



# **TECHNICAL SPECIFICATION**

## **FOR**

- 1) 125MVAR, 420kV Bus Shunt Reactors
- 2) 80MVAR, 420kV Line Shunt Reactors
- 3) 145kV Neutral Grounding Reactors

# TECHNICAL SPECIFICATION

## 1.0 SCOPE:-

- 1.1 This Specification provides for design, engineering, manufacture, assembly, stage inspection, final inspection and testing before despatch, packing and delivery at destination Sub-station by road transport, unloading at site and supervision of erection, testing and commissioning of 125MVAR, 420kV Bus Shunt Reactors / 80MVAR, 420kV Line Shunt Reactors with 145kV Neutral Grounding Reactors complete with all fittings, accessories, associated equipments and spares, required for its satisfactory operation in any of the sub-stations of OPTCL in the State of Odisha.
- 1.2 The scope of supply includes the provision of training for Purchaser's personnel in regard to principle, design, manufacture, assembly, testing, operation and maintenance of offered Reactors at his works in the event of order, free of cost to OPTCL.
- 1.3 The Reactors shall conform in all respects to high standards of engineering, design, workmanship and the latest revisions of relevant standards at the time of offer and Purchaser shall have the power to reject any work or material which, in his judgment, is not in full accordance therewith. The reactor(s), offered shall be complete with all components, necessary for their effective and trouble free operation. Such components shall be deemed to be within the scope of supply, irrespective of whether those are specifically brought out in this Specification and/or the commercial order or not.
- 1.4 This specification also covers following provisions for the reactor,
- a) Dehydrating Breather(s) as per clause no.5.5.1.7 (m)
  - b) Optic fiber temperature sensor as per clause no. 5.5.11 (j)
  - c) RIP Bushing as per Cl. No -5.5.14.1
  - d) Oil sampling bottles as per clause no. 5.5.24
  - e) Nitrogen Injection system for protection against Fire & Explosion as per clause no.5.5.25
  - f) On line insulating oil drying system as per clause no. 5.5.26
  - g) On line Dissolved Gas (Multi-gas) and Moisture Analyser as per clause no. 5.5.27
- 1.5 The reactor(s), to be supplied against this specification shall be suitable for satisfactory continuous operation under the following Topographical and Meteorological conditions:-
- |    |   |                 |
|----|---|-----------------|
| a) | Maximum ambient air temperature (°C) -      | 50              |
| b) | Minimum ambient air temperature (°C)-       | 0               |
| c) | Average daily ambient air temperature (°C)- | 32              |
| d) | Relative humidity (%) -                     | 100             |
| e) | Average rainfall per annum (cm)-            | 150             |
| f) | Maximum altitude above mean Sea level (m)-  | 1000            |
| g) | Maximum wind pressure (Kg/m <sup>2</sup> )- | 80.84           |
| h) | Isoceraunic level (days/year)-              | 70              |
| i) | Seismic withstand factor(g)                 | 0.3             |
| j) | Wind Velocity-(Wind Zone to IS875) (m/sec)  | 50              |
| k) | Pollution level to IEC815                   | Heavy           |
| l) | Air-borne contamination, if any             | Highly Polluted |

## 1.6 Transportation

- (i) The supplier shall be responsible to select and verify the route, mode of transportation and make all necessary arrangement with the appropriate authorities for the transportation of the Reactor. The dimensions of the equipment shall be such that when packed for transportation, it will comply with the requirements of loading and clearance restrictions for the selected route. It shall be the responsibility of the supplier to coordinate the arrangement for transportation of the Reactor for all the stages from the manufacturer's works to OPTCL's site.
- (ii) The supplier shall carry out the route survey along with the transporter and finalize the detail methodology for transportation of the equipment and based on route survey; any modification/ extension/ improvement to existing road, bridges, culverts etc. if required, shall be in the scope of the bidder.
- (iii) The main tank of the reactor shall be transported on Hydraulic trailers equipped with GPS system for tracking the location of Reactor at all times during transportation from manufacturer's works to the designated site. The supplier shall intimate to purchaser about the details of transporter engaged for transportation of the Reactor. The requisite details for tracking the Reactor during transit shall be provided to the purchaser. Requirement of Hydraulic trailer is envisaged for the reactor.
- (iv) All metal blanking plates and covers, which are specifically required to transport and storage of the reactors shall be considered part of the reactors and handed over to the Purchaser after completion of the erection. Bill of quantity of these items shall be included in the relevant drawings/documents.

**For details of Transportation, Packing & Forwarding, please refer clause no. 12 of Technical Specification.**

## 2.0 STANDARDS:-

- 2.1 The Bus reactors and associated equipment and accessories shall, except where modified by this Specification, be designed, manufactured and tested in accordance with the latest editions of the relevant International (IEC), Indian (IS) and British (BS) standards. In case of conflict, the order of precedence shall be (1) IEC, (2) IS, (3) Other. Reference to particular standard or recommendation in this Specification does not relieve the Supplier of the necessity of providing goods and services, complying with other relevant standards or recommendations.
- The list of standards, provided in this Specification is not to be considered exhaustive and the supplier shall ensure that equipment supplied under this contract meet the requirements of the relevant standard whether or not it is mentioned here.

IEC	IS	BS/other	Title
IEC: 60076-6			Reactors
IEC: 60076 (Part-1 to 5)			Power Transformers
-	-	6056	Methods of measurement of transformer and Reactor sound levels
-	-	4360	Weldable structural steel

-	-	61	Threads for light gauge copper tube and fittings
-	-	3600	Steel pipes and tubes for pressure purpose
-	-	4504	Flanges for pipes, valves and fittings
529	13947	EN60529	Enclosures for electrical apparatus (App.C-13947)
60137(1995)	2099	223	Bushings for alternating voltages above 1000V
223	-	4963	Tests on hollow insulators
60296(Amd1-1986)	335	BS-14	Specification for unused mineral insulating oil for Transformers and reactors
34	325	-	Three phase Induction Motors
185	2705	-	Current Transformers
518	-	-	Dimensional standardization of terminals for HV Equipment
-	3637	-	Gas operated relays
186	3156	-	Specification for voltage transformers
617	-	-	Graphical Symbols for drawings
-	2629	729	Galvanising
-	2633	-	Methods of testing uniformity for zinc coated articles
-	5	-	Colours for ready mixed paints and enamels
-	2147	-	Degree of protection provided by enclosures for Low voltage switchgears and control gears
-	3401/1992	-	Silicagel
-	9434	-	Guide for sampling and analysis of dissolved gas in oil filled equipment.
-	12676	-	Oil impregnated paper insulated Bushing Dimension and requirements.
60071, P-1-1993 P-2-1996	-	-	Insulation Co-ordination
-	375	-	Markings & Arrangements for switchgear Bus bars, Main connections and Auxiliary wiring
-	3638/1996	-	Application Guide for Gas operated Relays.
-	8269	-	Methods for switching Impulse Test on High Voltage Insulator
-	8263	-	Method for Radio Interference Tests on High Voltage Insulators.
-	3202	-	Code of practice for climate proofing of Electrical Equipment.
-	6702/1972	-	Method for determination of Electric strength of Insulating Oils.
-	6103/1971	-	Method of Test for specific Resistance of Elect. Insulating Liquids.
-	6262/1971	-	Method of Test for power factor and Dielectric Constant of Electrical Insulating Liquids.
-	6104/1971	-	Method of Test for Interfacial Tension of oil

60044, Amd P1-2000, P-6-1992	-	-	against water by the Ring Method. Instrument Transformers.
60060, P-1-1989, Amd P-2-1996	-	-	High Voltage Test Techniques.
60085 (1994)	-	-	Thermal Evaluation and classification of Elect. Insulation.
60270 (1981)	-	-	Partial Discharge Measurements.
60404-8-7 (1998)	-	-	Specification for Individual Materials-Cold Rolled Grain oriented Electrical Steel sheet and strip delivered in fully processed state
60529 (Amd 1-1999)	-	-	Degree of protection, provided by enclosures (IP-Code)
60551(Amd 1-1995)	-	-	Determination of Transformer and Reactor Sound Levels.
60567(1992) -	-	-	Guide for sampling Gases and oil from oil- filled Electrical equipment for the analysis of free and Dissolved Gases
60599(1999)	-	-	Mineral Oil-Impregnated Electrical Equipment in service-Guide to the Interpretation of Dissolved and Free Gases Analysis.
60722 (1982)	-	-	Guide to the Lightning and Switching Impulse Testing of Power Transformers and Reactors.
60815 (1986)	-	-	Guide for selection of Insulators in respect of polluted conditions.
60947, P-1-7 (1984-2000)	-	-	Low voltage switchgear & control gear.
-	-	IEEE Std 80	Guide for safety and AC Sub-station Grounding.
-	-	IEEE Std 979	Guide for Sub-station Fire protection.
-	-	IEEE Std 980	Guide for containment and control of oil spills in Sub-stations.
-	-	CBIP Pub.317/ 2013	Manual on Transformer & Reactor.
-	-	NFPA	National Fire Protection Association.
-	-	NEMA-- Standard No.1.	
-	-	Indian Electricity Rules-1956.	-

## 2.2 The standards, mentioned above are available from:

Standard:	Name and Address:
IS	Bureau of Indian Standards, Manak Bhawan, 9-Bahadur Sahah Zafar Marg, New Delhi - 110002, India.
IEC	International Electro Technical Commission,

3, rue de Verembe,  
P.O. Box -131,  
CH-1211, Geneva-20, SWITZERLAND.

- 2.3 Reactors meeting with requirements of other authoritative International Standards that ensure equal or better performance than the standards, mentioned above shall also be considered. When the reactor, offered by the supplier conforms to other standards, salient points of difference between standards adopted and the standards, specified in this specification shall be clearly brought out in the offer. Two copies of such standards with authentic translation in English shall be furnished by the successful bidder.

### 3.0 AUXILIARY POWER SUPPLY:-

Auxiliary electrical equipment shall be suitable for operation on the following supply system.

- |     |  |  |
|-----|--|--|
| (a) | Power devices like drive motors of Rating 1KW and above. | 415V, 3Phase, 4 Wire, 50 Hz, neutral Grounded AC supply. |
| (b) | Lighting, space heaters and KW Meters.                   | 240V, single phase, 50Hz, neutral Grounded AC supply.    |
| (c) | Alarm control and protective Devices.                    | 220V, DC, 2 Wire.  |

Each of the foregoing supplies shall be made available by the purchaser at the terminal point for each transformer for operation of accessories and auxiliary equipment. Supplier's scope includes supply of interconnecting cables, terminal boxes etc. The above supply voltage may vary as below and all devices shall be suitable for continuous operation over entire range of voltages.

- |      |              |   |
|------|--------------|---|
| (i)  | AC Supply: - | Voltage $\pm 10\%$<br>Frequency $\pm 3\%$ |
| (ii) | DC Supply: - | - 15% to + 10%                            |

### 4.0 PRINCIPAL PARAMETERS:-

#### A) For 125 MVAR & 80MVAR, 420kV Shunt Reactor

The Reactors shall conform to the following specific parameters:-

Sl. No.	Item.	Specification.
1	Type of Reactor/ Installation.	3 Phase shunt reactor(125 MVAR for Bus & 80 MVAR for Line) shall be of either gapped core type or magnetically shielded air core type (Shell type) construction, suitable for outdoor installation.
2	Rated Capacity at 420KV	125 MVAR / 80 MVAR
3	Type of Mounting.	On wheels, mounted on rails.
4	Service	Outdoor
5	Suitable for rated system frequency	50 Hz ( $\pm 3\%$ ).
5.a	Rated Voltage of reactor, $U_r$ (1 p.u)	420kV
5.b	Maximum continuous operating voltage ( $U_{max}$ )	1.05 $U_r$
5.c	Nominal system voltage	400kV
6	No. of Phases.	3 (Three)
7	No. of Windings / Phase	One.

