

पावर ग्रिड कारपोरेशन ऑफ इंडिया लिमिटेड
(भारत सरकार का उद्यम)
POWER GRID CORPORATION OF INDIA LIMITED
(A Government of India Enterprise)



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संदर्भ संख्या/Ref. Number

C/ENGG/HVDC/RP800/200/160

Date: 25/04/2017

ABB AB
HVDC
SE-771 80 Ludvika
Sweden

Kind Attn.: Mr. Andrew McGlade, Project Director
Smt. Aruna Gulati AGM, BHEL

Subject: $\pm$ 800 KV, 6000 MW HVDC terminals associated with HVDC Bipole link between Western region (Raigarh, Chhattisgarh) and Southern region (Pugalur, Tamil Nadu)- North Trichur (Kerala) Specification No.: CC-CS/651-SR2/HVDC-3063/7/G10 - General Requirements for Main Circuit Apparatus

NOA No.: CC-CS/651-SR2/HVDC-3063/7/G10/NOA-II/5817, CC-CS/651-SR2/HVDC-3063/7/G10/NOA-II/5818
CC-CS/651-SR2/HVDC-3063/7/G10/NOA-III/5819, CC-CS/651-SR2/HVDC-3063/7/G10/NOA-IV/5820
CC-CS/651-SR2/HVDC-3063/7/G10/NOA-V/5821 all dated 08.06.2016

Dear Sir,

कृपया उपरोक्त विषय पर आपके पत्र संख्या TM-RP1-170172 दिनांक 20.04.17 का अवलोकन करें दस्तावेजों पर टिप्पणियाँ / अनुमोदन संलग्नित पेज में दिया गया है

In reference to your letter no: TM-RP1-170172 dated 20.04.17. We are here in conveying comments/ approval on the drawings/ documents listed in attached sheet. For approval/ comments code of each drawing/ documents, please refer the category indicated in remarks column.

अगर हमारे द्वारा वाँछित संशोधन के अलावा आप कोई संशोधन करना चाहते हैं तो कृपया उसे पूर्ण तर्कसंगति के साथ हाईलाइट करें एवं दस्तावेज को पुनः अनुमोदन हेतु दुबारा प्रेषित करें

In case of any modification other than those desired by us are carried out, the same shall be highlighted clearly in the Drawing/ Document with full justification thereof and resubmitted for approval.

दस्तावेजों में जो टिप्पणी / अनुमोदन दिया गया है उससे संविदाकार अपनी संविदा जिम्मेदारियों से समय-समय पर लागू भारतीय स्टेचुररी कानून के अंतर्गत उसकी जिम्मेदारियों जैसे डायमैनशन की यथार्थताएं निर्माण में इस्तेमाल की गई सामग्री वजन मात्राएं अभिकल्प ब्योरा (design details) असम्बल फिटस निष्पादन ब्योरा और सामग्री पुर्ति से मुक्त नहीं होगा तथा क्रेता का इस संविदा के अधीन कोई भी अधिकार प्रतिबंधित नहीं होगा

Approval/ comments conveyed herein neither relieves the Contractor of his contractual obligation and his responsibilities for correctness of dimensions, material of constructions, weight, quantities, design details, assemble fits, performance particulars and conformity of the supplies with the Indian Statutory Laws as may be applicable, nor does it limits the Purchaser's right under the Contract.

सधन्यवाद

Thanking you.

Yours faithfully

(B. B. Mukherjee)

(बी.बी. मुखर्जी)

AGM (Engg-HVDC)

अपर महाप्रबंधक (अभि एच वी डी सी)

Sl. No.	Document No./ Drawing No.	Document Title	Category of Approval	Remarks/ comments
1.	1JNL355425 Rev. G	General Requirements for Main Circuit Apparatus	I	

CATEGORIES: -

- I Approved.
- II Approved with comments.
- III Returned for correction.
- IV For Information

Udju
25/4/17

HVDC	±800kV, 6000MW HVDC Raigarh – Pugalur Terminals	Document Transmittal
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ABB, HVDC
RP800 Project Office
4th Floor, Plot No. 58
Sector 44, Gurgaon – 122001.
India

