



BHARAT HEAVY ELECTRICALS LIMITED

TRANSMISSION BUSINESS ENGINEERING MANAGEMENT

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TITLE Indoor DC & Outdoor DC Post insulators				NAME	TTR	SKS
				DATE	14/08/17	14/08/17
				GROUP	TBEM	W.O. No
Customer	Power grid Corporation Of India Ltd. (POWERGRID)					
PROJECT	±800kV, 6000MW HVDC Raigarh – Pugalur Terminals					
CA NO.	CC-CS/651-SR2/HVDC-3063/7/G10/CA-I/5817-5821 date: 2017-01-25					
Station	Raigarh & Pugalur					
Rev No.	Date	Altered	Checked	Approved	Revision Details	
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1 Scope, Quantities and Specific Technical Requirements

1.1 Scope

This technical specification covers the requirements of design, manufacture, testing at works, packing, loading at works and transport to *site* of Indoor DC post insulators and Outdoor DC post insulators complete with all nuts, bolts and washers for inter unit joining & for bolting the Post insulators units to structure.

The equipment is required for the following project:

Name of customer : Power Grid Corporation of India Ltd (POWERGRID)
Name of the project : ±800kV, 6000MW HVDC Raigarh – Pugalur Terminals
Contractor : Bharat Heavy Electricals Limited (BHEL)
Site : Raigarh & Pugalur

1.2 Specification

The insulators shall comply with the following requirement specifications (included with this specification)

- 1) 1JNL446257 Rev. B : Indoor DC insulators
- 2) 1JNL446256 Rev. A : Indoor DC insulators

The above Requirement Specifications (RS) applicable to Indoor DC post insulators and Outdoor DC post insulators. Please refer to below 1.8 enclosures for any other information, which is not covered by above RSes pertaining to Indoor DC post insulators and Outdoor post insulators only.

Incase of any conflict between this specification, RSes and enclosures, vendor shall inform to BHEL for final decision.

1.3 General technical requirement

Please refer to 1JNL355425 Rev. G “General requirements for main circuit apparatus”.

1.4 Quantities

Sl. No	Item description	Main quantity (Nos)	Spares qauntity (Nos)	Total quantity (Nos)
Indoor post insulators (refer 1JNL446257)				
Raigarh converter station				
1	Item 384, DC post insulator	48	5	53
Pugalur Converter station				
1	Item 394, DC post insulators	32	3	35
Outdoor post insulators (refer 1JNL446256)				
Raigarh converter station				
1	Item 321, DC post insulators	13	2	15

Sl. No	Item description	Main quantity (Nos)	Spares qauntity (Nos)	Total quantity (Nos)
2	Item 322, DC post insulators	242	24	266
3	Item 328, DC post insulators	8	1	9
4	Item 330, DC post insulators	8	1	9
5	Item 331, DC post insulators	16	2	18
6	Item 371, DC post insulators	4	1	5
Pugalur Converter station				
1	Item 341, DC post insulators	14	2	16
2	Item 342, DC post insulators	305	31	336
3	Item 347, DC post insulators	4	1	5
4	Item 348, DC post insulators	8	1	9
5	Item 350, DC post insulators	8	1	9
6	Item 351, DC post insulators	16	2	18
7	Item 371, DC post insulators	4	1	5

Note:

- 1) Insulators shall be supplied complete with Hot Dip Galvanised Hardware for inter unit joining and fixing to structure (both top & bottom)
- 2) Final quantity may vary upto ±30%
- 3) Please refer the RS of 1JNL446257 & 1JNL446256 for items mentioned above.

1.5 Qualifying requirements

A) The bidder must be an original equipment manufacturer (OEM) of Post Insulators and should have valid type test reports as per Requirement Specifications:- 1JNL446257 & 1JNL446256.

And

B) The bidder should have supplied at least 30% of required quantity of DC post insulators (or) 220kV AC (or) Higher than 220kV AC Post insulators class in any one year in last five (5) years from date of 19.05.2015.

1.6 Manufacturing quality plan

Bidder to follow valid POWERGRID approved Quality Plan (QP) at contract stage.



1.7 Deviations

The bidder shall list all the deviation from the specification separately. Offers without specific deviation will be deemed to be totally in compliance with the specification and NO DEVIATION on any account will be entertained at a later date.

1.8 Enclosures

[1] 1JNL355425 Rev. G : General requirements for main circuit apparatus

[2] Customer technical specification section 6.9 HVDC insulators, Bushings, buses and hardware & Customer Technical Specification Section 6.15.2 BUSHINGS AND SUPPORT INSULATORS

±800kV, 6000MW HVDC Raigarh – Pugalur Terminals Raigarh - Pugalur	Document number, revision 1JNL446257, B		Page 1 of 13	Language en
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Prepared Sheeba PT, 2015-12-23	Approved Naik Ashish, 2017-06-17			
Title Indoor DC Insulators				

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1 General

This Specification gives the general requirements on insulator deliveries for the Raigarh and Pugalur converter stations, of the $\pm 800\text{kV}$, 6000MW HVDC Raigarh and Pugalur Terminals Project.

This Requirement Specification applies to post insulators and long rod insulators to be used inside the Valve halls. The insulators shall be complete including needed corona rings.

The insulators shall also comply with the applicable requirements given in Section 6.9 and 6.15.2 of the Customer's Technical specification and General Requirements for Main Circuit Apparatus 1JNL355425. In case of any conflict between this RS, Customer Technical Specification and General Requirements for Main Circuit Apparatus, the supplier shall inform ABB AB HVDC for a final decision.

2 Quantities

2.1 Raigarh Converter Station

Item No.	VHall P1	VHall P2	VHall P3	VHall P4	Erection Spares	Total Quantity	Scope
380	Not in scope						
381							
382							
383							
384	12	12	12	12	5	53	BHEL

Note: For same design of different insulator items, spares will be adjusted.

2.2 Pugalur Converter Station

Item No.	VHall P1	VHall P2	VHall P3	VHall P4	Erection Spares	Total Quantity	Scope
390	Not in scope						
391							
392							
393							
394	8	8	8	8	3	35	BHEL

Note: For same design of different insulator items, spares will be adjusted.

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3 Standards

The insulators shall be designed according to applicable standards, see clause 12.