8	Type of Cooling	ONAN	
9	Method of connection	Star with neutral brought out	
10	System Earthing	Effectively solidly earthed	
11	System fault level	63 kA	
12	Permissible current unbalance among Different phases	± 2%	
13	Harmonic content in phase current	The crest value of the 3 <sup>rd</sup> Harmonic component in phase current not to exceed 3% of the crest value of the fundamental when the reactor is energized at rated voltage with sinusoidal wave form.	
14	Ratio of Zero Sequence Reactance to Positive Reactance(X0/X1)	Between 0.9 to 1.0 (The bidder must clearly specify the exact figure)	
15	Tolerance on reactance at rated voltage & rated frequency	± 5%	
16	Range of constant Impedance	Up to 1.5 p.u. voltage (Bidder shall furnish the complete saturation characteristics of the reactor upto 2.5 p.u. voltage)	
17	Tolerance on current at rated voltage	0 to 5% of rated current	
18	Permissible Temperature Rise over ambient Temperature at Maximum continuous operating voltage (Umax). (Umax=1.05 Ur)		
a	Of top oil measured by thermometer & Optic Fiber Temperature Sensor	40° C (MAX.)	
b	Of winding measured by resistance Method	45° C (MAX.)	
c	Of winding hot spot measured by Optic Fiber Temperature Sensors	54° C (MAX.)	
19	Insulation level of winding	HV	Neutral
a	1.2/50 microsecond wave Shape Lightning Impulse Withstand Voltage(kVp)	1300	650
b	Switching Impulse Withstand Voltage (KVP)	1050	-
c	Power frequency withstand voltage (KV- rms).	570	275
d	Tan Delta value of windings	<0.005. (Tan delta shall be measured at ambient temperature. No temperature correction factor shall be applied)	
20	Bushings	HV	Neutral
a	Rated Voltage(kV)	420	145
b	Rated current(Min) in Amp	1250	1250
c	Type of bushing	RIP bushing	RIP bushing
d	Mounting	Tank Cover	
e	1.2/50 microsecond wave Shape Lightning Impulse Withstand	1425	650

	Voltage(kVp)				
f	Switching Impulse Withstand Voltage (KVP)	1050	-		
g	Power frequency withstand voltage (KV- rms).	695	305		
h	Minimum Total Creepage Distance(mm)	10500	3625		
i	Tan Delta value of bushings (Tan delta shall be measured at ambient temperature. No temperature correction factor shall be applied)	<0.004	<0.004		
j	Maximum partial discharge level at Um (pC)	10	10		
21	Maximum partial discharge level at 1.5 p.u.(pC) [as per IEC60076-3]	500			
22	Vibration level at rated voltage & frequency	Maximum:- $\leq 200$ Microns Peak to Peak, Average:- $\leq 60$ Microns Peak to Peak			
	Stress on tank wall	$\leq 2.0\text{Kg/Sq. mm}$ at any point on Tank			
23	Maximum Noise Level at rated voltage & Frequency(dB)	80			
24	Minimum clearances in air (mm)	Phase to phase		Phase to ground	
a	Winding(420kV)	4000		3500	
b	Neutral(145kV)	1600		1380	
25	Over voltage operating capability and duration	1.05 Ur for continuous operation. 1.25 Ur for 5 minutes. 1.50 Ur for 1 minute.			
26	Minimum Knee point voltage	150% of rated voltage			
27	Maximum Flux Density in any part of the core and yoke at rated MVA, rated voltage	1.3 Tesla			
28	Material of winding Conductor	Copper			
29	Maximum current density for windings at rated current	2.8 A/mm <sup>2</sup>			
30	Type of core construction (for gapped core design)	Radially laminated core packet			
31	Type of oil preservation	Air Cell type			
32	Polarization index i.e. ratio of IR values at 600 sec. to 60 sec.	Shall be greater than or equal to 2, as per Cl.No-7.2.13.4 IEEE Standard C57.152-2013.			
33	Maximum permissible losses at rated voltage, rated frequency and at 75° C (KW)	160 – for 125MVAr Reactor, 115 – for 80MVAr Reactor.			
34	Bushing Current Transformers	Core	Line Side	HV Neutral Side	Common Neutral side
a	Ratio	Core-1	400/1A	400/1A	400/1A
		Core-2	400/1A	Suitable for WTI	



				(To be decided during design review)	
		Core-3	400/1A	2000-1000-500/1A	
		Core-4	400/1A	2000-1000-500/1A	
b	Minimum knee point voltage / burden & accuracy class	Core-1	400V, TPS Class	400V, TPS Class	400V, TPS Class
		Core-2	400V, TPS Class	Suitable for WTI (To be decided during design review)	
		Core-3	400V, TPS Class	1000-500-250V, TPS Class	
		Core-4	10VA, Class-0.2	1000-500-250V, TPS Class	
c	Maximum CT Resistance & Excitation current	Core-1	1 ohm, $\leq 30\text{mA}$ at $V_k/2$	1 ohm, $\leq 30\text{mA}$ at $V_k/2$	1 ohm, $\leq 30\text{mA}$ at $V_k/2$
		Core-2	1 ohm, $\leq 30\text{mA}$ at $V_k/2$	-	
		Core-3	1 ohm, $\leq 30\text{mA}$ at $V_k/2$	10-5-2.5 Ohm, 8-15-30 at $V_k/2$	
		Core-4	-----	10-5-2.5 Ohm, 8-15-30 mA at $V_k/2$	
d	Application	Core-1	REF	REF	REF
		Core-2	Reactor Backup	Winding Temp. Indicator(On one phase only)	
		Core-3	Spare	Line Protection(Main-I)/T. Zone differential protection/Spare	
		Core-4	Metering	Line Protection(Main-II)/T. Zone differential protection/Spare	
e.	<b>NB:- The CT ratio &amp; other aspects of BCT shall be finalized during detail engineering.</b>				

#### **B) For 145kV Neutral grounding Reactor:-**

The neutral grounding reactors shall be used in Line Reactor between the neutral end of the Reactor and ground to limit the secondary arc current and the recovery voltage to a minimum value.

Following are the Technical particulars/ parameters envisaged for NGR:-

Clause No.	Description	Parameters
1	<b>Technical Parameters</b>	
1.1	Rated voltage from insulation	145
1.2	Connection	Between neutral of reactor and ground

1.3	Cooling System	Natural Oil Cooling(ONAN)	
1.4	Cooling medium	Insulating Oil	
1.5	Frequency	50Hz	
1.6	No. of Phases	01(Single)	
1.7	Service	Outdoor	
1.8	Type	Oil filled outdoor application	
1.9	Insulation	Graded	
1.10	Max. continuous current (rms)	10A	
1.11	Rated short time current (rms) (10secs.)	60A	
1.12	Rated impedance at rated short time and continuous current	As specified in section Project/to be decided during detail engineering	
1.13	Max. temperature rise over ambient temperature of 50°C at rated voltage		
i.	of top oil measured by thermometer	40°C	
ii.	of winding measured by resistance	45°C	
1.14	Insulation level for winding	Line Side	Ground Side
i.	Lightning Impulse withstand Voltage(kVp)	650	95
ii.	One Minute Power Frequency withstand Voltage(kVrms)	275	38
1.15	Bushings	Line Side	Ground Side
i.	Rated Voltage(kV)	145	24
ii.	Lightning Impulse withstand Voltage(kVp)	650	125
iii.	One Minute Power Frequency withstand Voltage(kVrms)- <b>Dry/Wet</b>	305 / 275	55 / 50
iv.	Type of bushing	RIP bushing	Porcelain
v.	Minimum Total Creepage Distance(mm)	3625	600
vi.	Tan Delta value of bushings (Tan delta shall be measured at ambient temperature. No temperature correction factor shall be applied)	<0.004	-
1.16	Method of grounding	Solidly connected between neutral of shunt reactor and earth.	
1.17	Whether neutral is to be brought out	Yes, through 24kV Porcelain bushing	
1.18	Minimum clearances in air (mm)	Phase to phase	Phase to ground
i.	Line side	1600	1380
ii.	Ground side	220	220
1.19	Bushing Current Transformers	Line side/Neutral side	
i.	Type	Ring type	
ii.	Ratio	200/1	
iii.	Accuracy Class	PS	
iv.	Burden	N/A	
v.	Min. Knee Point Voltage	200V	
vi.	Max. resistance of secondary winding	1.0 Ohms	
vii.	Max. Excitation current	30mA at V <sub>k</sub> /4	

viii.	Application	REF
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### **5.1 GENERAL TECHNICAL REQUIREMENTS:-**

- a) The shunt reactor shall be of either gapped core type or magnetically shielded air core type (shell type) construction.

In case of coreless construction following requirements are stipulated.

- i) A magnetic shield shall be provided around the coreless coils.
  - ii) Non-magnetic material sheet shall form the central core to minimize the vibrations.
- b) Shunt reactor shall be connected to the Bus of 400KV system for reactive load compensation and shall be capable of controlling the dynamic over voltage occurring in the system due to load rejection.
- c) Shunt Reactors of 420KV class shall be capable of operating continuously at a voltage 5% higher than the rated voltage without exceeding the winding hot spot temperature of 104°C. Maximum ambient temperature shall be considered as 50°C.
- d) The 420KV class reactor shall be designed to withstand the following over voltages repeatedly without risk of failure:
- 1.05 Ur for continuous operation.
  - 1.25 Ur for 5 minutes.
  - 1.50 Ur for 1 minute. (Where Ur= Rated voltage of shunt reactor=420KV)
- e) The hot spot temperatures and surface temperatures in the magnetic circuit (core) shall be calculated with maximum allowed 125°C and 120°C respectively under over voltage conditions specified above.
- f) Also, the most onerous temperature of any part of the core and its supporting structure in contact with insulation or non-metal material shall not exceed the safe operating temperature of that material. Adequate temperature margins shall be provided to maintain long life expectancy of these materials.
- g) Tank hot spot temperature under over voltage conditions specified above shall not exceed 130°C, considering maximum ambient temperature as 50°C.
- h) The reactors shall be designed for switching surge overvoltage of 2.5 p.u. and temporary overvoltage of the order of 2.3 p.u. for few cycles followed by power frequency overvoltage up to 1.5 p.u. The reactor must withstand the stress due to above transient dynamic conditions which may cause additional current flow as a result of changed saturation characteristics / slope beyond 1.5 p.u. voltage.
- i) The Reactor shall be so designed to have constant impedance up to 1.5 times rated voltage.
- j) The reactor shall perform satisfactorily under both the power frequency and switching surge over voltages, without causing any damage to the winding.
- k) The reactor shall be designed to avoid harmonic current generation under system over-voltage conditions and the risk of non-linear ferro-resonance of heavy inrush currents.
- l) Radio interference and Noise level:
- (i) The reactors shall be designed with particular attention to suppression of maximum harmonic voltage, especially the third and fifth so as to minimize interference with communication circuits.
  - (ii) The noise level of the reactor, when energized at rated voltage and frequency shall not exceed the values specified in Clause 4 (Principal Parameter) measured under the conditions, as defined in IEC.

### **5.2.0 REACTOR LOSSES:-**

**A) Maximum permissible losses at rated voltage, frequency & at 75°C:-**

**i) 125MVAR Reactor - 160KW.**

**ii) 80MVAR Reactor - 115KW.**

**B) Liquidated damage for excessive losses:-**

On testing, if it is found that actual losses are more than the above values but within the tolerance limit as per relevant IEC(latest version), an undisputed liquidated damages of **Rs.3,13,858.00/KW** shall be recovered from the supplier. For fractional Kilowatt, penalties shall be applied on prorata basis. No bonus shall be payable for losses, which are less than those, stated in the Bid.

The purchaser reserves the right to reject the transformer, if on testing, the losses exceed the declared losses beyond tolerance limits as per IEC.

- 5.3 In case of failure of the Reactor, the supplier shall take back the faulty Reactor from its plinth for repair at their own cost (or replace the Reactor with a new Reactor) and deliver, at their own cost, unload at the destination sub-station Reactor plinth within three months period from the date of intimation of defects to the satisfaction of the owner, at free of cost. If the delivery after repair/replacement will not be completed within three months, then the supplier shall pay penalty @ 0.5% of the contract price for each calendar week of delay from the end of three months period from the date of intimation of defects. Also, the Purchaser reserves the right for forfeiture of the total Composite Bank Guarantee and all the Securities, available with OPTCL, in case the Supplier fails to pay the penalty by one month before the expiry of the guarantee period. Also, this will be taken as adverse in all future tenders.

5.4 **CLEARANCE :-**

The overall dimensions of the reactor shall allow for sufficient clearances for installation in a 420/245/145 KV switchyard with bay width of 27000/18000/10500 mm and beam height of 22/15/11 m.

5.5 **CONSTRUCTIONAL DETAILS:**

The features and constructional details of shunt reactor shall be in accordance with the requirements stated hereunder. The components & fittings associated with the reactors are subject to Purchaser's approval.