Transmittal No: TM-RP1-170172
Issue Date: 2017-04-20

Managed by: P, Srinivasan

To: Powergrid (RP800) - Engineering

Attn: Mr. B.B. Mukherjee, AGM (Corporate Engineering)

Cc: Mr. M.M. Goswami, GM (Corporate Engineering), Mr.R.N. Singh, Executive Director (RP800), Mr.Rajeev K Chauhan (ED-Engineering)

Enclosed please find the following documents for Approval

Documents of TM-RP1-170172

Doc No	Revision	Title	Document Kind	For Info / Approval	Customer comments due Date	EQ class	Station
1JNL355425	G	General requirements for main circuit apparatus	Requirement specification	Approval	2017-05-11	000	Raigarh - Pugalur
1JNL355425 - RoR	A	General requirements for main circuit apparatus - RoR	Record of review	Approval	2017-05-11	000	Raigarh - Pugalur

Please Note: In our earlier Transmittal TM-RP1-170145 dated 07-April-2017 we had send Rev F and we are now sending Rev G and **please treat Rev F as withdrawn**. The same RoR is being resent along with Rev G for your review and approval please.

Best regards
P.Srinivasan
Document Control

E-mail: srinivasan.p@in.abb.com

The above documents are submitted for approval / comments as per the requirements of GCC Clause 20.3.1 read with SCC GCC Clause 20.3.2.



Project: $\pm$ 800 kV, 6000MW HVDC Raigarh – Pugalur Terminals

Document id: 1JNL355425-ROR Rev. A

Record of Review – Document Comment Sheet

Contract No:	CC-CS/651-SR2/HVDC-30637/G10/CA-I/5817-5821	Reviewer Initials	Name	Company / Dept
ABB Document No & Rev:	1JNL355425 Rev. D; 1JNL355425 Rev. E	BD	Björn Djurberg	ABB HVDC, TSE
ABB Transmittal No:	TM-RP1-170003; TM-RP1-170080			
Date:	2017-01-03; 2017-03-01			
Document Title:	General Requirements for Main Circuit Apparatus			
Station:	Raigarh – Pugalur			
POWERGRID Letter No:	C-ENGG-HVDC-RP800-200-09; C-ENGG-HVDC-RP800-200-69			
Date:	2017-01-24; 2017-03-08			

Col.	II
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No	Page/ Chapter/ Rev	Initials/ Date	Comments from POWERGRID	Letter	Initials / Date	ABB / BHEL clarifications
1a)	1//Rev.D		Section 3.3.1 of the document: Please specify various indoor areas for which this section is	200/09	BD / 2017-02-12	This has no application in RP800 (requirement remains from NEA800 DC hall).
1b)	2//Rev.E	01-03-2017	Sr. No. 1a) of the ROR: Please remove the "Other areas" conditions if it is not applicable for Raigarh - Pugalur HVDC project. Please revise the document accordingly.	200/69 Open	BD / 2017-03-09	RS has been revised accordingly.
2a)	1//Rev.D		Section 3.3.2 of the document: Please specify the environment conditions of all the areas where control cabinets are located (e.g. control room, bay kiosks etc.).	200/09 Closed	BD / 2017-02-12	This section is for all control cabinets located in control rooms including e.g. the FRB. If control cabinets would be placed elsewhere it will be stated in respective Requirement Specification with added information which environment is applicable.
3a)	1//Rev.D		Section 3.3.3 of the document: Please specify various indoor areas for which this section is applicable.	200/09 Closed	BD / 2017-02-12	This section is for equipment located indoor without air conditioning.



