 4.12.13.

6.9.4.5 TEMPERATURE RISE TEST

Temperature rise test shall be conducted as per IEC-60137 corresponding to the overload current level.

6.9.5 ROUTINE TESTS

The routine tests shall be performed as called for in the applicable standards.

For jointed copper conductor bushing, extended heat run test for 24 hours after stabilization shall be conducted.

6.15.2 BUSHING AND SUPPORT INSULATORS

6.15.2.1 GENERAL

Bushings shall be manufactured and tested in accordance with IEC-60137 and IS-2099 & IS-3347 while hollow column insulators shall be manufactured and tested in accordance with IEC-233 and IS-5284. The support insulators shall be manufactured and tested as per IEC-60168, IEC-60273 and IS-2544. The insulators shall also conform to IEC-60815 as applicable.

The AC bus post insulator may be Polymer insulator. All AC bushings up to 400kV shall be RIP bushings.

The insulation levels shall be determined by the contractor in accordance with Section 4 of this Specification, but the minimum performance characteristics for the 400kV ac shall be as specified in Clause 6.15.2.3.

All bushings shall be one piece only and no joints shall be accepted. If joint is unavoidable on a bushing, the Contractor shall seek Employer's approval on a case to case basis. For wall bushings, all required necessary material to fix it to the wall shall be supplied along with the bushing.

6.15.2.2 CONSTRUCTIONAL FEATURES

a) Porcelain used shall be homogeneous and free from imperfections that might affect the mechanical or dielectric quality.

b) Glazing of the porcelain shall be of uniform brown colour, free from blisters, burns and other similar defects. The ground surface shall not be glazed.

c) Condenser type bushing shall be provided with:

i) Oil level gauge.

ii) Oil filling plug and drain valve if not hermetically sealed.

iii) Tap for capacitance and tan delta test.

d) When bushings have an under-oil end of re-entrant form, the pull through lead shall be fitted with a gas bubble deflector.

e) Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.

f) Bushings of identical rating shall be interchangeable.

g) No arching horns shall be provided on the bushings.

h) All ferrous parts shall be hot dip galvanized or zinc plated and passivated. All joints shall be air tight. Insulator/bushing design shall be such as to ensure a uniform compressive pressure on the joints.

i) Support insulators/bushings/hollow column insulators shall be designed to have ample insulation, mechanical strength and rigidity for the conditions under which they shall be used.

j) When operating at rated voltage there shall be no electric discharge between conductor and insulators which would cause damage to conductors or insulators by the formation of substances produced by chemical action. No radio interference shall be caused when operating at rated voltage.

k) 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.

l) The Bidder/Contractor shall define the type of insulator (type A or B) as per IEC-60168.

m) Bushing porcelain shall be robust and capable of withstanding the internal pressures likely to occur in service. The design and location of clamps and the shape and the strength of the porcelain flange securing the bushing to the tank shall be such that there is no risk of fracture. All portions of the assembled porcelain enclosures and supports other than gaskets, which may in any way be exposed to the atmosphere shall be composed of completely non hygroscopic material such as metal or glazed porcelain.

n) Special precaution shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection. The surface of all paper insulation shall be finished with non-hygroscopic varnish which can not be damaged easily.

6.15.2.4 TESTS

Each type of bushing and insulator shall be subjected to type and routine tests in accordance with applicable standards and acceptance test shall include one minute dry power frequency withstand test and ultrasonic test (except for hollow insulator).

The ultra sonic test shall be done on the porcelain before assembly. All sample tests and special tests shall also be conducted.

Additional type tests to be carried out if joint is provided in bushing as follows:

1. Mechanical Bonding test at Jointed Section

2. Tracking and Erosion Test (IEC-60587)
3. Water diffusion Test (Samples to be taken from jointed area)
4. Gas leakage test followed by mechanical tests at the joint area.

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पावर ग्रिड कॉरपोरेशन ऑफ इंडिया लिमिटेड
POWER GRID CORPORATION OF INDIA LIMITED

± 800KV, 6000MW HVDC Terminals Associated With HVDC Bipole Link Between Western Region (Raigarh, Chhattisgarh) and Southern Region (Pugalur, Tamil Nadu) - North Trichur (Kerala)

Approved in Category :	I	II	III	IV

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Signature :			
Date :	03/04/17		

Cat - I

1. General

Each high voltage apparatus on a HVDC-station shall have terminals for connection to main circuit apparatus, bus bars, grounding grid, or other equipment. The terminals shall comply with the requirements in this specification.

The purpose with this specification is to standardize terminals for HVDC-apparatus and to minimize the quantity of different terminal connectors used in a HVDC-station.

A terminal is a conducting part of a device to which a terminal connector is fastened. Bolts are used to make the connection separable. In a bolted type connector the contact between the two parts is made by pressure exerted by one or more clamping bolts.