5.5.1 **TANK AND TANK ACCESSORIES:**

5.5.1.1 **TANK:-**

- (a) The reactor shall be enclosed in a suitably stiffened welded / bolted steel tank such that the reactor can be lifted and transported without permanent deformation or oil leakage.  
The construction shall employ weldable, low carbon, tested quality structural steel of an approved grade to BS: 4360 / IS: 2062. The minimum thickness of side, base and tank cover shall be 20mm, 50mm and 20mm respectively.
- (b) The tank of the reactor shall be complete with all accessories and shall be designed so as to allow complete reactor in the tank and filled with oil, to be lifted by crane or jacks, transported by road or rail without over-straining any joint and without causing subsequent leakage of oil.
- (c) All seams and those joints, not required to be opened at site shall be factory-welded and wherever possible they shall be double welded. After completion of tank construction and before painting, dye penetration test shall be carried out on welded parts of jacking bosses, lifting lugs and all load bearing members. Also radiographic tests

- shall be carried out on 5% of total weld length. The requirement of post-weld heat treatment for tank/stress relieving parts shall be based on recommendations of BS: 5500, Table 4.4.3.1 / IS: 10801. Welding shall conform to BS-5135 / IS-9595.
- (d) All necessary precautions shall be taken to prevent ingress of moisture between flange plates, around gaskets and O-rings, at insulator/flange interfaces etc. due to high humidity.
  - (e) Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water.
  - (f) The tank shall be of proven design either bell type with bolted/welded joint or conventional type with welded/bolted cover. Bell type tank construction shall be provided with the joint at about 500 mm. above the bottom of the tank. In case the joint is welded, it shall be provided with flanges, suitable for repeated welding. The joint shall be provided with a suitable gasket to prevent weld splatter inside the tank. Proper tank shielding shall be done to prevent excessive temperature rise at the joint.
  - (g) The main tank body excluding radiators shall be capable of withstanding vacuums i.e. 100.64 KN/m<sup>2</sup> of gauge pressure, 760 mm of Hg.
  - (h) The tank shall be designed to withstand:-
    - (i) Mechanical shocks during transportation.
    - (ii) Vacuum filling of oil.
    - (iii) Continuous internal pressure of 35 KN/m<sup>2</sup> over normal hydrostatic pressure of oil.
  - (I) Wherever possible, the reactor tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipe. The vent pipes shall have minimum inside diameter of 15 mm except for short branch pipes, which may be 6 mm minimum inside diameter.
  - (j) All joints other than those, which may have to be broken, shall be welded, when required, they shall be double-welded. All bolted joints to the tank shall be fitted with suitable oil-tight gaskets, which shall give a satisfactory service under the operating conditions and guaranteed temperature-rise conditions. Special attention shall be given to the methods of making hot oil tight joints between the tank and the cover as also between the cover and the bushing and all other outlets to ensure that the joints can be remade satisfactorily at site and with ease with the help of semi-skilled labour. If gasket is compressible, metallic stops shall be provided to prevent over compression.
  - (k) Adequate space shall be provided at the bottom of the tank for collection of sediments.
  - (l) The base of each tank shall be so designed that it shall be possible to move the complete reactor unit by skidding in any direction without injury when using plates or rails.
  - (m) Tank shields shall be such that no magnetic fields shall exist outside the tank. They shall be of magnetically permeable material. If required, impermeable shields shall be provided at the coil ends. Tank shield shall not resonate when excited at the natural frequency of the reactor.
  - (n) Suitable guides shall be provided in the tank for positioning the core and coil assembly.
  - (o) The tank shall be designed such that it can be mounted on the plinth directly.
  - (p) When the reactors are provided with separately mounted radiators, flexible joints shall be provided in the main oil pipes, connecting the reactor tank to the radiator banks to reduce vibration and facilitate erection and dismantling.
  - (q) The reactor tank, fittings, radiators and all accessories shall be designed to withstand seismic acceleration, as specified.

- (r) All connections, bolted to the tank shall be fitted with suitable gas oil resistant gaskets, made of such a material that no serious deterioration occurs under service conditions. Gaskets of nitrile rubber or equivalent shall be used to ensure perfect oil tightness. All gaskets shall be of closed design (without open ends) and shall be of one piece only. Rubber gaskets, used for flange connections of the various oil compartments shall be laid in grooves or in groove-equivalent retainers on both sides of the gaskets throughout their total length. Care shall be taken to secure uniformly distributed mechanical pressure over the gaskets and retainers throughout the total length. Gaskets of neoprene and/or any kind of impregnated/ bonded cork or cork only which can easily be damaged by over-pressing are not acceptable. Use of hemp as gasket material is also not acceptable.
- The properties of the gaskets / O-ring shall comply with the requirements of IS-11149. The gaskets to be used shall not be older than one year. Gaskets / O-rings shall be replaced every time whenever the joints are opened.
- (s) **Tank hotspot-** under extreme conditions, the maximum temperature on any metal part shall not exceed 130°C.

#### 5.5.1.2 **LIFTING AND HAULAGE FACILITIES:-**

Tank shall be provided with:

- (a) Lifting lugs: Four symmetrically placed lifting lugs shall be provided so that it will be possible to lift the complete reactor when filled with oil without structural damage to any part of the reactor. The factor of safety at any one point shall not be less than 2.
- (b) A minimum of four jacking pads in accessible position to enable the reactor complete with oil to be raised or lowered using hydraulic jacks.
- (c) Each jacking pad shall be designed to support with an adequate factor of safety at least half of the total mass of the reactor filled with oil allowing in addition for maximum possible misalignment of the jacking force to the centre of the working surface.
- (d) Suitable haulage holes shall be provided.
- (e) 04 nos. of Gate valves for UHF sensors for PD Measurements at various locations. Location of valves shall be finalized during design review.
- (f) Suitable provisions of pockets for OTI, WTI & RTDs including two spare pockets.

#### 5.5.1.3 **FOUNDATIONS, CABLE DUCTING ETC.:-**

The Supplier will have to liaise with the Purchaser or its authorised contractor immediately after Design approval to finalize the detailed design of the following:-

- Reactor main tank foundations.
- Cooler bank foundations.
- Marshalling kiosk/control cabinet location and foundation.
- Cable ducting requirements.
- Adequate bunding design for the complete containment of all oil spills.
- Any other civil/electrical requirements for the installation of the reactor.

#### 5.5.1.4 **TANK COVER:**

- (a) The tank cover shall be of adequate strength, shall not distort when lifted and shall be provided with suitable flanges having sufficient and properly spaced bolts. At least two adequately sized inspection openings, one at each end of the tank shall be provided for easy access to the internal connections of bushings, winding connections and earthing links. The inspection covers shall not weigh more than 25 Kg. The inspection cover shall

- be provided with lifting handles.
- (b) The tank and cover shall be designed in such a manner so as to leave no external pockets in which water can lodge, no internal pockets in which oil can remain when draining the tank or in which air can be trapped when filling the tank, and to provide easy access to all external surfaces for painting. The design of the tank cover should not present a safety hazard to personnel working on top of the unit.
  - (c) It must be possible to remove any bushing without removing the tank cover.
  - (d) One pocket shall be provided for stem type thermometer in addition to those for the Bulbs of the oil temperature and winding temperature indicators. These pockets shall be located in the position of the maximum oil temperature and it must be possible to remove any bulb of OTI/WTI/RTD without lowering the oil level in the tank. Captive screwed caps shall be provided to prevent the ingress of water to the thermometer pockets when they are not in use. *The tank wall penetrations shall be leak proof, suitably marked with respective sensor identification.*
  - (e) Bushings, turrets, covers of inspection opening, thermometer pockets etc. shall be designed to prevent ingress of water into or leakage of oil from the tank.
  - (f) All bolted connections shall be fitted with weather proof, hot oil resistant, resilient gasket in between for complete oil tightness. If gasket is compressible, metallic stops shall be provided to prevent over-compression.
  - (g) The tank cover shall be so designed to prevent retention of rain water and shall not distort when lifted. The internal surface of the top cover shall be shaped to ensure efficient collection and direction of free gas to the buchholz relay.
  - (h) The tank cover and all covers for mounting, cleaning, man-holes, hand holes and inspection openings on tank etc. shall be earthed by suitable grounding conductors of the flexible type, having a cross-section of minimum 95 mm<sup>2</sup>. Appropriate earthing studs with bolts and washers, made of stainless steel shall be provided.
  - (i) **Currents flowing in tank cover and bushing turrets** - To allow for the effect of possible induced and capacitive surge current, the tank cover and bushing turret shall be fixed to the reactor in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.
  - (j) The Reactor shall be provided with a 100mm nominal diameter butterfly valve and bolted blanking plate, gasket and shall be fitted at the highest point of the reactor for maintaining vacuum in the tank.
  - (k) **Gas Venting:** - The reactor cover, and generally the internal spaces of the reactor and all pipe connections shall be designed so as to provide efficient venting of any gas in any part of the reactor to the buchholz relay. The space created under inspection / manhole covers shall be filled with suitable material to avoid inadvertent gas pockets. The covers shall be vented at least at both longitudinal ends. The design of gas venting shall take into accounts the slopes of the plinth (if any) on which the reactor is being mounted.

#### 5.5.1.5 **AXLES AND WHEELS:**

- (a) The reactor shall be placed directly on concrete plinth foundation. To facilitate the movement of reactor to its foundation over rail track, the reactor shall be designed with flanged bi-directional wheels and axles of a suitable size to carry the full weight of the reactor, oil and accessories. These shall be so designed as not to deflect excessively to interfere with the movement of the reactor. Wheels, axles and bearings shall be fully corrosion - resistant and complete with fittings to facilitate lubrication.
- (b) Suitable locking arrangement along with foundation bolts shall be provided for the wheels to prevent accidental movement of the reactor.

- (c) The wheels are required to swivel and they shall be arranged so that they can be turned through an angle of 90 degrees when the tank is jacked up to clear of rails. Means shall be provided for locking the swivel movements in positions parallel to and at right angles to the longitudinal axis of the tank.
- (d) The rail track gauge shall be 5'6" (1676 mm) along longer axis as well as along shorter axis.
- (e) Foundation layout details will be furnished by the supplier during detailed Engineering.

#### 5.5.1.6. **ANTI-EARTHQUAKE CLAMPING DEVICE :-**

To prevent reactor movement during earthquake, clamping device shall be provided for fixing the reactor to the foundation. The Bidder shall supply necessary bolts for embedding in the concrete foundation. The arrangements shall be such that the reactor can be fixed to or unfastened from these bolts, as desired. The fixing of the reactor to the foundation shall be designed to withstand seismic events to the extent that a static co-efficient of 0.3g, applied in the direction of least resistance to that loading, will not cause the reactor or clamping devices as well as bolts to be over-stressed. Special steps must be taken to prevent mal-operation of Buchholz relay in such conditions.

The details of the device used and its adequacy, suitability and design calculations to withstand seismic load shall be brought out in the additional information schedule.

#### 5.5.1.7 **CONSERVATOR VESSELS, OIL GAUGES AND BREATHERS:-**

- (a) The conservator shall have air cell type constant oil pressure system to prevent oxidation and contamination of oil due to contact with moisture. Conservator, complete with sump and drain valve shall be provided in such a position, so as not to obstruct the electrical connections to the reactor having a capacity between highest and lowest visible levels of 7½% of the total cold oil volume in the Reactor and the cooling equipment from minimum ambient temperature to 110 Degree C. The capacity of the conservator tank shall be such that the reactor shall be able to carry the specified over load without overflowing of oil. The minimum indicated oil level shall be with the feed pipe from the main tank covered with not less than 15 mm depth of oil and the indicated range of oil level shall be minimum to maximum.
- (b) If the sump is formed by extending the feeding pipe inside the conservator vessel, this extension shall be for at least 25 mm. The conservator shall be designed so that it can be completely drained by means of the drain valve provided, when mounted as in service.
- (c) The conservator tank shall be bolted on to its support of mounting to allow for its removal for cleaning/repair. It shall be bolted onto the main tank to allow for its removal for cleaning/repair. The conservator shall be fitted with lifting lugs in such a position so that it can be removed for cleaning purposes. Suitable provision shall be kept to replace air cell and cleaning of the conservator as applicable.
- (d) Conservator shall be fitted with magnetic oil level gauge with potential free high and low oil level alarm contacts and prismatic oil level gauge. The indicator shall have the minimum and maximum levels, indicated along with the normal level at an oil temperature of 25° C. The temperature markings shall preferably be integral with the level-indicating device. The gauge should be readable from the reactor base level. Sight glasses of oil level indicators shall be of laminated security glass. Sight glasses of transparent plastics will not be accepted.
- (e) Taps or valves shall not be fitted to oil gauge.
- (f) The oil connection from the reactor tank to the conservator vessel shall be arranged at a



rising angle of 3 to 9 degrees to the horizontal up to the Buchholz Relay and shall consist of 80 mm inside diameter pipes as per IS: 3639.

- (g) A valve shall be provided at the conservator to cut off the oil supply to the reactor, after providing a straight run of pipe for at least a length of five times the internal diameter of the pipe on the tank side of the gas and oil-actuated relay and at least three times the internal diameter of the pipe on the conservator side of the gas and oil-actuated relay.
- (h) The conservator tank shall be equipped with a nitrile rubber diaphragm or bag reinforced with nylon cloth & filled with dry air, which isolates the reactor oil space from the ambient air. The bag shall work satisfactorily and without damage at all anticipated oil temperatures.
- (i) Provision shall be made for monitoring the integrity of rubber bag and giving an electrical alarm when the bag is damaged.
- (j) The connection of air cell to the top of the conservator is by air proof seal preventing entrance of air into the conservator. The main conservator tank shall be stenciled on its underside with the words **"Caution: Air cell fitted"**. Lettering of at least 150 mm size shall be used in such a way to ensure clear legibility from ground level when the reactor is fully installed. To prevent oil filling into the air cell, the oil filling aperture shall be clearly marked. The reactor rating and diagram plate shall bear a warning statement that the **"Main conservator is fitted with an air cell"**.
- (k) The conservator tank and piping shall be designed for complete vacuum / filling of the main tank and conservator tank. Provision must be made for equalising the pressure in the conservator tank and the air cell during vacuum / filling operations to prevent rupturing of the air cell.
- (L) The reactor manual shall give full and clear instructions on the operation, maintenance, testing and replacement of the air cell. It shall also indicate shelf life, life expectancy in operation, and the recommended replacement intervals.
- (m) Dehydrating Silicagel Filter Breather**  
Conservator shall be fitted with a dehydrating silicagel filter breather. Connection shall be made to a point in the oil conservator not less than 50 mm above the maximum working oil level by means of a pipe with a minimum diameter of 25 mm. Breather & Connecting pipes shall be securely clamped and supported to the reactor or other structure supplied by the supplier, in such a manner so as to eliminate undesirable vibration and noise. No valve is to be placed between breather & conservator. Minimum quantity of silica gel will be 1Kg for every 3500 Litres of oil in the tank.