Project: $\pm$ 800 kV, 6000MW HVDC Raigarh – Pugalur Terminals

Document id: 1JNL355425-ROR Rev. A

Record of Review – Document Comment Sheet

No.	Page/Chapter/Rev	Initials/Date	Comments from POWERGRID	Letter	Initials / Date	ABB / BHEL clarifications
4a)	1//Rev.D		Section 6.1 of the document: All openings shall be properly provided with suitably profiled EPDM gaskets/ XLPE Foam gaskets in line with the T. S. Clause 3.6.5.9P1ease update the gasket material accordingly.	200/09	BD / 2017-02-12	Neoprene is considered better, more reliable and is being used in other HVDC-stations with good experience. This was also discussed and clarified in NEA800.
4b)	2//Rev.E	01-03-2017	Sr. No. 4a) of the ROR: As per T. S. Clause 3.6.5, All doors, removable covers and plates of CONTROL CABINETS, JUNCTION BOXES, TERMINAL BOXES 8: MARSHALLING BOXES shall be gasketed all around with suitably profiled EPDM gaskets/ XLPE Foam gaskets.	200/69 Open	BD / 2017-03-09	RS cl 6.1 has been revised.
5a)	1//Rev.D		Second Para in Section 9.1 of the document (i.e. Previous type test for Converter transformer bushings,.....): Please change the date from May 19, 2008 to July 28, 2008 in line with the First Stage Bid Opening date mentioned at NOA Clause 1.3.	200/09 Closed	BD / 2017-02-12	RS is revised accordingly.
6a)	1//Rev.D		Third Para in Section 9.1 of the document (i.e. Previous type test for LT transformer,.....): Please change the date from May'19, 2005 to July 28, 2005 in line with the First Stage Bid Opening date mentioned at NOA Clause 1.3.	200/09 Closed	BD / 2017-02-12	RS is revised accordingly.
7a)	1//Rev.D		Section 9.1 of the documents. Please mention that For HVDC insulators, bushings, busses, . conductors etc., the additional special type tests as mentioned in T. 8. Clause 6.9.4 shall also be carried out on a unit of each type and rating.	200/09 Closed	BD / 2017-02-12	Kindly note that all equipment specific tests will be stated in respective Requirement Specification.



Project: $\pm$ 800 kV, 6000MW HVDC Raigarh – Pugalur Terminals

Document id: 1JNL355425-ROR Rev. A

Record of Review – Document Comment Sheet

No.	Page / Chapter / Rev.	Initials / Date	Comments from ROWGRID	Letter	Initials / Date	ABB / BHEL clarifications
8a)	1//Rev.D		Section 11.3 of the document: Please add following in line with the T. 5. Clause 4.4.6.2. a) The dc voltage applicable for creepage distance calculation of Transformer .Valve winding Bushing inside Valve Hall, shall be, $\sqrt{[(U_{max}/2) * (Z - 0.5)]^2 + [U_s/\sqrt{3}]^2}$ where Z = 2 for Y & Z = 1 for Δ U_{max} = Maximum DC Voltage Pole to neutral U_s = Maximum valve side secondary voltage of converter transformer	200/09 Closed	BD / 2017-02-12	Equipment specific creepage distances and calculations of base voltage for creepage will be stated in respective Requirement Specification. ABB confirm the calculation for transformer creepage is made accordingly.
8b)	1//Rev.D		The base voltage applicable for calculation of valve arrester creepage distance shall be, $U_{creepage} = \left(\frac{1}{\sqrt{3}} + \frac{\sqrt{3}}{8\pi} \right) * CC0V$ where U_n is the fundamental voltage including possible harmonics 'n' added across the insulator in rms. The specific creepage distance for valve arresters shall be 14 mm/ems. Furthermore, please mention that all creepage distances shall be as per relevant Clauses of T. S.	200/09 Closed	BD / 2017-02-12	See answer to 8a) above. ABB confirm the calculation for valve arrester creepage is made accordingly.
9a)	2//Rev.D		Section 11.5 of the document: Please mention that all DC insulators shall comply the requirements specified in T. 5. Clause 6.9.	200/09	BD / 2017-02-12	Please note that the general requirements on all main circuit insulators are given in this RS. The specific requirements on equipment such as testing requirements are given in the respective equipment Requirement Specifications.