4 Technical Data

4.1 Raigarh Converter station

	Item 380	Item 381	Item 382	Item 383	Item 384 VHall Neutral bus floor mounted insulator (Porcelain)
Voltage to ground (kV _{rms})					110
Voltage to ground (kV _{dc})					95
LIWL (kV)					534
SIWL (kV)					516
Dry DC Withstand Voltage (kV)					1.25 x 95
Minimum Creepage distance (mm)					1900
Maximum Tension force (kN)					-
Minimum Cantilever strength (kN) + Seismic load.					8
Mounting details					On Floor
Length of the Insulator(mm)					

Not in scope

Note: For some of these insulators, the length of the insulator will be determined by the valve hall design which is longer than that determined by the voltage level. In such case the length of the insulator are specified.

4.2 Pugalur Converter station

	Item 390	Item 391	Item 392	Item 393	Item 394 VHall Neutral bus floor mounted insulator (Porcelain)
Voltage to ground (kV _{rms})					45
Voltage to ground (kV _{dc})					0
LIWL (kV)					504
SIWL (kV)					490
Dry DC Withstand Voltage (kV)					
Minimum Creepage distance (mm)					630
Maximum Tension force (kN)					-
Minimum Cantilever strength (kN) + Seismic load.					8
Mounting details					On Floor
Length of the Insulator(mm)					

Not in scope

Note: For some of these insulators, the length of the insulator will be determined by the valve hall design which is longer than that determined by the voltage level. In such case the length of the insulator are specified.

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5 Design

5.1 General

Insulators may be installed (mounted) directly on the ground plane without metal support structure. This condition shall be taken into consideration when the arcing distances of the insulators are determined.

Creepage distances given in clause 4 of this Requirement Specification shall be followed. The insulator sheds shall be evenly distributed along the whole insulator.

Both ends of the long rod insulators shall be furnished with couplings conforming to IEC Pub. 60471-1977, 22L.Clevis shall be on the top and Tongue at the bottom of the insulator.

For Shed profiles refer General Requirements for Main Circuit Apparatus 1JNL355425.

Definition for length of long rod insulator see Fig. 1,

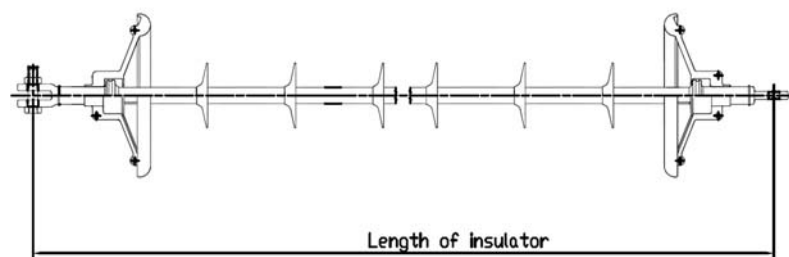


Fig 1

5.2 Surface Treatment

The surface treatment and the color of the equipment shall comply with General Requirements for Main Circuit Apparatus 1JNL355425.

6 Marking

According to supplier's standard.

7 Environment

7.1 Indoor conditions

The indoor environment conditions are specified in General Requirements for Main Circuit Apparatus 1JNL355425.

7.2 Outdoor conditions

Not applicable.

7.3 Seismic requirements

Seismic requirements shall be according to General Requirements for Main Circuit Apparatus 1JNL355425.

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8 Quality Program

The Supplier shall have implemented and documented a quality program level meeting ISO 9001. If the Supplier do not have design responsibility ISO 9002 is acceptable.

8.1 QC Documentation

The documentation must be written in English and shall be complete, reviewed and signed for verification and approved by the Supplier.

The quality documents shall be sufficiently detailed and easy to understand. The quality documentation shall be available at the Supplier's premises and shall be delivered to Purchaser on request.

9 Tests

9.1 General

The insulators shall be tested in accordance with IEC 61462, IEC 60168, IEC 60060-1, IEC 61109, other relevant IEC standards and applicable parts of customer's technical specification 6.9 and 6.15.2.

Solid core ceramic post insulators shall be tested according to IEC 60168. Solid core composite long rod insulators shall be tested according to IEC 61109. Composite hollow post insulators shall be tested according to IEC 61462.

9.1.1 Type tests

9.1.1.1 Dry Lightning impulse withstand voltage test

Test according to IEC 60168 Clause 4.5 / IEC 61109 Clause 11.1 shall be performed. No flashover shall occur.

9.1.1.2 Dry Switching impulse withstand voltage test

Test according to IEC 60168 Clause 4.6 / IEC 61109 Clause 11.1 shall be performed. No flashover shall occur.

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.

9.1.1.3 Dry DC Withstand Voltage test

Test according to IEC/IEEE 65700-19-03 Clause 10.2.2 shall be performed as a dry test. No flashover shall occur.

9.1.1.4 Mechanical failing load test/Mechanical load test

Test according to IEC 60168 Clause 5.2 / IEC 61109 Clause 10.4.2 shall be performed. For Composite insulators test according to IEC 61462 shall be performed.

9.1.1.5 Bending deflection test

Test according to IEC 60168 Clause 5.3 to a level of 70% of mechanical failing load shall be performed.

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9.1.2 Type test report

The supplier shall provide valid type test reports for all type tests applicable for equipments, to be offered. These type reports should be of the tests performed after July 28, 2008 and should be to the satisfaction of purchaser and Customer, Powergrid Corporation of India. Failing which type tests shall be performed on the insulators and a complete summary of type tests with the required type test reports and verifications shall be provided.

The Supplier shall fill in the document numbers of applicable existing certified type test reports. If test reports and verifications from **previously performed** type tests or verifications are referred to, the Supplier shall give details regarding similarities and differences in the design and **supporting the approval of such test reports and verifications**. The report shall provide sufficient identification of the goods.

The Type Test reports and verifications shall fulfill the requirements given in the specific Requirement Specification for the equipment. The tests shall be sufficiently described, named according to applicable standard and with reference to the applicable standard stated.

Test Certificates for type tests (design tests) shall be certified test reports from official, independent laboratories or under the surveillance of an internationally recognized inspection agency.

9.1.3 Routine tests

9.1.3.1 Routine visual examination

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.3.2 Routine Mechanical test

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.4 Routine test report

Routine tests shall be performed on each unit to demonstrate the integrity of manufacturing and the ability to meet design requirements. Certified routine test records shall always be submitted to Purchaser after completion of the testing.