The design shall be such that:

- a) Passage of air is through silicagel.
- b) Silicagel is isolated from atmosphere by an oil seal.
- c) Moisture absorption indicated by a change in colour of the crystals.
- d) Breather is mounted approximately 1200 mm above rail top level.
- e) To minimise the ingress of moisture three breathers (of identical size) shall be connected in series for main tank conservator. Supplier shall provide flexible connection pipes to be used during replacement of any silicagel breather.

#### 5.5.1.8 PIPING WORKS FOR CONSERVATOR

- (a) Pipe work connections shall be of adequate size preferably short and direct. Only radiused elbows shall be used.
- (b) The feed pipe to the reactor tank shall enter the reactor cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the reactor side of the Buchholz relay, and straight for not less than three times that diameter

on the conservator side of the relay. This pipe shall rise towards the oil conservator, through the Buchholz relay, at an angle of not less than 5 degrees. The feed pipe diameter for the main conservator shall be not less than 80mm. Gas-venting pipes shall be connected to the final rising pipe between the reactor and Buchholz relay as near as possible in an axial direction and preferably not less than five times pipe diameters from the Buchholz relay.

- (c) A double flange valve of preferably 50 mm shall be provided to fully drain the oil from the main tank conservator.
- (d) Pipe work shall neither obstruct the removal of opening of inspection or manhole covers.

## **5.5.2 VALVES AND LOCATION: -**

### **5.5.2.1 General: -**

- (a) Blank flanges, plates or captive screw caps shall be fitted to all valves and pipe ends, not normally connected in service.
- (b) The omission of any, or the provision of alternative arrangements to the listed requirements, which alter the functional nature of the valve system, will not be accepted.
- (c) All valves up to and including 100 mm shall be of Gun Metal. Larger valves may be of Gun Metal or may have cast iron bodies with Gun Metal fittings. They shall be of the full way type with internal screw and shall be opened by turning counter clockwise when facing the hand wheel. Suitable means shall be provided for locking the valves in the open and close positions. Provision is not required for locking individual radiator valves.
- (d) Means shall be provided for padlocking the valves in the open and closed positions. Provision is not required for locking individual radiator valves.
- (e) Each valve shall be provided with an indicator to show clearly the position of the valve.
- (f) All valves shall be provided with flanges having machined faces.
- (g) All valves shall be suitable for continuous operation with reactor oil at 100° C.
- (h) Oil sampling valves shall have provision to fix rubber hose of 10 mm size to facilitate oil sampling.
- (i) Each reactor shall be fitted with the valves, identified in the following Sub-sections as a minimum requirement.
- (j) Inside surface of all cast iron valves coming in contact with oil shall be applied with one coat of oil resisting/varnish with two coats of red oxide zinc chromate primer followed by two coats of fully glossy finishing paint conforming to IS: 2932. Outside surface except gasket setting surface of butterfly valves shall be painted with two coats of red oxide zinc chromate conforming to IS: 2074 followed by two coats of fully glossy finishing paint.
- (k) All valves shall be painted with a shade (preferably red or yellow), distinct and different from the main tank surface and as per the painting system & procedure specified.
- (l) All hardware used shall be hot dip galvanized / stainless steel.

### **5.5.2.2 MAIN TANK:-**

- (a) One filter valve located near to the top of the tank.
- (b) One filter valve located near to the bottom of the tank and diagonally opposite to the filter valve required against(a). Where design permits, this valve may be combined with item (c).
- (c) One drain valve with such arrangements as may be necessary inside the tank to ensure that the tank can be completely drained off oil as far as practicable. This valve shall also be provided with an approved oil sampling device.
- (d) Two oil valves for taking oil samples from the top and bottom of the tank. The top-oil sampling point shall be brought down to be accessible from ground level.
- (e) A flanged valve suitably positioned near the top of the main tank for the connection by the

Purchaser of a 'Hydran' monitor.

- (f) A flange for the vacuum control switch tank will be provided on the tank cover.

#### 5.5.2.3 **CONSERVATOR:-**

- (a) One valve between the conservator and gas actuated relay for the reactor tank.
- (b) One drain valve for oil conservator tank so arranged that the tank can be completely drained of all oil. It shall also be fitted with an oil-filling hole with cap.
- (c) **Flow sensitive conservator Isolation valve**
  - i) In order to restrict the supply of oil in case of a fire in Reactor, flow sensitive valve shall be provided to isolate the conservator oil from the main tank.
  - ii) A valve which shall be flow sensitive and shut off when the flow in the pipe is more than the flow expected in the permissible normal operating conditions. This valve shall be located in the piping between the conservator and the buchholz relay and shall not affect the flow of oil from and to the conservator in normal conditions.
  - iii) When the flow from conservator to main tank is more than the normal operating conditions, the valve shall shut off by itself and will have to be reset manually. It shall be provided with valve open/close position indicator along with alarm contact indication in control room during closing operation of valve. This valve shall be provided with locking arrangement for normal position and oil filling / filtration position. A suitable platform or ladder (if required) shall be provided to approach the valve for manual reset.

#### 5.5.2.4 **RADIATORS AND COOLER BANKS:-**

Valves of adequate size as per 'CBIP Manual on Reactors (Publication No. 317:2013)' at each point of connection to the tank shall be provided.

5.5.2.5 **Air release plug(s):-** of adequate size shall be provided.

**N.B.: However, type, size, additional locations if required shall be finalized during detailed engineering & design review, which shall be provided at no extra cost to OPTCL.**

#### 5.5.3 **JOINTS AND GASKETS:-**

- (a) All joint faces shall be arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.
- (b) Nitrile base cork or equivalent shall be used for gaskets. Oil resistant synthetic rubber gaskets are not permissible except where the synthetic rubber is used as a bonding medium for cork or similar material or where metal inserts are provided to limit compression.
- (c) Gaskets shall be consistent with the provision of a good seal and full details of all gaskets sealing arrangement shall be shown on the drawings.

#### 5.5.4(A) **PRESSURE RELIEF DEVICE:-**

- a) Adequate number of pressure relief devices (at least 2 numbers) shall be provided at suitable locations preferably close to bushing turret/ cover. These shall have opening diameter of at least 100 mm for rapid release of any pressure that may be generated in the tank and which may result in damage to equipment. The device shall maintain its oil tightness under static oil pressure equal to the static operating head of oil plus 20kPa. The device shall operate & attain its full opening in not more than 2.5ms, when subject to an internal pressure impulse equal to static operating head of oil plus 50kPa. It shall be

capable of withstanding full internal vacuum at mean Sea level. It shall be mounted directly on the tank. It shall automatically reset when pressure falls below this value. There will be no leakage of oil after resetting of PRD. Means shall be provided to prevent the ingress of rain or dust. Pressure relief devices of the type mounted below normal oil level shall be of the resetting type once the dangerous pressure has been reduced to prevent unnecessary release of oil.

- b) Contacts shall be provided for alarm and trip and initiation on operation of the device. Baffles shall be provided when necessary to safely control the direction in which oil or gas is ejected.
- c) Unless otherwise approved, the relief device shall be mounted on the main tank and if on the cover, shall be fitted with a skirt projecting 25 mm. inside the tank to prevent gas accumulation.
- d) Loss of oil on operation of the relief device shall be contained within the reactor oil retaining area.
- e) The bidders shall furnish constructional, design details of pressure relief device(s) and calculations along with the bids to prove that the size and setting of pressure relief device(s) is adequate, considering the rating of the reactor, the quantity of oil in the Reactor and the insulating oil will not catch fire in case of any short/ground fault inside the reactor.
- f) The terminal box/boxes of PRD should conform to degree of protection as per IP-55 of IEC- 60529.
- g) One set of potential free contacts per device shall be provided for alarm/tripping. Following routine tests shall be conducted on PRD:
  - i) Air pressure test
  - ii) Liquid pressure test
  - iii) Leakage test
  - iv) Contact operation test
  - v) Dielectric test on contact terminals

#### 5.5.4(B) **SUDDEN PRESSURE RELAY:-**

Adequate number of Sudden Pressure relay with alarm/trip contacts shall be provided on tank of reactor. Operating features, size and quantity shall be reviewed during design review. Pressurized water ingress test for Terminal Box (routine tests) shall be conducted on Sudden Pressure Relay.

#### 5.5.5 **EARTHING TERMINALS:**

(i) Two (2) earthing pads (each complete with two (2) nos. holes, M16 bolts, plain and spring washers) suitable for connection to 75 x 12 mm galvanized steel grounding flat shall be provided each at position close to earth of the two (2) diagonally opposite bottom corners of the tank.

(ii) Two earthing terminals suitable for connection to 75 x 12 mm galvanized steel flat shall also be provided on each cooler, individual/common marshalling box and any other equipment mounted separately. For the tank-mounted equipment like online drying/ Online DGA/ Optical Sensor Box etc. double earthing shall be provided through the tank for which provision shall be made through tank and connected through two flexible insulated copper link.

(iii) To allow for the effect of possible induced and capacitive surge current, good electrical connection is maintained between the tank and turrets. Equipotential flexible copper link of suitable size at least 4 Nos. for Tank mounted turret with tank and tank with cover and or Bell shall be provided. For other components like - pipes, conservator support etc connected to tank shall also be provided with equipotential flexible copper link.

(iv) Each reactor unit should have provision for earthing suitable for connection to grounding mat when Reactor is out of service for longer duration. For this purpose, neutral shall have provision for connection to ground by a brass/tinned copper grounding bar supported from the tank by using porcelain insulator. The end of the tinned/brass copper bar shall be brought to the bottom of the tank at a convenient point for making bolted connection to 75 X 12 mm GS flat connected to station grounding mat. The other end of the tinned/brass copper bar shall be connected to the neutral bushing through flexible conductor/jumper. The Reactor terminal shall also be earthed through neutral by flexible copper connection. The supplier shall provide suitable arrangement for the above.

#### **5.5.6 CORROSION PROTECTION:**

##### **5.5.6.1 General:**

- (a) Bidders shall state clearly the corrosion protection, applied to aluminum and aluminum-alloy parts.
- (b) Bidders shall draw attention to all exposed points in their equipment at which aluminum or aluminum- alloy parts are in contact with or in close proximity to other metals and shall state clearly the protection employed at each point to exclude air and moisture.
- (c) A full description of the corrosion prevention system, proposed by the Bidder shall be given and this is subject to acceptance by the purchaser. This description shall include details of surface preparation, rust inhibition, and paint thickness, treatment of fasteners and painting of surfaces in contact with oil.

5.5.6.2 The minimum standards acceptable to the purchaser are:-

##### **(a) Hot Rolled Steel:**

- (i) Grit blasting to grade sa 2.5 of ISO 8501-1.
- (ii) Epoxy-base zinc primer. Coating thickness 25 micrometer.
- (iii) Zinc spraying of tank bottom. Thickness 100 micrometer.
- (iv) Epoxy-based micaceous iron-oxide paint. Coating thickness 40 micrometer.
- (v) Alkyd or phenolic-based micaceous iron-oxide paint. Coating thickness-40 micrometer.

##### **(b) Radiators and Fasteners larger than 12 mm:-**

- (i) Hot dip galvanized to IS: 2633.
- (ii) Cleaning and surface preparation followed by paint treatment as specified above.

##### **(c) Smaller fasteners, cable clips:-**

Use of non-ferrous material, stainless steel or appropriate plated components.

#### **5.5.7 RATING, DIAGRAM AND VALVE PLATES:-**

The following plates or an approved combined plate shall be fixed to each reactor Tank at an average height of 1500 mm above the ground level:-

- (a) A rating plate bearing the data, specified in IEC 76 Part - 6. This plate shall also include: -
  - (i) losses at rated voltage & frequency & at rated output at 75°C
  - (ii) Winding resistance of each winding at 75° C.
- (b) A diagram plate showing in an approved manner, the internal connections in accordance with IEC 76 Part-I giving the correct physical relationship of the terminals.
- (c) A plate showing the location and function of all valves and air-release cocks or plugs.

This plate shall also if necessary warn operators to refer to the Maintenance Instructions before applying vacuum.

- (d) Current reactor's Rating Plate.
- (e) Diagram plate, indicating the oil levels in the conservators dependent on the oil temperature.
- (f) Loading plan plate, showing transport dimensions and masses. This plate shall also warn the erection staff not to remove any cover, before filling the tank with oil to such a level where the windings are not exposed to the atmosphere. This shall be fixed directly on to the reactor tank and shall not be removed for transport.
- (g) Identification plates, alpha-numerical number in an approved manner, for all fans, marshaling cabinets, breathers, valves, cocks, accessories etc. (minimum size: 110mm x 50mm) rigidly fastened by rivets on corrosion proof base plates. In addition, the function (description) of the related devices shall be clearly indicated on these plates. The alphanumerical numbers on the identification plates shall be of such a size as to be clearly legible from the floor level.
- (h) Plates, showing all control, measuring and monitoring circuits and terminal blocks. These plates shall be rigidly fixed at the inner side of the hinged door of the concerned marshaling kiosk.