Project: $\pm$ 800 kV, 6000MW HVDC Raigarh – Pugalur Terminals

Document id: 1JNL355425-ROR Rev. A

Record of Review – Document Comment Sheet

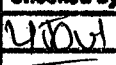
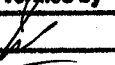
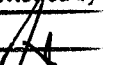
No	Page / Chapter / Rev	Initials / Date	Comments from POWGRID	Letter	Initials / Date	ABB / BHEL clarifications
9b)	2//Rev.E	01-03-2017	Sr. No. 9a) of the ROR: Please modify the Section 11.5 of the document as follows: "Insulators shall generally conform to customer's Technical Specification Clauses 6.9 & 6.15.2, as applicable, see Appendix 2".	200/69 Open	BD / 2017-03-09	RS has been revised accordingly.
10a)	2//Rev.D		First Para in Clause 3.5.1 of Section 17 Appendix 2 (The minimum weight of the zinc coating.....) of the document: Please add "Zinc coating in coastal area, if applicable, shall not be less than 900 gm/ sq. m." in line with the 51 no. 32 of Amendment 1 (rev) — Part B.	200/09 Closed	BD / 2017-02-12	RS is revised accordingly. However, not applicable as the stations are not located in coastal area.
11a)	2//Rev.D		Fourth Para in Clause 6.15.2.1 of Section 17 Appendix 2 (All bushings shall be Polymer insulator.....) of the document: Please add the text, " For wall bushings, all required necessary material to fix it to the wall shall be supplied along with the bushing." in line with the T. S. Clause 6.15.2.1.	200/09 Closed	BD / 2017-02-12	RS is revised accordingly.
12a)	2//Rev.D		Clause 6.15.2.1 of Section 17 Appendix 2 of the document: Please add a para, "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," in line with the T. S. Clause 6.15.2.1.	200/09 Closed	BD / 2017-02-12	RS is revised accordingly.
13a)	2//Rev.D		Section 3.5 of the document: Please clarify that based on which parameters/ conditions the environmental classes are considered for different areas of Raigarh and Pugalur.	200/09 Closed	BD / 2017-02-12	Environmental class C3 is chosen as "Urban and industrial atmosphere" as per ISO 12944-2.
						Other updates in Revision F of 1JNL355425
					BD / 2017-03-09	Wind speed has been updated according to discussions, please see Powergrid letter 100/88 dated 2017-03-22

±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

Table of contents

1	General information.....	2
2	Lifetime.....	2
3	Environment.....	2
4	Materials and workmanship	7
5	Auxiliary power	8
6	Terminal boxes and control cabinets	9
7	Motors.....	9
8	Terminal blocks.....	10
9	Quality program	11
10	Name plates and markings.....	12
11	Insulators.....	12
12	Colors	17
13	Enclosure	18
14	References	18
15	Revision history	20
16	Appendix 1	22
17	Appendix 2	26

	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, Chattisgarh) 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		

Document number , revision 1JNL355425 , G	Page 2 (39)
Title General requirements for main circuit apparatus	

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).

Document number , revision 1JNL355425 , G	Page 3 (39)
Title General requirements for main circuit apparatus	

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.*

Document number , revision 1JNL355425 , G	Page 4 (39)
Title General requirements for main circuit apparatus	

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

Document number , revision 1JNL355425 , G	Page 5 (39)
Title General requirements for main circuit apparatus	

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.

Document number , revision 1JNL355425 , G	Page 6 (39)
Title General requirements for main circuit apparatus	

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.

Document number, revision 1JNL355425, G	Page 7 (39)
Title General requirements for main circuit apparatus	

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

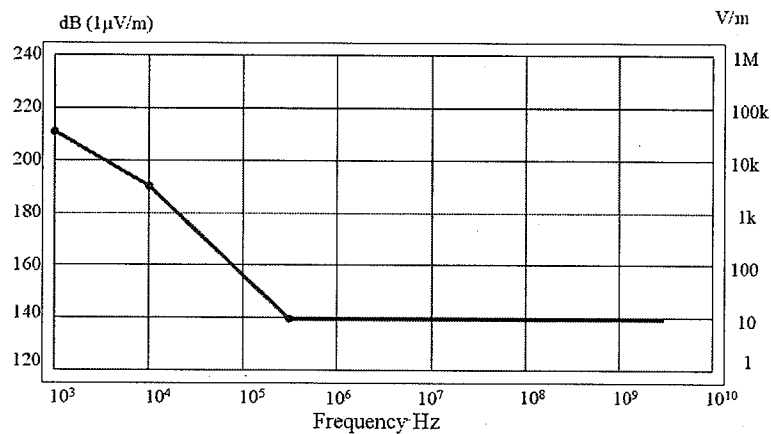


Figure Additional immunity requirements inside valve hall or converter enclosure, as applicable.