The routine tests shall fulfill the requirements given in the specific Requirement Specification. The tests shall be sufficiently described, named according to applicable standard and with reference to the applicable standard stated. A table of content shall be provided in case the equipment consists of combined apparatus subject to routine test and in case of several separate test reports for each individual. The report shall provide sufficient identification of product including the project specific references given by Purchaser.

9.1.5 Sample tests

9.1.5.1 Verification of dimensions

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.5.2 Temperature cycle test

Test according to IEC 60168 Clause 5.4 shall be performed.

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9.1.5.3 Mechanical failing load test/Verification of Specified Mechanical load/Mechanical tests

Test according to IEC 60168/ IEC 61109/ IEC 61462 shall be performed.

9.1.5.4 Porosity test

Test according to IEC 60168 Clause 5.6 shall be performed.

9.1.5.5 Galvanizing test

Test according to IEC 60168/IEC 61109 /IEC 61462 shall be performed.

9.1.5.6 Ultrasonic test

Ultrasonic test shall be performed on porcelain insulators (except for hollow insulator) as acceptance/sample test.

9.1.6 Verifications

The 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. 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.

9.1.7 Inspection and Test Plans (ITP)

The Supplier shall submit Inspection and Test Plans based on the requirements of the Specifications and the same shall be approved by customer.

The inspection and test plan shall cover all essential inspections for the product and shall state, detailed enough for full understanding, the required inspection and testing methods, acceptance criteria, reports, etc. All reference documents and quality records referred to in ITP's shall be open to Purchaser and his Customer for review at the Supplier's/Manufacturer's premises.

Hold points and/or witnessing points, normally including type and/or routine tests, shall be defined in the ITP's

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9.1.8 Inspection Notification

Requirements regarding Customer's participation at inspection of tests, approval of test reports and test will be given after Purchase order.

The Supplier shall notify Purchaser in writing 45 days before any relevant test indicated in the inspection and test plan, for co-ordination with the Customer, if nothing else is stated in the Contract/purchase order.

If the inspection and acceptance tests show that the goods, or any parts thereof, do not comply with the requirements in the Purchaser order, the Supplier shall without delay remedy any deficiencies in order to ensure that the goods comply herewith. New tests shall then be carried out at Purchaser's request.

If the Supplier delays the test, Purchaser has the right to treat this in the same manner as delayed delivery.

Inspection and/or witnessing of testing by the Purchaser and/or his Customer shall not relieve the Supplier from any responsibility.

An Inspection Notification is included as an attachment to the purchase order for final customer requests to participate when testing the goods.

The Supplier shall submit the Inspection Notification properly completed, for all activities requiring a notification.

10 Documentation

10.1 General

All documents shall conform to international practice and shall be issued with a unique and easily identifiable document number.

Whenever a document is changed in any way, a new revision of said document shall be issued. The revision number, date and reason for revision shall be indicated. Page one of a document shall always be issued with a new revision number, whenever any other page of the document is revised.

The Supplier shall be responsible for any errors or omissions in the Manufacturer's documentation.

It is Supplier's responsibility to ensure that the information imparted in the documentation is sufficient in all respects.

The documentation shall be considered as of equal importance as any other part of the supply.

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10.2 Document types

The delivery shall include, but not be limited to, the following document types:

Dimension outline drawings

Technical description

Test certificates.

Packing lists in English.

All documents listed above shall be presented to the Contractor for review well in advance of final delivery time, as stated in the purchase order.

Document and drawings shall be sent by E-mail (file format PDF).

10.3 Language

The language in all documents shall be English.

11 Enclosures

- [1] 1JNL355425 - General Requirements for Main Circuit Apparatus
- [2] Customer Technical Specification Section 6.9 HVDC INSULATORS, BUSHINGS, BUSES AND HARDWARE and Section 6.15.2 BUSHINGS AND SUPPORT INSULATORS.

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12 References

- | | | |
|------|--------------------|--|
| [1] | IEC 60168 (1994) | Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000 V. Amendment No. 1 (1997), Amendment No. 2 (2000) |
| [2] | IEC 60273 (1990) | Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V. |
| [3] | IEC 60305 (1995) | Insulators for overhead lines with a nominal voltage above 1000V - Ceramic or glass insulator units for AC systems - Characteristics of string insulator units of the cap and pin type |
| [4] | IEC 60383-1 (1993) | Insulators for overhead lines with a nominal voltage above 1000 V- Part 1: Ceramic or glass insulator units for AC systems - Definitions, test methods and acceptance criteria. |
| [5] | IEC 60383-2 (1993) | Insulators for overhead lines with a nominal voltage above 1000 V - Part 2: Insulator strings and insulator sets for AC systems - Definitions, test methods and acceptance criteria |
| [6] | IEC 60433 (1998) | Insulators for overhead lines with a nominal voltage above 1000 V - Ceramic insulators for AC systems - Characteristics of insulator units of the long rod type |
| [7] | IEC 60575 (1977) | Thermal-mechanical performance test and mechanical performance test on string insulator units |
| [8] | IEC 60815 -4(2016) | Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 4: Insulators for d.c. systems |
| [9] | IEC 62155(2003) | Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1000V |
| [10] | IS 2544(1973) | Porcelain post insulators for systems with nominal voltage greater than 1000V |
| [11] | IEC 61462 (2007) | Composite hollow insulators - Pressurized and un- pressurized insulators for use in electrical equipment with rated voltage greater than 1000 V - Definitions, test methods, acceptance criteria and design recommendations. |
| [12] | IEC 60060-1(2010) | High-Voltage test techniques. General definitions and test requirements. |
| [13] | 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. |
| [14] | IEC 60437 (1997) | Radio interference test on high-voltage insulators |
| [15] | ISO 9001 (1994) | Quality System. Model for assurance in design, development, production, installation and servicing. |

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13 Revision History

Rev. B	Prepared Sheeba PT 31-03-2017	Approved Ashish Naik 31-03-2017
Revision text Modified based on Customer comments and other updates. Changes made are marked.		