Outdoor arranged plates are to be of polished stainless steel of top quality only (back ground clear, engraving black, depth of engraving 0.5mm) stainless steel, capable of withstanding the rigours of continuous outdoor service at site. Plates, arranged inside control and marshaling cubicles may be of material in accordance with manufacturer's standard, e.g. glass -fibre reinforced synthetic resin (subject for approval). All plates other than those located on tank cover shall be easily and clearly legible from ground level.

#### 5.5.8. **CORE: -**

- a) The leg magnetic packets (cheeses) shall be made from state of the art low loss electrical steel CRGO (HIB grade or better). The "Cheeses" shall be designed to minimize losses and equalize the distribution of flux in the legs and shall be of 'Radially laminated core packet design'
- b) High degree of dimensional accuracy is required, while manufacturing the core to obtain reactance and phase currents within permissible limits.
- c) The "cheeses" shall be bonded using high temperature epoxy resins to assure that they will remain bonded in service at the maximum temperatures that will occur in the magnetic circuit and for the full expected life. Vacuum impregnation is preferred. The supplier shall present data on the characteristics of the packets at the time of design review.
- d) Material with high temperature withstand capability and with high modulus of elasticity such as ceramic/ slate spacers shall be used to separate the core packets. High temperature, mechanically stable material shall be used between the end packets and the top and bottom yokes. Special care shall be taken not to impede the cooling in these areas.
- e) Means shall be provided to distribute the flux from the "cheeses" and the windings to the top and bottom yokes to prevent concentrations of flux with resulting high temperatures in the yokes.
- f) The yokes shall be designed such that high temperatures resulting from unequal distribution of the flux in the yokes will not occur.
- g) The spaces between "cheeses" will be designed so that high temperatures will not result due to fringing of flux at the oil gaps between them. The designer shall calculate the temperatures resulting from fringing.

- h) The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths within itself or to the earthed clamping structure and production of flux component at right angles to the plane of laminations which may cause local heating.
- i) The fundamental mechanical resonance mode of the reactor frame must be designed to fall away from twice the power frequency.
- j) Anti-vibration pads are used between active part and tank bottom.
- k) **Minimum knee point voltage is 150% of rated voltage. Accordingly, the operating flux density for design should be carefully chosen within the stipulated value to achieve the above minimum knee point voltage. The tenderer shall quote the practical achievable no load current at different percentages of rated voltage as per Guaranteed Technical Particulars along with a linear graph confirming the above said knee point voltage which will be verified during testing and determination of the same as per clause No. 3.2.7 of IEC-60076-6 of IEC-2007.**
- l) The tenderer will offer the core for inspection and approval by the Purchaser during manufacturing stage. Tenderer's notice for this purpose shall be accompanied with the following documents towards use of prime core.
  - (i) Invoice of the supplier.
  - (ii) Mill's test certificates.
  - (iii) Packing list.
  - (iv) Bill of lading.
  - (v) Bill of entry certificates by customs.
- m) Core material shall be directly procured either from the manufacturer or through their accredited marketing organizations of repute and not through any agent. All the core import documents must be in the name of the reactor manufacturer / the accredited marketing organization.
- n) The bidder should preferably have in-house core-cutting facility for proper monitoring and control on quality and also to avoid any possibility of mixing of prime material with defective/ second grade material. However, the core-cutting operation may be witnessed by OPTCL's representatives at the works of the manufacturer and specific loss, other tests will be conducted on samples of core materials, selected at random by OPTCL's representative. The following procedure is to be adopted for those manufacturers who have no in-house core-cutting facility:
  - (1) In the offer, against tender for reactors, the bidder should mention names of at least three manufacturers of Reactor core material who have at least 5 (five) years experience in manufacturing of Reactor grade core. The Reactor manufacturer (RM) can purchase the core from such manufacturer(s) for which approval will be accorded by OPTCL.
  - (2) The bidder should specify the grade, thickness of core material in the offer along with submission of all graphs/ documents, relating to the grade of core material, offered by them.
  - (3) The documents, as mentioned against Sl. 'i' should be submitted to OPTCL, once the core materials are landed in any of the Indian ports and same should be offered to OPTCL for inspection. The representative, deputed by OPTCL for such inspection will record the following information:-
    - a) Purchase order No. & Date.
    - b) No. of packed coils with package Nos.
    - c) Gross weight.
    - d) Net weight
    - e) Port of loading.

- f) Port of discharge.
  - g) Name of the ocean vessel.
  - h) Grade and thickness of core material.
  - i) Any other information, as mentioned on the body of packed coils.
- (4) The bidder in its offer will mention the names of at least three Sub-vendors, to whom they intend to assign their core cutting. Such sub-vendors should have been approved by other Electricity Boards/ Electrical utilities and are accredited by some International recognized certification body like ISO: 9000 etc., to ensure that a minimum quality parameters and tolerances are maintained. The experience, the details of core-cutting facilities, finishing and testing facilities etc., as available with such sub-vendors should be clearly outlined in the bid.
- (5) On award of contract, the RM is to assign the core-cutting to such sub-vendor(s) for which approval is to be given by OPTCL
- (6) After the packed core coils are received by the OPTCL's approved sub-vendors, the RM is to offer the same to OPTCL for deputing representative(s) to first note down the details as per Sl (3) above and witness the cutting of cores and relevant tests on core samples.
- (7) The RM will offer the core materials for inspection during assembly stage and witnessing the stage inspection and relevant tests.
- m) Further, the Bidder is required to furnish the copies of import documents (as mentioned at Sl.'i' above) along with the tender offer in support of their direct import of core materials in the recent past.

#### **5.5.8.1 Internal Structure Design:**

- a) The structural design shall be made so that pressure will be maintained to prevent loosening resulting from thermal expansion and contraction during all loading cycles.
- b) The design shall be made in such a way that excessive vibration does not occur in the windings, structural supports of the windings and magnetic circuit and this will be subjected to design review.
- c) The structure shall be designed to withstand the clamping and magnetic forces. The calculated magnetic forces will be furnished at the time of design review.
- d) Core and winding shall be capable of withstanding the shock during transport, installation and service. Adequate provision shall be made to prevent movement of core and winding relative to tank during these conditions.

#### **5.5.8.2. Earthing of core and clamping structure:**

- a) If grounding of the core cheeses are required, a separate strap shall be brought to a terminal located in a waterproof enclosure on the tank. Separate ground leads will be routed from the top and bottom yokes to separate terminals in the enclosure.
- b) The core shall be earthed to the core clamping structure at one point only, through a removable external link suitably located and protected to facilitate testing after installation of the reactor. The removable links shall have adequate section to carry ground fault current. Separate identification name plate/labels shall be provided for the 'Core' and 'Core clamp' on the tank cover.



- c) Unless otherwise approved, no core earthing connection shall be of minimum size of 80 sq.mm copper with exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 sq. mm tinned copper where they are clamped between the laminations.
- d) Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, tinned copper bridging strips shall be inserted to maintain electrical continuity between sections.
- e) A drawing showing the details of the earthing design and connection shall be furnished during detailed engineering.

#### 5.5.8.3 **SIZE OF EARTHING CONNECTIONS:-**

To be proposed by the manufacturer for the Purchaser's approval.

#### 5.5.9. **WINDINGS:-**

- a) The supplier shall ensure that the windings of all EHV class reactors are made in dust proof, conditioned atmosphere. **The bidder shall furnish the facilities, available in this regard at their works along with the bid.**
- b) The conductors shall be of electrolytic grade copper free from scales and burrs.
- c) The insulation of Reactor windings and connections shall be free from insulating compounds which are liable to soften, ooze out, shrink or collapse and shall be non-catalytic and chemically inactive in Reactor oil during service.
- d) Coil assembly and insulating spacers shall be so arranged as to ensure free circulation of oil and to reduce the hot spot of the winding.
- e) The coils would be made up, shaped and braced to provide for expansion and contraction due to temperature changes.
- f) The conductor shall be transposed at sufficient intervals in order to minimize eddy currents and to equalise the distribution of currents and temperature along the winding.
- g) The windings shall be designed to withstand the dielectric tests specified. The type of winding used shall be of time tested. An analysis shall be made of the transient voltage distribution in the windings, and the clearances used to withstand the various voltages. Margins shall be used in recognition of manufacturing tolerances and the fact that the system will not always be in the new factory condition.
- h) The barrier insulation including spacers shall be made from high-density pre-compressed pressboard (1.1 gm/cc minimum for load bearing and 1 gm/cc minimum for non-load bearing) to minimize dimensional changes.
- i) All spacers shall have rounded edges. Radially stepped spacers between winding disks will not be accepted.

- j) The conductor insulation shall be made from high-density (at least 0.75 gm/cc) paper having high mechanical strength. The characteristics for the paper will be reviewed at the time of design review.
- k) An electrostatic shield, made from material that will withstand the mechanical forces, will be used to shield the high voltage windings from the magnetic circuit unless otherwise approved.
- l) **The insulation paper shall be of high quality and the value of degree of polymerization shall not be less than 1200 Pv and the necessary test certificate shall be submitted along with the stage inspection report. Provision shall be made in the reactor tank for taking sample of paper for testing purpose in future and the location shall be easily accessible and indicated in the reactor tank by affixing special caution plate.**
- m) Tan delta value for windings shall be less than 0.005. Tan delta shall be measured at ambient temperature. No temperature correction factor shall be applied.

#### **5.5.9.1 Bracing of windings:-**

All winding insulation shall be processed to ensure that there will be no detrimental shrinkage after assembly. All windings shall be pre-sized before being clamped. Windings shall be provided with clamping arrangements which will distribute the clamping forces evenly over the ends of the winding.

The bracing of the windings and connections shall be such that these parts shall safely withstand the cumulative effects of stresses which may occur during handling, transportation, installation and service including line-to-line and line-to-ground faults.

Full details of the winding clamping arrangements, and their adjustment in or out of the tank together with relevant drawings and values, shall be submitted during design review.

#### **5.5.9.2. Current carrying connections:-**

The mating faces of bolted connections shall be appropriately finished and prepared for achieving good long lasting, electrically stable and effective contacts. All lugs for crimping shall be of the correct size for the conductors. Connections shall be carefully designed to limit hot spots due to circulating eddy currents.

#### **5.5.9.3. Winding terminations into bushings:-**

- a) Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions to ensure the integrity of the Reactor in service.
- b) The winding-end termination, insulation system and transport fixings shall be so designed that the integrity of the insulation system generally remains intact during repeated work in this area.
- c) Allowances shall be made on the winding ends for accommodating tolerances on the axial dimensions of the set of bushings and also for the fact that bushings may have to be rotated.

- d) In particular, rotation or straining of insulated connections shall be avoided during the fastening of conductor pads (or other methods) on the winding ends onto the termination surfaces of the bushing.
- e) Suitable inspection and access facilities into the tank in the bushing oil-end area shall be provided to minimize the possibility of creating faults during the installation of bushings.

**5.5.10. GAS AND OIL-ACTUATED RELAYS:-**

- (a) Each reactor shall be fitted with gas and oil-actuated relay equipment having alarm contacts, which close on collection of gas or low oil level, and tripping contacts which close following oil surge conditions.
- (b) Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.
- (c) Each relay shall be fitted with a calibrated glass window for indication of gas volume.
- (d) To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point, approximately 1200 mm above ground level. Where it shall be terminated by a cock, which shall have provision for locking to prevent unauthorized operation.
- (e) The design of the relay mounting arrangements, the associated pipe work and the cooling plant shall be such that mal-operation of the relay will not take place under normal service conditions, during starting or stopping of the Reactor oil circulation under any oil temperature conditions, through fault conditions, nor be influenced by the magnetic fields around the Reactor during the external fault conditions.
- (f) The pipe work shall be so arranged that all gas arising from the reactor will pass into the gas and oil-actuated relay. The oil circuit through the relay must not form a delivery path in parallel with any circulating oil pipe, nor is to be tied into or connected through the pressure relief vent. Sharp bends in the pipe work shall be avoided. For this reason, bushing turrets, if fitted shall have vent pipes, which will route any gas collection through the relay.
- (g) A machined surface shall be provided on the top of each relay to facilitate the setting of the relays and to check the mounting angle in the expansion pipe and the cross level of the relay.
- (h) A straight run of pipe work shall be provided for a length of five times the internal diameter of the pipe on the conservator side of the gas and oil-actuated relay.
- (i) The surge float contacts shall close at a rate of steady oil flow between the following limits. As far as possible, the limits shall also be met when the relay is subjected to oil surge conditions, produced by rapid opening of a lever operated gate valve.
- (j) The relays shall be so located as to be easily accessible from the top of the tank. Oil Pipe Connection I.D. (mm) Operational Limits for Relay.

[Rising angles of 1° to 9°.]