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.

Document number , revision 1JNL355425 , G	Page 8 (39)
Title General requirements for main circuit apparatus	

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

Document number , revision 1JNL355425 , G	Page 9 (39)
Title General requirements for main circuit apparatus	

6 Terminal boxes and control cabinets

6.1 Design

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

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

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

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

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

6.2 Equipment heaters

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

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

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

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

7 Motors

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

Document number , revision 1JNL355425 , G	Page 10 (39)
Title General requirements for main circuit apparatus	

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.

Document number, revision 1JNL355425, G	Page 11 (39)
Title General requirements for main circuit apparatus	

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,

Document number , revision 1JNL355425 , G	Page 12 (39)
Title General requirements for main circuit apparatus	

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,

Document number , revision 1JNL355425 , G	Page 13 (39)
Title General requirements for main circuit apparatus	

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

Document number, revision 1JNL355425, G	Page 14 (39)
Title General requirements for main circuit apparatus	

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.

- *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.

Document number, revision 1JNL355425, G	Page 16 (39)
Title General requirements for main circuit apparatus	

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.

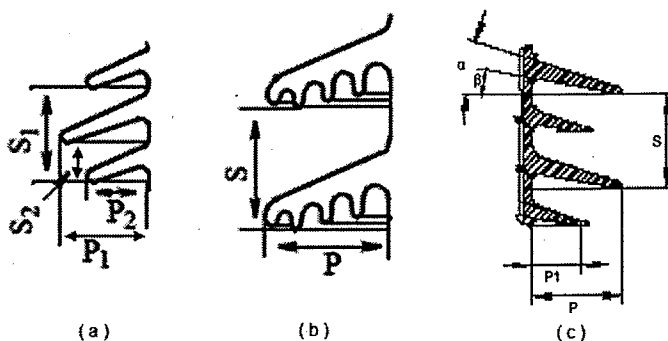


Figure Parameters of insulator sheds: (a) alternating profile of a porcelain insulator; (b) deep under-rib profile of a porcelain insulator; (c) alternating profile of a polymer insulator

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.

Document number, revision 1JNL355425, G	Page 17 (39)
Title General requirements for main circuit apparatus	

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 ($P_1 - P_2$) ≥ 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.

Document number , revision 1JNL355425 , G	Page 18 (39)
Title General requirements for main circuit apparatus	

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 |

Document number, revision 1JNL355425, G	Page 19 (39)
Title General requirements for main circuit apparatus	

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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> |

Document number , revision 1JNL355425 , G	Page 20 (39)
Title General requirements for main circuit apparatus	

[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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Document number , revision 1JNL355425 , G		Page 21 (39)
Title General requirements for main circuit apparatus		

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		

Document number , revision 1JNL355425 , G	Page 22 (39)
Title General requirements for main circuit apparatus	

16 Appendix 1

16.1 Qualification of HTM

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

5.6 Hydrophobicity test

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

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

5.6.1 Test specimens

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

- a. Contact Angle (CA) method: three flat-type specimens, each with area of (30~50) cm², thickness of (3~6)mm.
- b. Hydrophobicity Class (HC) method: five flat-type specimens, each with area of (50~100) cm².
- c. Surface cleaning prior to test: Use Ethanol absolute to clean the surface and then rinse the surface with deionized water (or distilled water). After dried, place the specimens in a dust-proof container and keep them under standard laboratory conditions for at least 24 hours.
- d. Specimen polluting and transference of hydrophobicity: after the specimens are pre-cleaned, spray the specimens with methods specified in B2.2 and B2.3 of Annex B, with salt density of 0.1mg/cm², ash density of 0.5mg/cm². After polluted, place the specimens in a dust-proof container under standard laboratory ambient conditions for transference of hydrophobicity over 4 days.