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	Approved Naik Ashish, 2017-06-17			
Prepared Sheeba PT, 2015-12-23				
Title Outdoor DC Insulators				

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1. General

This Specification gives the general requirements on insulator deliveries for the Raigarh and Pugalur converter stations, of the $\pm 800\text{kV}$, 6000MW HVDC Raigarh and Pugalur Terminals Project.

This Requirement Specification applies to post insulators and long rod insulators to be used in the outdoor DC yards. The insulators shall be complete including needed corona rings.

The insulators shall also comply with the applicable requirements given in Section 6.9 and 6.15.2 of the Customer's Technical specification and General Requirements for Main Circuit Apparatus 1JNL355425. In case of any conflict between this RS, Customer Technical Specification and General Requirements for Main Circuit Apparatus, the supplier shall inform ABB AB HVDC for a final decision.

2. Quantities

2.1 Raigarh Converter Station

Item No.	DC Filter	DC Yard	Erection spares	Total Quantity	Scope
320	Not in scope				
321	-	13	2	15	BHEL
322	52	190	24	266	BHEL
323	Not in scope				
325					
326					
327					
328	8	-	1	9	BHEL
330	8	-	1	9	BHEL
331	16	-	2	18	BHEL
371	-	4	1	5	BHEL

Note:

Quantities shall be revised based on the final approved layouts.
For same design of different insulator items, spares will be adjusted.

2.2 Pugalur Converter Station

Item No.	DC Filter	DC Yard	Erection spares	Total Quantity	Scope
340	Not in scope				SEABB
341	-	14	2	16	BHEL
342	52	253	31	336	BHEL
345	Not in scope				SEABB
346					SEABB
347	4	-	1	5	BHEL
348	8	-	1	9	BHEL
350	8	-	1	9	BHEL
351	16	-	2	18	BHEL
371	-	4	1	5	BHEL

Note:

Quantities shall be revised based on the final approved layouts.
For same design of different insulator items, spares will be adjusted.

3. Standards

The insulators shall be designed according to applicable standards, see clause 12.

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4. Technical Data

4.1 Raigarh Converter station

	Item 320 Pole Bus Insulator (Polymer)	Item 321 Neutral Bus Insulator (Porcelain)	Item 322 Neutral bus /DC Filter Insulator/ DC breaker Insulator/ Metallic return bus Insulator (Porcelain)	Item 323 DC Breaker Long rod Insulator (Polymer)	Item 325 DC Filter HP2/6 Insulator (Polymer)	Item 326 DC Filter HP2/6 Insulator (Polymer)	Item 327 DC Filter HP12/24 Insulator (Polymer)	Item 330 DC Filter HP12/24 Insulator (Porcelain)	Item 331 DC Filter HP12/24 Insulator (Porcelain)	Item 328 DC Filter ST/RI Insulator (Porcelain)	Item 371 DC yard OCT arrangeme nt Post insulator (Porcelain)
Voltage to ground (kV _{rms})	110	95	95	95	95	95	95	8	98	3	Not Applicable
Voltage to ground (kV _{dc})	95	95	95	95	95	95	95	-	-	-	-
LIWL (kV)	534	644	644	644	644	644	644	586	644	566	110
SIWL (kV)	516	460	460	460	460	460	460	-	460	407	-
Wet DC Withstand Voltage (kV)	1.25*95	1.25*95	1.25*95	1.25*95	1.25*95	1.25*95	1.25*95	-	-	-	-
RIV Test Voltage (kV _{rms})	-	-	-	-	-	-	-	-	-	-	-
Minimum Creepage distance (mm)	6600	5700	5700	5700	5700	5700	5700	480	5880	180	Not Applicable
Cantilever strength Upright (kN)	10	10	10	10	10	10	10	10	10	10	10
Cantilever strength underhung (kN)	2	2	2	2	2	2	2	2	2	2	2
Tension strength (kN)	-	-	-	-	-	-	-	-	-	-	-
Compressive strength (kN)	-	-	-	-	-	-	-	-	-	-	-
Torsion Strength (kNm)	-	-	-	-	-	-	-	-	-	-	-
Minimum Mounting/Pedestal Height(mm)	See Fig 7	See Fig 7	See Figs 3,4,5,6,7	See Fig 3	See Fig 7	See Fig 6,7	See Fig 7	See Fig 2,4	See Fig 2,4,5,6	See Fig 7	

Note: 1. See clause 4.3 of this Requirement specification for definition of cantilever strength.
2. Compressive strength disregarding buckling hazard.

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4.2 P
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	Item 340 Pole Bus Insulator (Polymer)	Item 341 Neutral Bus Insulator (Porcelain)	Item 342 Neutral bus/DC Filter Insulator/ Metallic Return bus/DC breaker Insulator (Porcelain)	Item 345 DC Filter HP2/6 Insulator (Polymer)	Item 346 DC Filter HP2/6 Insulator (Polymer)	Item 347 DC Filter HP12/24 Insulator (Porcelain)	Item 350 DC Filter HP12/24 Insulator (Porcelain)	Item 351 DC Filter HP12/24 Insulator (Porcelain)	Item 348 DC Filter ST/RI Insulator (Porcelain)	Item 371 DC yard OCT arrange ment Post insulator (Porcelain)
Voltage to ground (kV _{rms})	Not in scope	45	15	Not in scope			8	18	3	Not Applicable
Voltage to ground (kV _{dc})		≈0	≈0				-	-	-	
LIWL (kV)		504	125				328	210	331	110
SIWL (kV)		490	-				233	175	233	-
Wet DC Withstand Voltage (kV)	Not in scope	-	-	Not in scope			-	-	-	-
RIV Test Voltage (kV _{rms})		-	-				-	-	-	-
Minimum Creepage distance (mm)		2700	900				1032	774	129	Not Applicable
Cantilever strength Upright (kN)		10	10				10	10	10	10
Cantilever strength underhung (kN)		2	2				2	2	2	2

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Tension strength (kN)	100	-	-	-	-	-	-	-	-	-
Compressive strength (kN)	500	-	-	-	-	-	-	-	-	-
Torsion Strength (kNm)	10	-	-	-	-	-	-	-	-	-
Minimum Mounting/Pedestal Height(mm)	See Fig 7	See Fig 7	See Fig 7	See Fig 6,7	See Fig 7	See Fig 6,7	See Fig 7	See Fig 2.4	See Fig 2.5	See Fig 7

N o t e .:

1. See clause 4.3 of this Requirement specification for definition of cantilever strength.
2. Compressive strength disregarding buckling hazard.