25	700-1300
50	750 - 1400
75	900 - 1600

- (k) The gas collection contacts shall operate within the angle limits, specified for test:
- (l) The clearance between oil pipe work and live metal shall be not less than the minimum clearances as per standard practice.
- (m) Pressurized water ingress test for Terminal Box (Routine Test) shall be conducted on

**5.5.11. TEMPERATURE INDICATING DEVICES AND ALARMS:-**

The Reactor shall be provided with approved devices for indicating the oil temperature and hot spot winding temperature of each winding. The devices shall have a dial type indicator and in addition, a pointer to register the highest temperature reached and re-setting device. Each temperature device shall have three separate contacts fitted, one of which shall be used to control the cooling plant motors, one to give an alarm and one to trip the associated circuit breakers.

**(a) Oil Temperature Indicator (OTI)**

The thermometer for top oil temperature indication should be of 150mm dial type. A temperature-sensing element, suitably located in a pocket on top oil shall be furnished. This shall be connected to the OTI by means of capillary tubing. Accuracy class of OTI shall be  $\pm 1.5\%$  or better. The temperature indicator dials shall have linear graduations to clearly read at least every 2 deg. C.

**In addition to the above, the following accessories shall be provided for remote indication of oil temperature.**

**Temperature transducer with Pt100 sensor**

RTD shall be provided with Pt100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The Pt100 temperature sensor shall have three wire ungrounded system. The calibration shall be as per IEC 60751-2 or equivalent. The Pt100 sensor may be placed in the pocket containing temperature sensing element. RTD shall include image coil, for OTI system and shall provide dual output 4-20mA for SCADA system. The transducer shall be installed in the Individual Marshalling Box. Any special cable required for shielding purpose, for connection between Pt100 temperature sensor and transducer, shall be in the scope of the supplier. 4-20mA signal shall be wired to Control & relay panel for further transfer data to SCADA through IEC 61850 compliant communications.

**(b) Winding Temperature Indicator (WTI).**

A device for measuring the hot spot temperature of the winding shall be provided. It shall comprise of the following:-

- i) Temperature sensing element.
- ii) Image Coil.
- iii) Auxiliary CT(S), if required to match the image coil, shall be provided and mounted in the cooler control cabinet. The current Transformers shall be of class 1, and the rated primary current shall correspond to the rated current of the reactor winding. The effective resulting rated secondary current shall be 2A. Matching units between current reactors and thermal replicas shall not be provided.
- iv) 150 mm diameter local indicating instrument with maximum reading pointer, mounted in cooler control cabinet and with two adjustable electrically independent ungrounded contacts (besides that required for control of cooling equipment), one for high winding temperature alarm and one for trip. The temperature indicator dials shall have linear graduations to clearly read at least 2 deg. C
- v) Calibration device.
- vi) In addition to the above, the following indication equipment shall be provided for the winding for remote indication.
  - 1) Conventional Remote winding temperature indicator & Remote Oil

temperature indicator: - It shall be suitable for flush mounting on RTCC panel. The difference between local and remote indication at any given time shall not exceed 1 deg. C.

- 2) Remote Optic Fiber temp. Indicators.
- 3) Auxiliary supply, if required, in RTCC panel, for above, shall be 220V DC only.
- 4) The drawing showing details of above shall be submitted to the purchaser.
- 5) Accuracy class of WTI & OTI shall be +/- 1.5% or better.
- 6) Any special cable(s), required for shielding purpose for connection between cooler control cabinet and remote winding temperature indicator control circuit shall be in Bidder's scope.

**Temperature transducer with Pt100 sensor for each winding:**

RTD shall be provided with Pt100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The Pt100 temperature sensor shall have three wire ungrounded system. The calibration shall be as per IEC 60751-2 or equivalent. The Pt100 sensor may be placed in the pocket containing temperature sensing element. RTD shall include image coil, Auxiliary CTs, if required to match the image coil, for WTI system and shall provide dual output 4-20mA for SCADA system. The transducer, Auxiliary CT shall be installed in the Individual Marshalling Box. Any special cable required for shielding purpose, for connection between Pt100 temperature sensor and transducer, shall be in the scope of the supplier. 4-20mA signal shall be wired to Control & relay panel for further transfer data to SCADA through IEC 61850 compliant communications.

The temperature indicators (OTI & WTI) shall be so mounted that the dials are about 1200mm from the ground level. Glazed door of suitable size shall be provided for convenience of reading.

- (c) The winding temperature indicators shall be housed in the cooler control cabinet/marshalling kiosk. The tripping contacts of the winding temperature indicators shall be adjustable to close between 80°C and 150°C and to re-open when the temperature has fallen by not more than 10°C.
- (d) All contacts shall be adjustable to a scale and must be accessible on removal of the relay cover. Alarm and trip circuit contacts shall be suitable for making or breaking 150 VA between the limits of 30 and 250 Volts AC or DC and of making 500 VA between the limits of 110 and 250 V DC.
- (e) The temperature indicators in the marshalling kiosk shall be so designed that it is possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment.
- (f) The working parts of the instrument shall be made visible by the provision of cut-away dials and glass-fronted covers. All setting and error adjustment devices shall be easily accessible.
- (g) Connections shall be brought from the device to terminal boards, placed inside the marshalling cubicle.
- (h) Terminals, links and a 63 mm moving iron ammeter shall be provided in the marshalling kiosk for the WTI for: -
  - (i) Checking the output of the current transformer.
  - (ii) Testing the current transformer and thermal image characteristics.
  - (iii) Disconnecting the bulb heaters from the current transformer secondary circuit to enable the instrument to be used as an oil temperature indicator.
- (i) Sight glasses of temperature indicators shall be of laminated security glass. Sight glasses of

transparent plastics will not be accepted.

- j) In addition to the above, '**OPTIC FIBER TEMPERATURE SYSTEM**' of proven quality and performance in Indian Utilities shall be provided in each reactor for measurement of temperature of windings, oil and core. Bidders are required to state in their offers regarding performance of such Optic Fiber Temperature System along with the names of the end-users in India. The end-user's certificates for such system will be furnished by the Bidders along with their Tender offers.

Following is the criteria for temperature measurement of oil, windings and core by using Fiber Optic Sensors: -

1. System shall be with fiber optic sensors with proven and rugged technology. The probes shall be directly installed in each winding of reactor to measure the winding hot spot, top oil and core temperature. There will be **minimum five probes** inside the reactor, out of which one probe should be installed in top of the reactor for the detection of top oil temperature.
2. One probe shall be installed in each phase winding at the hottest spot of each of the phase windings, one probe in hottest spot of the core and one probe for top oil temperature measurement. The locations of the probes shall be proposed by the Manufacturer and locations, to be finalized by agreement with the purchaser.
3. Probes shall be able to be completely immersed in hot reactor oil; they shall withstand exposure to hot kerosene vapour during the reactor insulation drying process. The probes shall meet the requirement to eliminate the possibility of partial discharge in high electrical stress areas in the reactor.
4. Temperature range of the system should be  $-30^{\circ}\text{C}$  to  $+200^{\circ}\text{C}$  and accuracy of  $\pm 2^{\circ}\text{C}$  with no recalibration required.
5. Probes shall be all silica, double PFA Teflon jacketed; Kevlar cabled fiber with perforated outer jacket to allow complete oil filling; and Teflon protective Helix wrap having improved visibility and mechanical strength.
6. A microprocessor based monitoring and recording unit shall be a part of the system, having 5(five) channels. System should include analog outputs for each measurement channel. Temperature resolution of the analog outputs shall be  $\pm 0.1^{\circ}\text{C}$  and the system shall offer user programmable temperature alarm outputs with 6 relays, alarm lights and controller system status indicators. All inputs and outputs of the system shall meet the requirements of surge test of IEEE C37.90.1-1989 in which a 3000V surge is applied to all the inputs and outputs without permanent damage to the instrument.
7. The system shall be capable of retaining temperature data of a minimum of 90 days at one (1) reading/minute and should retain max temperature of each channel until reset.
8. **The reactor manufacturer should submit data showing that the probes are located in the hottest point of the windings ,oil & core while submitting drawings for approval.**
9. The Fiber Optic cables are to be brought out of the main tank through tank wall penetrator feed through plate. The Feed through plate shall be welded on to the Tank. The external fiber optic extension cable shall then be run to main control cabinet,

routed inside the conduits with large bend radius. Protective cover shall be provided for the Tank Wall Feed through Plate.

10. The controller / measuring system having at least 5 channels shall be housed in cooler control cubicle or in a separate enclosure having degree of protection IP56 class, mounted on the reactor tank. The position shall be clearly indicated in the GA drawings.
11. Temperature Rise Test Measurement shall be made with the FO Thermometers. The Optic Fiber Temperature System shall be operational during temperature rise tests and be demonstrated during these tests. During probe verification, the hottest probes for each phase shall be identified and temperature data for all probes (hourly readings) recorded and reported in the test report. The hot spot temperature rise of the windings above ambient temperature shall not exceed 54 deg. C and the top oil temperature rise above ambient temperature shall not exceed 40 deg. C as per this specification.
12. For remote indications on RTCC panel, output of 4to 20mA shall be made available. Digital Temperature Indicators shall be provided in the RTCC Panel for indications of temperatures in each of the windings, top oil and core from the Optic Fiber Temperature Sensor Controller Unit. This shall also be demonstrated during temperature rise test.
13. The output of FO system shall be suitable for PC interface with USB port. All required software shall be provided.
14. Any other accessories required for satisfactory operation of fiber optic sensor temperature measurement system shall be provided.
15. All type test reports as per relevant standard shall be submitted with the technical bid.
16. The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative. Services of FO system supplier during manufacturing, testing, commissioning and after sales service even beyond guarantee period shall have to be arranged and provided by the bidder.

#### 5.5.12. **COOLING EQUIPMENT AND ITS CONTROLS:**

##### 5.4.12.1. **Cooling Equipment:**

- (a) The Reactor shall be designed for Oil Natural Air Natural cooling (ONAN).
- (b) The radiator bank of the shunt reactor shall be either tank mounted or separately mounted based on manufacturer's standard practice.
- (c) Design of cooling system shall satisfy the performance requirements. The radiator shall be of sheet steel in accordance with IS 513 and minimum thickness 1 mm.

**Each radiator shall be provided with the following items: -**

- One shut off valve at the top.
- One shut-off valve at the bottom.
- Air release device at the top.
- Lifting lugs to lift entire cooling assembly.
- Air release device and oil plug on oil pipe connections.

- Loose blanking plates for blanking off the main oil connections.
- Visual oil flow indicators, fitted with the electrical contacts to close when oil is not flowing. Contacts are to be connected in the cooler fail alarm circuit.

**Each radiator bank shall be provided with the following items: -**

- Main and sampling device at the bottom.
  - Expansion joints, one each on top and bottom cooler pipe connections.
  - A thermometer pocket fitted with captive screw cap, in the inlet and in the outlet oil pipes.
- (d) Each radiator bank shall be detachable and shall be provided with flanged inlet & outlet branches.
- (e) If radiators are directly mounted on tank, sufficient number of thermometer pockets fitted with Captive Screw Cap on the inlet & outlet of tank side pipe of radiators shall be provided to record temperature during temperature rise test.
- (f) The cooler pipes, support structure including radiators and its accessories shall be hot dip galvanized.

**N. B.: - The omission of any or the provision of alternative arrangements to the above requirements will not be accepted.**

**(g) OIL PIPES AND FLANGES :**

- All oil piping, necessary for connecting of each reactor to its conservator, cooler banks and oil pumps etc. shall be supplied under this contract.
- The oil piping shall be of approved material with machined flanged joints.
- Copper pipe work is to comply with BS.61.
- Dimensions of steel pipes shall be in accordance with BS. 3600: 1973 and the drilling of all pipe flanges shall comply with BS: 4504:1969.
- An approved expansion piece shall be provided in each oil pipe connection between the reactor and each oil cooler bank.
- All necessary pipe supports, foundation bolts and all other attachments are to be provided.
- It shall be possible to drain any section of pipe work independently of the rest and drain valves or plugs shall be provided as necessary to meet this requirement.

**5.5.12.2. Marshalling Box:**

- Each reactor unit shall be provided with a marshaling box.
- The marshaling box shall have all necessary devices, meant for local temperature indicators. All the contacts of various protective devices, mounted on the reactor shall also be wired up to the terminal board in the cooler control cabinet. All the secondary terminals of the bushing CTs shall also be wired up to the terminal board at the cooler control cabinet.
- The marshaling box shall house the temperature indicators, auxiliary CTs. and the terminal boards, meant for termination of various alarm and trip contacts as well as various bushing CT Secondaries. Alternatively, the two sections may be provided as two separate panels, depending on the standard practices of the supplier.
- The temperature indicators shall be so mounted that the dials are not more than 1600 mm from ground level. Glazed door of suitable size shall be provided for convenience of reading.

**5.5.12.3. TERMINAL BLOCK:**

- The terminal blocks( 'ELMEX' Make, Type – OAT 6 or its equivalent), to be provided shall



be fully enclosed with removable covers and made of moulded, non-inflammable plastic material with block and barriers, moulded integrally. Such block shall have washer and binding screws for external circuit wire connections, a white marking strip for circuit identification and moulded plastic cover. All terminals shall be clearly marked with identification numbers or letters to facilitate connection to external wiring.