5.6.2 Method of hydrophobicity measurement

- a. Contact Angle (CA) method: This method has the purpose of revealing the hydrophobicity state on surface by directly measuring the static contact angle of [water] droplets on a solid surface. The contact angle (θ) may be measured with a CA meter, measuring microscope or photography. The volume of each droplet is about (4~7) μ l (i.e. each droplet weighs 4~7mg). For each specimen, the θ of five droplets will be measured (the average of the 15 measurements on the three specimens is denoted in θ_{av} , minimum denoted in θ_{min}).
- b. Hydrophobicity class (HC) method: This method has the purpose of revealing the hydrophobicity state on a solid surface so as to classify it into hydrophobicity classes. Seven classes of hydrophobicity (HC 1~ HC7) have

Document number, revision 1JNL355425, G	Page 23 (39)
Title General requirements for main circuit apparatus	

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° ~ 30° 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° ~ 70° . 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.

Document number, revision 1JNL355425, G	Page 24 (39)
Title General requirements for main circuit apparatus	

- 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.

Document number, revision 1JNL355425, G	Page 25 (39)
Title General requirements for main circuit apparatus	

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

Document number , revision 1JNL355425 , G	Page 26 (39)
Title General requirements for main circuit apparatus	

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 lamicaid. 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.

Document number , revision 1JNL355425 , G	Page 27 (39)
Title General requirements for main circuit apparatus	

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.

Document number, revision 1JNL355425, G	Page 28 (39)
Title General requirements for main circuit apparatus	

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

Document number , revision 1JNL355425 , G	Page 29 (39)
Title General requirements for main circuit apparatus	

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.*

Document number , revision 1JNL355425 , G	Page 30 (39)
Title General requirements for main circuit apparatus	

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.

Document number , revision 1JNL355425 , G	Page 31 (39)
Title General requirements for main circuit apparatus	

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

Document number, revision 1JNL355425, G	Page 32 (39)
Title General requirements for main circuit apparatus	

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.*

Document number , revision 1JNL355425 , G	Page 33 (39)
Title General requirements for main circuit apparatus	

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.

Document number , revision 1JNL355425 , G	Page 34 (39)
Title General requirements for main circuit apparatus	

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.

Document number , revision 1JNL355425 , G	Page 35 (39)
Title General requirements for main circuit apparatus	

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

Document number , revision 1JNL355425 , G	Page 36 (39)
Title General requirements for main circuit apparatus	

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.

Document number , revision 1JNL355425 , G	Page 37 (39)
Title General requirements for main circuit apparatus	

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.*

Document number , revision 1JNL355425 , G	Page 38 (39)
Title General requirements for main circuit apparatus	

- e) Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.*
- f) Bushings of identical rating shall be interchangeable.*
- g) No arching horns shall be provided on the bushings.*
- h) All ferrous parts shall be hot dip galvanized or zinc plated and passivated. All joints shall be air tight. Insulator/bushing design shall be such as to ensure a uniform compressive pressure on the joints.*
- i) Support insulators/bushings/hollow column insulators shall be designed to have ample insulation, mechanical strength and rigidity for the conditions under which they shall be used.*
- j) When operating at rated voltage there shall be no electric discharge between conductor and insulators which would cause damage to conductors or insulators by the formation of substances produced by chemical action. No radio interference shall be caused when operating at rated voltage.*
- k) The design of the insulator shall be such that stresses due to expansion and contraction in any part of the insulator shall not lead to deterioration.*
- l) The Bidder/Contractor shall define the type of insulator (type A or B) as per IEC-60168.*
- m) Bushing porcelain shall be robust and capable of withstanding the internal pressures likely to occur in service. The design and location of clamps and the shape and the strength of the porcelain flange securing the bushing to the tank shall be such that there is no risk of fracture. All portions of the assembled porcelain enclosures and supports other than gaskets, which may in any way be exposed to the atmosphere shall be composed of completely non hygroscopic material such as metal or glazed porcelain.*
- n) Special precaution shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection. The surface of all paper insulation shall be finished with non-hygroscopic varnish which can not be damaged easily.*

6.15.2.4 TESTS

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

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

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

- 1. Mechanical Bonding test at Jointed Section*

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