4.3 Cantilever Strength

DEFINITION OF CANTILEVER STRENGTH OF POST INSULATOR

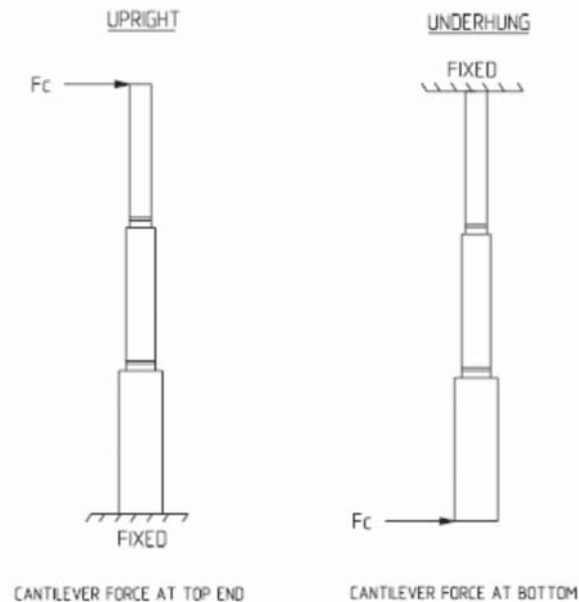


Fig.1

5. Design

5.1 General

Creepage distances given in clause 4 of this Requirement Specification shall be followed.

Both ends of Item 323 shall be furnished with couplings conforming to IEC Pub. 60471- 1977, 22L. Clevis shall be on the top and Tongue at the bottom of the insulator.

For Shed profiles refer General Requirements for Main Circuit Apparatus 1JNL355425.

5.2 RIV design

Maximum radio interference voltage for frequency between 0.5 to 2 MHz shall be $2500\mu\text{V}$. The maximum RIV for DC Filter insulators with Item Nos. 325, 326, 327, 328, 330 & 331 and 345, 346, 347, 348, 350 & 351 for Raigarh and Pugalur Converter Station shall be $1000\mu\text{V}$ respectively. The test voltage is specified in clause 4.1 and 4.2.

5.3 Surface treatment

The surface treatment and the color of the equipment shall comply with General Requirements for Main Circuit Apparatus 1JNL355425.

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6. Marking

According to supplier's standard.

7. Environment

7.1 Indoor conditions

Not applicable.

7.2 Outdoor conditions

The outdoor environment conditions are specified in General Requirements for Main Circuit Apparatus 1JNL355425.

7.3 Seismic requirements

Seismic requirements shall be according to General Requirements for Main Circuit Apparatus 1JNL355425.

8. Quality Program

The Supplier shall have implemented and documented a quality program level meeting ISO 9001. If the Manufacturer do not have design responsibility ISO 9002 is acceptable.

8.1 QC Documentation

The documentation must be written in English and shall be complete, reviewed and signed for verification and approved by the Supplier.

The quality documents shall be sufficiently detailed and easy to understand. The quality documentation shall be available at the Supplier's premises and shall be delivered to Purchaser on request.

9. Tests

9.1 General

The insulators shall be tested in accordance with IEC 61462, IEC 60168, IEC 60060-1, IEC 61109, other relevant IEC standards and applicable parts of customer's technical specification 6.9 and 6.15.2.

Solid core ceramic post insulators shall be tested according to IEC 60168.
Solid core composite long rod insulators shall be tested according to IEC 61109.
Composite hollow post insulators shall be tested according to IEC 61462.

9.1.1 Type Tests

9.1.1.1 Lightning impulse withstand voltage test

Test according to IEC 60168 Clause 4.5 / IEC 61109 Clause 11.1 shall be performed. No flashover shall occur.

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9.1.1.2 Wet Switching impulse withstand voltage test

Test according to IEC 60168 Clause 4.6 / IEC 61109 Clause 11.1 shall be performed. No flashover shall occur.

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.

9.1.1.3 Wet DC Withstand Voltage test

Test according to IEC/IEEE 65700-19-03 Clause 10.2.2 shall be performed. Water shall be applied according to the requirements of IEC 60060-1. No flashover shall occur.

9.1.1.4 Mechanical failing load test/Mechanical load test

Test according to IEC 60168 Clause 5.2 / IEC 61109 Clause 10.4.2 shall be performed. For Composite insulators test according to IEC 61462 shall be performed.

Please note, some of the insulators are horizontal mounted. Hence, the test on the insulators shall be performed by mounting insulators horizontally. Refer Appendix.

9.1.1.5 Bending deflection test

Test according to IEC 60168 Clause 5.3 to a level of 70% of mechanical failing load shall be performed.

Please note, some of the insulators are horizontal mounted. Hence, the test on the insulators shall be performed by mounting insulators horizontally. Refer Appendix.

9.1.1.6 Radio Interference test

Test according to IEC 60437 shall be performed.

9.1.2 Type test report

The supplier shall provide valid type test reports for all type tests applicable for equipments, to be offered. These type reports should be of the tests performed after July 28, 2008 and should be to the satisfaction of purchaser and Customer, Power Grid Corporation of India. Failing which type tests shall be performed on the insulators and a complete summary of type tests with the required type test reports and verifications shall be provided.

The Supplier shall fill in the document numbers of applicable existing certified type test reports. If test reports and verifications from **previously performed** type tests or verifications are referred to, the Supplier shall give details regarding similarities and differences in the design and **supporting the approval of such test reports and verifications**. The report shall provide sufficient identification of the goods.

The Type Test reports and verifications shall fulfill the requirements given in the specific Requirement Specification for the equipment. The tests shall be sufficiently described, named according to applicable standard and with reference to the applicable standard stated.

Test Certificates for type tests (design tests) shall be certified test reports from official, independent laboratories or under the surveillance of an internationally recognized inspection agency.

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9.1.3 Routine tests

9.1.3.1 Routine visual examination

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.3.2 Routine Mechanical test

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.4 Routine test report

Routine tests shall be performed on each unit to demonstrate the integrity of manufacturing and the ability to meet design requirements. Certified routine test records shall always be submitted to Purchaser after completion of the testing.