- (b) All internal wiring to be connected to the external equipment shall terminate on terminal blocks, preferably vertically mounted on the side of each panel. The terminal blocks shall be 1100 V grade and have 10 Amps continuous rating moulded piece, complete with insulated barriers, non-disconnecting stud type terminals, washers, nuts and lock nuts. Terminal block design shall include a white fibre-marking strip with clear plastic, slipon/clipon terminal cover. Markings on the terminal strips shall correspond to wire number and terminal numbers on the wiring diagrams.
- (c) Terminal blocks for current reactor's secondary leads shall be provided with test links and isolating facilities. Also current reactor secondary leads shall be provided with short-circuiting and earthing facilities.
- (d) At least 20% spare terminals shall be provided on each panel and these spare terminals shall be uniformly distributed on all terminal blocks.
- (e) Unless otherwise specified, terminal blocks shall be suitable for connecting the following conductors on each side.
  - (i) For all circuits except current reactor circuits, minimum of two nos. 2.5 sq.mm copper.
  - (ii) For all CT circuits, minimum of two nos. 4 sq. mm. copper.
- (f) There shall be a minimum edge-to-edge clearance of 250 mm. between the first row of terminal block and the associated cable gland plate. Also the clearance between two rows of terminal blocks shall be minimum of 150 mm.
- (g) Arrangement of the terminal block assemblies and the wiring channel within the enclosure shall be such that a row of terminal blocks is run parallel and in close proximity long each side of the wiring duct to be provided for convenient attachment of internal panel wiring. The side of the terminal block, opposite the wiring duct shall be reserved for the owner's external cable connection. All adjacent terminal blocks shall also share this field-wiring corridor. A steel strip shall be connected between adjacent terminal block rows at 450 mm intervals for support of incoming cables.
- (h) The number and sizes of the purchaser's multi-core incoming cable will be furnished to the Bidder after placement of the order.

#### 5.5.12.4. **LABELS.**

- a) Labels shall be provided for all the apparatus such as relays, switches, fuses etc., contained in control cabinets/marshalling box.
- b) Description labels for mounting indoor or inside control cabinets/marshalling box shall be of such material that will ensure permanence of lettering. A matt of satin finish shall be provided to avoid dazzle from reflected light. Labels, mounted on dark surfaces shall have white lettering on a black background. All plates shall be of a material, which will not get corroded.
- c) Labeling shall be clear, concise and adequate.
- d) Labels shall be supplied as far as possible in the following four standard sizes
  - (i) Label for fuses and links shall measure approximately 28mm. to 45mm by 13mm. to 19mm. and lettering of 3mm to 6mm. shall be used according to the amount of inscription required. The lettering shall have strokes of approximately 1mm. width.
  - (ii) Labels for relays, contactors, thermal devices and similar apparatus shall measure

- 65mm. by 20mm. and shall have lettering as specified in (i) above.
- (iii) Labels for controllers and changeover switches shall measure 70mm by 30mm and where practicable have 20 mm lettering with 1.5 mm strokes.
  - (iv) The labels for the doors of junction boxes, marshalling boxes and similar equipment shall measure 125 mm x 50 mm and have 13 mm, lettering with 1.5 mm wide strokes.
  - (e) The labels for mounting outdoor shall be weather and corrosion proof. The letters/diagrams thereon shall be framed by etching or other such process, which will ensure permanence of the lettering/markings.
  - (f) Labels shall be attached to panels with brass screws or with steel screws which have received rust preventive treatment.

#### 5.5.13. **SCADA Integration:-**

All the online monitoring equipment i.e. Optical Temperature Sensors & Measuring Unit, Online Dissolved Gas (Multi-gas) and Moisture Analyser, On-line insulating oil drying system (Cartridge type) provided for individual reactor unit including spare (if any), are IEC 61850 compliant (either directly or through a Gateway). These monitoring equipment are required to be integrated with SAS through managed Ethernet switch conforming to IEC 61850. This Ethernet switch shall be provided in MB by the contractor. The switch shall be powered by redundant DC supply (as per available Station DC supply). Ethernet switch shall be suitable for operation at ambient temperature of 50 Deg C. All required power & control cables including optical cable, patch chord (if any) upto MB shall be in the scope of contractor. Further, any special cable between MB to switchyard panel room/control room shall be in the scope of contractor.

However, fiber optic cable, power cable, control cables, as applicable, between MB to switchyard panel room/control room and power supply (AC & DC) to MB and integration of above said IEC-61850 compliant equipment with Substation Automation System shall be under the scope of sub-station contractor.

#### 5.5.14. **TERMINAL AND CONNECTION ARRANGEMENTS:**

##### 5.5.14.1. **OUTDOOR BUSHINGS:**

- a) Bushings shall be robust and designed for adequate cantilever strength to meet the requirement of seismic condition. The electrical and mechanical characteristics of bushings shall be in accordance with IEC: 60137/DIN 42530. All details of the bushing shall be submitted for approval and design review.
- b) RIP bushing with composite polymer insulator shall be provided.
- c) RIP type bushing shall be provided with tap for capacitance and tan delta test. Test taps relying on pressure contacts against the outer earth layer of the bushing is not acceptable.
- d) Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.
- e) Bushings of identical rating shall be interchangeable to optimize the requirement of spares.
- f) Composite polymer insulator shall be seamless sheath of a silicone rubber compound. The housing & weather sheds should have silicon content of minimum 30% by weight. It should protect the bushing against environmental influences, external pollution and humidity. The

interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing strength of the polymer. The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core. The technique being followed with detailed procedure and sampling shall be decided during finalization of QAP.

The weather sheds of the insulators shall be of alternate shed profile as per IEC 60815-3. The weather sheds shall be vulcanized to the sheath (extrusion process) or moulded as part of the sheath (injection moulding process) and free from imperfections. The vulcanization for extrusion process shall be at high temperature and for injection moulding shall be at high temperature & high pressure. Any seams / burrs protruding axially along the insulator, resulting from the injection moulding process shall be removed completely without causing any damage to the housing. The track resistance of housing and shed material shall be class 1A4.5 according to IEC60587. The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. The composite insulator shall be capable of high pressure washing.

End fittings shall be free from cracks, seams, shrinks, air holes and rough edges. End fittings should be effectively sealed to prevent moisture ingress, effectiveness of sealing system must be supported by test documents. All surfaces of the metal parts shall be perfectly smooth with the projecting points or irregularities which may cause corona. All load bearing surfaces shall be smooth and uniform so as to distribute the loading stresses uniformly.

The hollow silicone composite insulators shall comply with the requirements of the IEC publications IEC 61462 and the relevant parts of IEC 62217. The design of the composite insulators shall be tested and verified according to IEC 61462 (Type & Routine test).

g) Clamps and fittings shall be of hot dip galvanized /stainless steel.

h) Bushing turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay.

i) No arcing horns shall be provided on the bushings.

j) RIP bushings shall be specially packed to avoid any damage during transit & suitable for long storage with non-returnable packing wooden boxes with hinged type cover, without any gaps between wooden planks. Packing box opening cover with nails/ screws type packing arrangement shall not be acceptable. Bushing oil end portion shall be fitted with metal housing with positive dry air pressure and a suitable pressure monitoring device shall be fitted on the metal housing during storage to avoid direct contact with moisture with epoxy. Alternatively oil filled metal housing with suitable arrangement for taking care oil expansion due to temperature variations shall also be acceptable. Manufacturer shall submit drawings / documents of packing for approval during detail engineering. Detail method for storage of bushing including accessories shall be brought out in the instruction manual.

k) The terminal marking and their physical position shall be as per IEC: 60076.

l) Tan Delta measurement at variable frequency (in range of 20 Hz to 350 Hz) shall be carried out on each condenser type bushing at reactor manufacturing works as routine test before dispatch and the result shall be compared at site during commissioning to verify the healthiness of the bushing. If the bushing Tan Delta goes beyond 0.005 or increase is more than 0.001 within the guarantee period with respect to the pre-commissioning values, the supplier shall arrange to replace the defective bushing by new one. No temperature correction factor shall be applicable for Tan Delta.

#### 5.5.14.2. **TERMINAL CONNECTORS:**

- (a) Bushing terminals shall be provided with terminal connectors of approved type and size for connection to external parts. Terminal connectors, offered must have been successfully type tested as per IS: 5561.
- (b)
  - (i) All castings shall be free from blow holes, surface blisters, cracks and cavities. All sharp edges and corners shall be blurred and rounded off. The aluminum alloy castings, if used, shall conform to designation A6 of IS: 617.
  - (ii) No part of clamp shall be less than 10 mm. thick.
  - (iii) All ferrous parts shall be hot dip galvanized conforming to IS: 2633. Spring washers and H.T. bolts shall be dectrogalvanised conforming to IS: 1573.
  - (iv) For bimetallic clamp, copper alloy linear of minimum thickness of 2 mm. shall be cast integral with aluminum body.
  - (v) Flexible connectors shall be made from tinned copper sheets.
  - (vi) Size of terminal/conductor for which the clamp is suitable and rated current under site conditions shall be embossed/punched on each component of the clamp, except hardware.
  - (vii) All current carrying parts shall be designed and manufactured to have minimum contact resistance.
  - (viii) The short time rating of terminal connector shall not be less than the short time rating of respective bushing.
  - (ix) Terminal connectors shall be subject to all type, routine and acceptance tests as per IS: 5561 (latest).
  - (x) Malleable cast iron for terminal connectors or any of its parts and accessories shall not be acceptable.
  - (xi) Bolts and Nuts used shall be of stainless steel or galvanized/passivated mild steel.

#### 5.5.14.3. **Current Transformer (Bushing & Outdoor Neutral Current Transformer):-**

- a) Current transformers shall comply with IEC-61869-1 and 61869-2.
- b) It shall be possible to remove the turret mounted current transformers from the Reactor tank without removing the tank cover. Necessary precautions shall be taken to minimize eddy currents and local heat generated in the turret.
- c) Current transformer secondary leads shall be brought out to a weatherproof terminal box near each bushing. These terminals shall be wired out to common marshalling box using separate cables for each core.
- d) Technical Parameters of Bushing CTs and Neutral CTs are mentioned in the principal parameters(CI. No-4). The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection. Bushing Current transformer parameters indicated in this specification are tentative and liable to change within reasonable limits. The supplier shall obtain Purchaser's approval before proceeding with the design of bushing current transformers.

- e) Secondary resistance and magnetising current characteristics of PX / PS class (protection) (as per IS or IEC) CT of same rating shall match. This is applicable for Neutral CT (outdoor) also and shall be reviewed during detail engineering.

**5.5.14.4. TERMINAL MARKING:**

Reactor terminals are to be provided with phase markings to the requirements of IEC- 616 and are subject to the agreement of the purchaser. Reactor terminals shall be silver/tin-plated copper.

**5.5.14.5 NEUTRAL EARTHING:**

The neutral terminals shall be brought to ground level by a brass or tinned copper grounding bar of approved size which shall be supported from the tank with porcelain insulators and connected to purchaser's local earth grid. The supplier must liaise with the purchaser or its approved contractor to finalize the details of installation of this earthing and mounting of the outdoor neutral C.T. on this.

**5.5.15. SPECIFICATION FOR MARSHALLING BOX:**

- a) Each shunt reactor shall be provided with Marshalling Box.
- b) All out door control cabinets shall be made of stainless steel sheet of at least 1.6 mm thick. The degree of protection shall be at least IP: 55 for outdoor and IP: 43 for indoor in accordance with IS: 13947/IEC: 60947.
- c) All doors, removable covers and plates shall be gasketed all around with suitably profiled. All gasketed surfaces shall be smooth straight and reinforced if necessary to minimize distortion to make a tight seal. For Control cubicle / Marshalling Boxes etc. which are outdoor type, all the sealing gaskets shall be of EPDM rubber or any better approved quality, whereas for all indoor control cabinets, the sealing gaskets shall be of neoprene rubber or any better approved quality. The gaskets shall be tested in accordance with approved quality plan, IS: 1149 and IS: 3400. Ventilating Louvers, if provided, shall have screen and filters. The screen shall be fine wire mesh of brass. All the separately mounted cabinets and panels shall be free standing floor mounted type and have domed or sloping roof. All the control cabinets shall be provided with suitable lifting arrangement.
- d) All the contacts of various protective devices mounted on the reactor and all the secondary terminals of the bushing CTs shall also be wired up to the terminal board in the Marshalling box. All the CT secondary terminals in the Marshalling box shall have provision for shorting to avoid CT open circuit while it is not in use. All the necessary terminations for remote connection to Purchaser's panel shall be wired up to the Marshalling box.
- e) A space heater and cubicle lighting with ON-OFF switch shall be provided in each panel.
- f) Necessary isolating switches and protective devices shall be provided at suitable points as per Purchaser's approved scheme.
- g) Marshalling box shall be floor mounted and of size not less than 1600mm (front) X 650mm (depth) X 1800mm (height).