A terminal with a terminal connector must:

- Function well without maintenance during a long period of time.
- Be designed to secure an unbroken transmission of current.
- Have low contact resistance to avoid overheating.
- Withstand different mechanical loads and stresses.
- Have sufficient corrosion resistance.

Terminals for current carrying connections and voltage connections are of two types:

Terminal with rectangular shape with two or more holes.

Terminal with cylindrical shape.

Terminals for earthing connections shall have a rectangular shape with two holes.

2. Standards

The terminals shall be designed to meet the requirements in IEC TR62271-301 [1]

3. High Current/Voltage Connections

In this specification a current carrying connector is defined as a separable, stationary, non-movable connection between a terminal and a terminal connector, having the primary function of transmitting power.

3.1 Material

Terminals for high current connections shall be manufactured of aluminum alloy with the following data.

- Copper content shall be below 0,1 % to prevent internal corrosion.
- Hardness requirement for aluminium in electrical use: > 60 HV
- Recommended standard qualities are ASTM 6061-T6 (SS aluminium 4102-06), ASTM 6063-T6 (SS aluminium 4104-06) and ASTM 6351-T6 (SS aluminium 4212-06), which are alloyed and hot aged.
- Recommended cast qualities are ASTM B 26-84, 356.0-T6 (SS aluminium 4253-04) and ASTM B 108-82b, 356.0-T6 (SS aluminium 4253-07).

PROPRIETARY AND SECRET INFORMATION

Terminals of aluminum shall not be treated. The alloy shall have almost the same cracking constancy as pure aluminum. The alloys sensitive for season cracking, layer corrosion or intercrystalline corrosion shall not be used.

Terminals for *surge arresters* may also be manufactured of galvanized steel.

Terminals with cylindrical shape may also be manufactured of copper. Terminals of copper or a copper alloy shall be Silver-plated to a thickness of minimum 10 µm. Nickel-plating is also acceptable, to a thickness of minimum 10 µm. A copper alloy which is sensitive for season cracking may not be used.

3.2 Terminals with rectangular shape

3.2.1 Current rating > 2000A

Terminals shall have 9 bolts for current rating between 2000A and 4000A & 12 bolts for current rating of 4850A with 14mm diameter and distance between holes (center to center) shall be 40 mm

Thickness shall be between 15 and 30 mm.

Bolt Size shall be M12.

To reduce eddy-currents, terminal thickness on air cooled reactors may be reduced to minimum 10 mm.

3.2.2 Current rating < 2000A

Terminals with rectangular shape shall have hole diameters of 14 mm. Distance between holes (center to center) shall be 40 mm.

Bolt size shall be M12.

To avoid high temperature in the high-current connection the quantity of bolts shall be sufficient. The current must not exceed 500 A/bolt.

Terminal thickness shall be between 15 and 30 mm.

To reduce eddy-currents, terminal thickness on air cooled reactors may be reduced to minimum 10 mm.

For equipment with low current rating (< 400 A) terminal thickness may be reduced to minimum 10 mm.

3.3 Terminals with cylindrical shape

Terminals for *Converter transformer indoor bushings and pole wall bushings* with cylindrical shape shall have a diameter of 130 mm and a minimum length of 160 mm.

Terminals of aluminum alloy is allowed up to 2500 A.

For currents above 2500 A copper must be used.

Cylindrical terminals if provided with current ratings between 2500A and 4850A, Tap diameter from supplier shall be approved by ABB.

Capacitor banks shall also have aluminum tubes as terminals. The high voltage terminal shall have a diameter of 356mm and the low voltage terminal shall have a diameter of 100 mm for high *Voltage DC Filter Capacitor.*

Diameter tolerance is +/- 0,5 mm.

4. Earthing Connections

The terminal shall be of rectangular shape with minimum two holes.

Hole diameter shall be 14 mm.

Distance between holes shall be 40 mm.

Bolt size shall be M12.

If clamp is provided with the arresters it must be possible to connect a copper conductor with cylindrical shape and an area of maximum 120 mm ^{2}.

Earthing conductors shall withstand 63 kA, 1sec for Raigarh and 50kA, 1 sec for Pugalur on the line side of the HVDC converter transformers.

Minimum earthing conductor size shall be 75 x12mm Flat Galvanized steel.

5. Mechanical Terminal Loads

Terminals for apparatus in HVDC-stations must withstand different types of mechanical loads such as:

- Static load from conductor.
- Dynamic loads due to equipment vibrations.
- Dynamic loads in conductor due to wind, short circuit forces etc.

Minimum required mechanical strength of a terminal is to withstand a force of 2 kN in any direction.

An exception to this requirement is AC- and DC-filter equipment with a current rating less than 750 A and for an operating voltage less than 145 kV, which shall minimum withstand a terminal force of 750 N in any direction.

Additional requirements of terminal loads, if any, on 800 kV DC-apparatuses shall be informed by ABB AB, HVDC separately.

6. References

[1] IEC TR62271-301 High-voltage switchgear and control gear
Part 301: Dimensional Standardization of terminals

7. Revision History

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