The routine tests shall fulfill the requirements given in the specific Requirement Specification. The tests shall be sufficiently described, named according to applicable standard and with reference to the applicable standard stated. A table of content shall be provided in case the equipment consists of combined apparatus subject to routine test and in case of several separate test reports for each individual. The report shall provide sufficient identification of product including the project specific references given by Purchaser.

9.1.5 Sample tests

9.1.5.1 Verification of dimensions

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.5.2 Temperature cycle test

Test according to IEC 60168 Clause 5.4 shall be performed.

9.1.5.3 Mechanical failing load test/Verification of Specified Mechanical Load/ Mechanical tests

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.5.4 Porosity test

Test according to IEC 60168 Clause 5.6 shall be performed.

9.1.5.5 Galvanizing test

Test according to IEC 60168/ IEC 61109 / IEC 61462 shall be performed.

9.1.5.6 Ultrasonic test

Ultrasonic test shall be performed on porcelain insulators (except for hollow insulator) as acceptance/sample test.

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9.1.6 Verifications

The 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. 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.

9.1.7 Inspection and Test Plans (ITP)

The Supplier shall submit Inspection and Test Plans based on the requirements of the Specifications and the same shall be approved by customer.

The inspection and test plan shall cover all essential inspections for the product and shall state, detailed enough for full understanding, the required inspection and testing methods, acceptance criteria, reports, etc. All reference documents and quality records referred to in ITP's shall be open to Purchaser and his Customer for review at the Supplier's/Manufacturer's premises.

Hold points and/or witnessing points, normally including type and/or routine tests, shall be defined in the ITP's

9.1.8 Inspection Notification

Requirements regarding Customer's participation at inspection of tests, approval of test reports and test will be given after Purchase order.

The Supplier shall notify Purchaser in writing 45 days before any relevant test indicated in the inspection and test plan, for co-ordination with the Customer, if nothing else is stated in the Contract/purchase order.

If the inspection and acceptance tests show that the goods, or any parts thereof, do not comply with the requirements in the Purchaser order, the Supplier shall without delay remedy any deficiencies in order to ensure that the goods comply herewith. New tests shall then be carried out at Purchaser's request.

If the Supplier delays the test, Purchaser has the right to treat this in the same manner as delayed delivery.

Inspection and/or witnessing of testing by the Purchaser and/or his Customer shall not relieve the Supplier from any responsibility.

An Inspection Notification is included as an attachment to the purchase order for final customer requests to participate when testing the goods.

The Supplier shall submit the Inspection Notification properly completed, for all activities requiring a notification.

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10. Documentation

10.1 General

All documents shall conform to international practice and shall be issued with a unique and easily identifiable document number.

Whenever a document is changed in any way, a new revision of said document shall be issued. The revision number, date and reason for revision shall be indicated. Page one of a document shall always be issued with a new revision number, whenever any other page of the document is revised.

The Supplier shall be responsible for any errors or omissions in the Manufacturer's documentation.

It is Supplier's responsibility to ensure that the information imparted in the documentation is sufficient in all respects.

The documentation shall be considered as of equal importance as any other part of the supply.

10.2 Document types

The delivery shall include, but not be limited to, the following document types:

Dimension outline drawings

Technical description

Test certificates.

Packing lists in English.

All documents listed above shall be presented to the Contractor for review well in advance of final delivery time, as stated in the purchase order.

Document and drawings shall be sent by E-mail (file format PDF).

10.3 Language

The language in all documents shall be English.

11. Enclosures

- [1] 1JNL355425 - General Requirements for Main Circuit Apparatus
- [2] Customer Technical Specification Section 6.9 HVDC INSULATORS, BUSHINGS, BUSES AND HARDWARE and Section 6.15.2 BUSHINGS AND SUPPORT INSULATORS.

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12. References

- [1] IEC 60168 (1994) Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000 V. Amendment No. 1 (1997), Amendment No. 2 (2000).
- [2] IEC 60273 (1990) Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V.
- [3] IEC 60305 (1995) Insulators for overhead lines with a nominal voltage above 1000V - Ceramic or glass insulator units for AC systems - Characteristics of string insulator units of the cap and pin type.
- [4] IEC 60383-1 (1993) Insulators for overhead lines with a nominal voltage above 1000V - Part 1: Ceramic or glass insulator units for AC systems - Definitions, test methods and acceptance criteria.
- [5] IEC 60383-2 (1993) Insulators for overhead lines with a nominal voltage above 1000V - Part 2: Insulator strings and insulator sets for AC systems - Definitions, test methods and acceptance criteria.
- [6] IEC 60433 (1998) Insulators for overhead lines with a nominal voltage above 1000V - Ceramic insulators for AC systems - Characteristics of insulator units of the long rod type.
- [7] IEC 60575 (1977) Thermal-mechanical performance test and mechanical performance test on string insulator units.
- [8] IEC 60815-4 (2016) Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 4: Insulators for d.c. systems
- [9] IEC 62155(2003) Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1000V.
- [10] IS 2544(1973) Porcelain post insulators for systems with nominal voltage greater than 1000V.
- [11] IEC 61462 (2007) Composite hollow insulators - Pressurized and un- pressurized insulators for use in electrical equipment with rated voltage greater than 1000 V - Definitions, test methods, acceptance criteria and design recommendations.
- [12] IEC 60060-1(2010) High-Voltage test techniques. General definitions and test requirements.
- [13] 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.
- [14] IEC 60437 (1997) Radio interference test on high-voltage insulators.
- [15] ISO 9001 (1994) Quality System. Model for assurance in design, development, production, installation and servicing.

13. Appendix

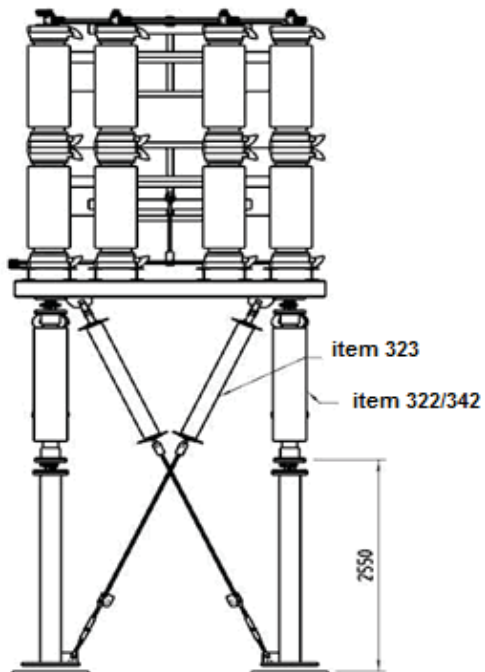
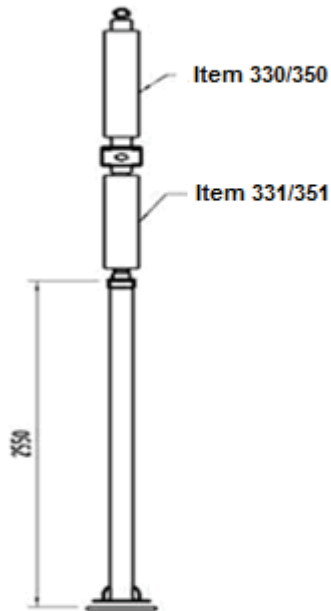


Fig.2

Fig.3

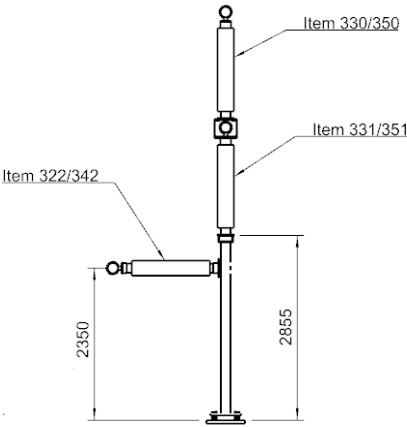


Fig.4

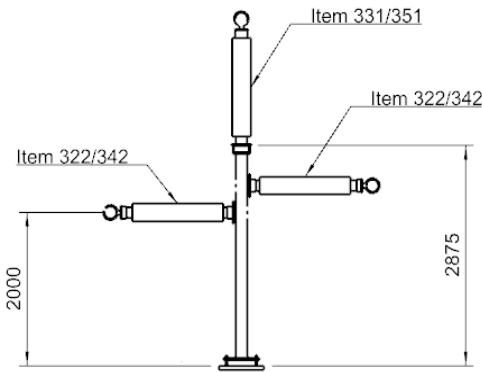


Fig.5

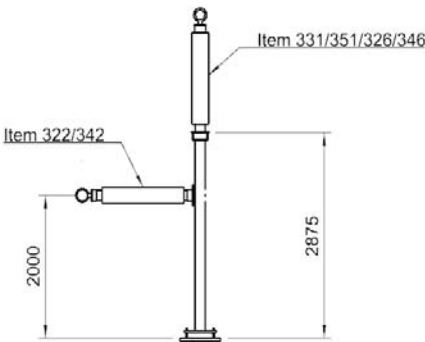


Fig.6

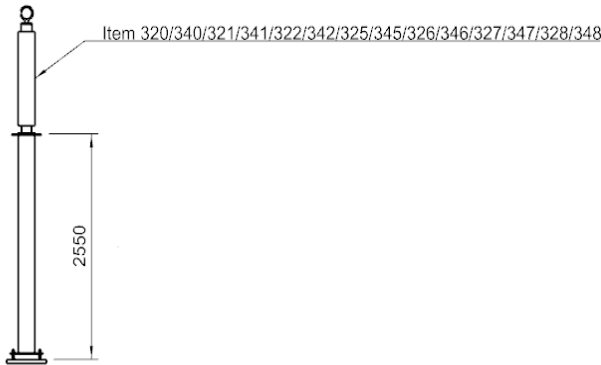


Fig.7

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14. Revision History

Rev. A	Prepared Dinesh Kumar Sarda, 23/05/2017	Approved Ashish Naik 23/05/2017
Revision text Revised as marked.		

6.15 HVAC INSULATORS, BUSHINGS, BUSES AND HARDWARE

6.15.1 GENERAL

The insulators, bushings, buses and hardware used in the HVAC switchyards shall be in accordance with the relevant Standards.

6.15.2 BUSHINGS 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.

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

The creepage distances for the porcelain and silicon rubber insulators shall be as per Section 4 of TS.

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.

All AC Bushings upto 400 KV level shall be RIP Bushings

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

±800kV, 6000MW HVDC Raigarh(Kotra) –Pugalur (New) HVDC Terminal ASSOCIATED WITH TRANSMISSION SYSTEM HVDC BIPOLE LINK BETWEEN WESTERN REGION AND SOUTHERN REGION
C/Engg HVDC/Spec/Chapter6/Rev.00

- 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.

6.15.2.3 PARAMETERS

The parameters shall be determined by the Contractor, however the minimum performance parameters for the 400 kV class post insulator shall be as follows:

a)	Lightning impulse withstand positive and negative (kVp) (Dry and wet)	1425
b)	Switching impulse withstand voltage (kVp)	1050

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c)	One min. power freq. withstand voltage (kV _{rms}) (Wet and Dry)	630
d)	Total creepage distance (mm)	10500
e)	Total min. cantilever strength (kg)	800
f)	Corona extinction voltage (kV _{rms})	320
g)	Total min. height of insulator (mm)	3500

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:

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

6.15.3 STRING INSULATORS & HARDWARE

6.15.3.1 GENERAL

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

Insulator hardware shall conform to IS-2486.

The insulation levels shall be determined by the Contractor in accordance with Section 4 of this Specification but the minimum performance characteristics shall be as Specified in '**Annexure-String Insulators**'

6.15.3.2

Not Used

6.15.3.3

Not Used

6.15.3.4 TESTS

±800kV, 6000MW HVDC Raigarh(Kotra) –Pugalur (New) HVDC Terminal ASSOCIATED WITH TRANSMISSION SYSTEM HVDC BIPOLE LINK BETWEEN WESTERN REGION AND SOUTHERN REGION

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~~ (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.

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.

HVDC

Requirement specification

±800kV, 6000MW HVDC Raigarh - Pugalur Terminals		Document number , revision 1JNL355425 , G		Page 1 (39)
		Status Approved	Resp. dept. TSE	Class no. FE - 000
Prepared Bjorn Djurberg, 2017-03-27		Approved Skytt Anna-Karin 2017-04-18		
Title General requirements for main circuit apparatus				

Summary

Enclosure to 1JNL446256 Rev. A "Outdoor DC Insulators" & 1JNL446257 "Indoor DC Insulators"

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	पावर ग्रिड कॉर्पोरेशन 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		
Checked by	Verified by	Reviewed by	
Signature : 			
Date : 25/4/17			

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1 General information

This Specification gives the general requirements on equipment deliveries for the converter stations for the $\pm 800\text{kV}$, 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 $(X - 2 \cdot \sigma)$, where X is the mean value and ' σ ' is the standard deviation. For load combinations in porcelain insulators and similar the following expressions shall be fulfilled:

$$\{F_t / (F_t)_b\} + \{M_b / (M_b)_b\} < 2/3$$

and

$$\{F_c / (F_c)_b\} + \{M_b / (M_b)_b\} < 2/3$$

Where:

F_t , F_c , M_b - calculated maximum tensile force; compressive force and bending respectively

(F) , $(F)_b$, $(M)_b$ - 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).

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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.*

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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 Raigarh 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

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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.

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3.6 EMC environment

The requirements stated below shall be met for secondary equipment.

<u>Location</u>	<u>Immunity requirements</u>	<u>Emission requirements</u>
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 61000-6-5 [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)
$1.0 \cdot 10^3$	210
$1.0 \cdot 10^4$	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.

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

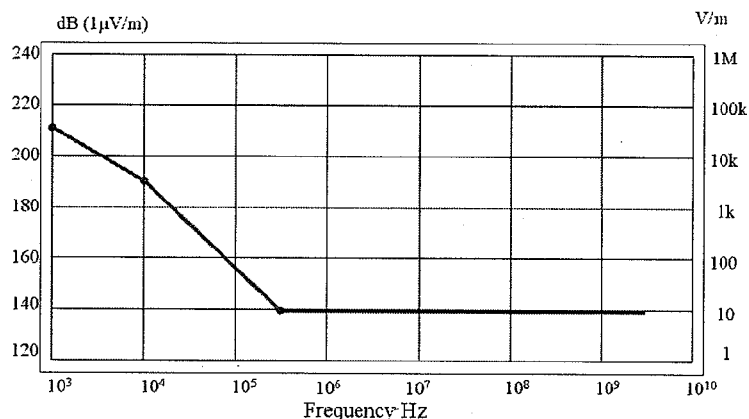


Figure Additional immunity requirements inside valve hall or converter enclosure, as applicable.

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.

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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

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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 hygostat, 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].

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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.

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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,

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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,

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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 $90 \pm 15^\circ$ 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 $CTI \geq 600$.

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: $\geq 30 \text{ kV/mm}$

Requirement specification

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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 $420/\sqrt{3}$ kV, $245/\sqrt{3}$ kV and $145/\sqrt{3}$ 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.

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- 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.

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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.

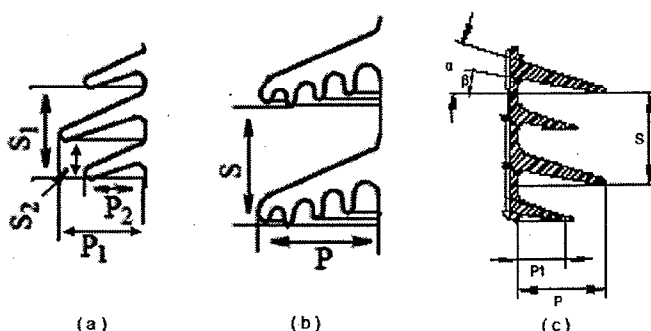


Figure Parameters of insulator sheds: (a) alternating profile of a porcelain insulator; (b) deep under-rib profile of a porcelain insulator; (c) alternating profile of a polymer insulator

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.

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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: $10^\circ \sim 25^\circ$.

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:
 $15 \text{ mm} < (P - P_1) \leq 20 \text{ mm}$.
- Upper inclination angle $\alpha > 10^\circ$
- Lower inclination angle $\beta > 3^\circ$.

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.

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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 |

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

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[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 Björn Djurberg	Approved Rodrigo Borquez
Revision text		

Rev. A	Prepared Björn Djurberg	Approved Rodrigo Borquez
Revision text		
- §1: Project name revised. - §9: Reference removed.		

Rev. B	Prepared Björn Djurberg	Approved 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. C	Prepared Björn Djurberg	Approved
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. D	Prepared Björn Djurberg	Approved
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Revision text
- §9.1: Type test validity date updated. - §11.3: Clarified usage of material for insulators.

Rev. E	Prepared Björn Djurberg	Approved
Revision text		
- Revised as per customer comments. - Type test validity date updated.		

Rev. F	Prepared Björn Djurberg	Approved
Revision text		
- Revised as per customer comments. - Wind speed updated for Raigarh-station.		

Rev. G	Prepared Nils Englund	Approved
Revision text		
- Wind speed updated for both stations		

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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 $(30\sim50) \text{ cm}^2$, thickness of $(3\sim6) \text{ mm}$.
- b. Hydrophobicity Class (HC) method: five flat-type specimens, each with area of $(50\sim100) \text{ cm}^2$.
- 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 0.1 mg/cm^2 , ash density of 0.5 mg/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 $(4\sim7) \mu\text{l}$ (i.e. each droplet weighs $4\sim7 \text{ mg}$). 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

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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 $20^{\circ}\sim 30^{\circ}$ 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 $50^{\circ}\sim 70^{\circ}$. 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) $\theta_{av} \geq 100^{\circ}$, $\theta_{min} \geq 90^{\circ}$;
 - (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 $10\mu\text{S}/\text{cm}$. 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) $\theta_{av} \geq 90^{\circ}$, $\theta_{min} \geq 80^{\circ}$;
- (2) Generally HC3~HC4, no more than 1 specimen measured to HC5.

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- 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) $\theta_{av} \geq 95^\circ$, $\theta_{min} \geq 90^\circ$;
 - (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) $\theta_{av} \geq 110^\circ$, $\theta_{min} \geq 100^\circ$;
 - (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.

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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

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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 lamincoid. 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.

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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.

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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*

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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.*

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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.

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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

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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.*

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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.

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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.

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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

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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.

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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.

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- 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*

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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.*