- h) Two auxiliary power supplies, 415 volt, three phase four (4) wire shall be provided by the Purchaser at Marshalling Box .
- i) Suitably rated power contactors, MCBs/MCCBs as required for entire auxiliary power supply system including distribution to marshalling boxes, Online DGA monitoring system, Online drying system and Fibre optic sensor Box etc., shall be provided by supplier. For each circuit separate MCBs / MCCBs shall be provided in the Marshalling Box.
- j) In case auxiliary power supply requirement is different than station auxiliary AC supply, then all necessary converters shall be provided by the supplier. Auxiliary power supply distribution scheme shall be submitted for approval.
- k) All loads shall be fed by one of the two feeders through an electrically interlocked automatic transfer scheme housed in the marshalling box. Design features of the transfer scheme shall include the following:
- Provision for the selection of one of the feeder as normal source and other as standby.
  - Upon failure of the normal source, the loads shall be automatically transferred after an adjustable time delay to standby sources.
  - Indication to be provided at marshalling box for failure of normal source and for transfer to standby source and also for failure to transfer.
  - Automatic re-transfer to normal source without any intentional time delay following re-energization of the normal source.
  - Both the transfer and the re-transfers shall be dead transfers and AC feeders shall not be paralleled at any time.

5.5.16(A) **INSULATING OIL:-**

(a)The insulating oil shall be virgin high grade inhibited, conforming to IEC-60296 & all parameters specified as below, while tested at supplier's premises. The supplier shall furnish test certificates from the oil manufacturer against the acceptance norms as mentioned below. The Unused inhibited Insulating Oil parameters including parameters of oil used at manufacturer's works, processed oil, oil after filtration and settling are as stipulated below.

**Unused inhibited Insulating Oil Parameters**

Sl. No.	Property	Test Method	Limits
<b>A</b>	<b>Function</b>		
1a.	Viscosity at 100degC	ISO 3104 or ASTM D445 or ASTM D7042	(Max.) 3 mm <sup>2</sup> /s
1b.	Viscosity at 40degC	ISO 3104 or ASTM D445 or ASTM D7042	(Max.)12 mm <sup>2</sup> /s
1c.	Viscosity at -30degC	ISO 3104 or ASTM D445 or ASTM D7042	(Max.)1800 mm <sup>2</sup> /s
2.	Appearance	A representative sample of the oil shall be examined in a 100 mm thick layer, at ambient temperature	The oil shall be clear and bright, transparent and free from suspended matter or sediment
3.	Pour point	ISO 3016 or ASTM D97	(Max.)- 40degC

4.	Water content a) for bulk supply b) for delivery in drums	IEC 60814 or ASTM D1533	(Max.) 30 mg/kg 40 mg/kg
5.	Electric strength (breakdown voltage)	IEC 60156	(Min.)50 kV(new unfiltered oil) / 70 kV (after treatment)
6.	Density at 20 deg C	ISO 3675 or ISO 12185 or ASTM D 4052	0.820 - 0.895 g/ml
7.	Dielectric dissipation factor (tan delta) at 90 deg C	IEC 60247 or IEC 61620 Or ASTM D924	(Max) 0.002
8.	Negative impulse testing KVp @ 25 deg C	ASTM D-3300	145 (Min.)
9.	Carbon type composition (% of Aromatic, Paraffins and Naphthenic compounds )	IEC 60590 and IS 13155 or ASTM D 2140	Max.Aromatic : 4 to12 % Paraffins : <50% & balance shall be Naphthenic compounds.
<b>B</b>	<b>Refining/Stability</b>		
1.	Acidity	IEC 62021-1 or ASTM D974	(Max) 0.01 mg KOH/g
2.	Interfacial tension at 27degC	ISO 6295 or ASTM D971	More than 0.04 N/m
3.	Total sulphur content	BS 2000 part 373 or ISO 14596 or ASTM D 2622	0.05 % (Max.) (before oxidation test)
4.	Corrosive sulphur	IEC 62535	Non-Corrosive on copper and paper
		ASTM D1275B	Non-Corrosive
5.	Presence of oxidation inhibitor	IEC 60666 or ASTM D2668 or D4768	0.08% (Min.) to 0.4% (Max.) Oil should contain no other additives .Supplier should declare presence of additives, if any.
6.	2-Furfural content	IEC 1198 or ASTM D5837	25 Microgram/litre (Max.)
<b>C</b>	<b>Performance</b>		
1	Oxidation stability -Total acidity -Sludge - Dielectric dissipation factor (tan delta) at 90degC	IEC 61125 (method c) Test duration 500 hour  IEC 60247	Max 0.3 mg KOH/g Max 0.05 % Max 0.05
2.	Oxidation stability	ASTM D2112 (a)	220 Minutes (Min.)
<b>D</b>	<b>Health, safety and environment (HSE)</b>		
1.	Flash point	ISO 2719	(Min.)135deg C
2.	PCA content	BS 2000 Part 346	Max 3%
3.	PCB content	IEC 61619 or ASTM D4059	Not detectable (Less than 2 mg/kg)
<b>E</b>	<b>Oil used (inhibited) for first filling, testing and impregnation of active parts at manufacturer's works shall meet parameters as mentioned below:</b>		

1	Break Down voltage (BDV)		70kV (min.)
2	Moisture content		5 ppm (max.)
3	Tan-delta at 90°C		0.002 (max)
4	Interfacial tension		More than 0.04 N/m
<b>F</b>	<b>Each lot of the oil shall be tested prior to filling in main tank at site for the following:</b>		
1	Break Down voltage (BDV)		70 kV (min.)
2	Moisture content		5 ppm (max.)
3	Tan-delta at 90°C		0.002 (Max)
4	Interfacial tension		More than 0.04 N/m
<b>G</b>	<b>After filtration &amp; settling and prior to energisation at site oil shall be tested for following:</b>		
1	Break Down voltage (BDV)	IS: 1866 / IEC 60422	70 kV (min.)
2	Moisture content at hot condition		5 ppm (max.)
3	Tan-delta at 90°C		0.002 (Max)
4	Interfacial tension		More than 0.04 N/m
5	*Oxidation Stability	Test method as per IEC 61125 method C, Test duration: 500hour for inhibited oil	
	a) Acidity		0.3 (mg KOH /g) (max.)
	b) Sludge		0.05 % (max.)
	c) Tan delta at 90 °C		0.05 (max.)
6	*Total PCB content		Not detectable (less than 2 mg/kg total)
	* Separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of the Purchaser		

- (b) Sufficient quantity of oil, necessary for first filling of tanks, radiators etc. at the proper level shall be supplied in returnable containers. The **10% extra** oil for topping up shall be supplied in non-returnable containers, suitable for outdoor storage.
- (c) The Inhibited oil used for first filling, testing and impregnation of active parts at manufacturer's works shall be of same type of oil (in line with IEC 60076-3 & IS:335 with latest amendments) which shall be supplied at site and shall meet parameters as per above specification.
- (d) The supplier shall despatch the reactor, filled with oil or in an atmosphere of Nitrogen. In the former case, the Bidder shall take care of the weight limitation on transport and handling facility at site. In the latter case, necessary arrangement shall be ensured by the supplier to take care of pressure drop of nitrogen during transit and storage till completion of oil filling during erection. A gas pressure testing valve with necessary pressure gauge and adapter valve shall be provided. **The reactor shall also be fitted with at least two nos. of impact recorders during transportation. These impact recorders are on returnable basis.**

**(e) Particles in the oil:**

The particle analysis shall be carried out in an oil sample taken after completion of the oil filtration at site. The procedure and interpretation shall be in accordance with the recommendation of CIGRE report WG-12.17- "Effect of particles on reactor dielectric strength".



**(f)Moisture content in solid insulation:**

Dummy insulation test block shall be inserted in the active part of reactor at factory and same shall be used to detect the volume of moisture content. Before application of vacuum and oil filling in the reactor, it will be ensured that moisture content in the dummy insulation test block is less than 0.5%. Measurement shall be carried out as per IEC.

The Test certificates conforming the quality of the oil as per the above specification shall be submitted by the supplier. The purchaser at his discretion may depute his representative(s) for witnessing the tests at the works of the supplier or its sub-vendor. The purchaser's representative may recommend for testing of sample oil at CPRI/ERDA including ensuring the percentage of naphthenic and paraffinic content in the offered oil. The cost for such testing shall be borne by the supplier. The purchaser at his discretion may also get the supplied oil, tested at Govt. approved laboratory for determination of quality, naphthenic and paraffinic contents as per above specification.

**5.5.16(B) Oil Filling:-**

(i)Procedures for site drying, oil purification, oil filling etc. shall be done as per Field Quality Plan (FQP).

(ii)The duration of the vacuum treatment shall be demonstrated as adequate by means of water measurement with a cold trap or other suitable method but shall generally not be less than 72 hours for the 420kV reactor. The vacuum shall be measured on the top of the Reactor tank and should be less than 1mbar.

(iii)Oil filling under vacuum at site shall be done with reactor oil at a temperature not exceeding 65°C. Vacuum shall not be broken until the Reactor is oil filled up to the Buchholz relay.

(iv)The minimum safe level of oil filling (if different from the Buchholz level) to which the Reactor shall be oil filled under vacuum, shall be indicated in the manual.

**5.5.16(C) Oil Treatment Plant:**

The Ultra High Vacuum type oil treatment plant of suitable capacity (minimum 6000 litres per hour) suitable for treatment of oil in EHV class Reactor shall be used in order to achieve properties of treated oil. The plant shall be capable of treatment of new oil (as per IEC 60296 and reconditioning of used oil (as per IS: 1866/IEC: 60422 for oil in service) at rated capacity on single pass basis as follows:

- a. Removal of moisture from 100 ppm to 3 ppm (max.)
- b. Removal of dissolved gas content from 10% by Vol. to 0.1% by vol.
- c. Improvement of dielectric strength break down voltage from 20 to 70 KV
- d. Vacuum level of degassing chamber not more than 0.15 torr/0.2 mbar at rated flow and at final stage. Machine shall have minimum of two degassing chambers and these should have sufficient surface areas to achieve the final parameters.
- e. Filter shall be capable of removing particle size more than 0.5 micron in the filtered oil.
- f. Processing temperature shall be automatically controlled and have an adjustable range from 40°C to 80°C.

**5.5.17 CLEANING, PAINTING AND TROPICALISATION:-**

- (a) All steel surfaces except galvanized surfaces or where otherwise specified, shall be shot blasted to remove all rust, scale and foreign matters from the surface. Oil, grease, dirt and swarf shall be thoroughly removed by emulsion cleaning. The surfaces shall then be chemically cleaned and surface treated by phosphating and dried in accordance with IS-6005 - "Code of practice for phosphating of iron and steel". Immediately after phosphating, the surfaces shall be given two coats of high quality zinc chromate primer.
- (b) The interior surfaces of mechanism chambers, boxes and kiosks, after preparation,

cleaning and priming shall be painted with one coat of zinc chromate primer, one coat of phenolic based undercoating, followed by two coats of phenolic based finishing paint to white colour, followed by a final coat of anti-condensation white paint of a type and make to the approval of the Purchaser. A minimum overall paint film thickness of 200 microns shall be maintained throughout.

- (c) All steel work and metal work, after preparation and priming shall be painted with one coat zinc chromate primer, one coat of phenolic based under coating and two coats of micaceous iron oxide paint to an overall thickness of 200 microns to hard gloss finishing Light Grey Shade No. 697 of IS:5. Each successive coat of paint shall be of slightly different shade to enable inspection.  
The finished surface shall present a pleasing appearance free from dents or unevenness surfaces.
- (d) It is the responsibility of the supplier to ensure that the quality of paints used shall withstand the tropical heat, temperature up to 120°C and extremes of weather conditions. The paint shall not peel-off, wrinkle, be removed by wind, storm and handling on site and the surface finish shall neither rust nor fade during the service life of the equipment.
- (e) After erection at site, the interior surfaces of mechanism chambers and kiosks shall be thoroughly examined and any deteriorated or mechanically damaged surfaces of such shall be made good to the full specification, described above.
- (f) After erection at site, all surfaces of steel works and metal works shall be thoroughly washed down and examined. Any deteriorated or otherwise faulty paint work shall be removed down to bare metal and made good to the full specification described above, then painted one further coat of phenolic based under coating and one coat phenolic based hard gloss finishing paint to provide an overall minimum paint film thickness of 200 microns.
- (g) All paint work shall be left clean and perfect on completion of the site works.

5.5.18. **BOLTS AND NUTS:-**

- (a) All bolts, studs, screw threads, pipe threads, bolt heads and nuts shall comply with the appropriate Indian Standards for metric threads, or the technical equivalent.
- (b) Except for small wiring, current carrying terminal bolts or studs for mechanical reasons shall not be less than 6 mm in diameter.
- (c) All nuts and pins shall be adequately locked.
- (d) Wherever possible, bolts shall be fitted in such a manner that in the event of failure of locking resulting in the nuts working loose and falling off, the bolt will remain in position
- (e) All bolts, nuts and washers, placed in outdoor positions shall be treated to prevent corrosion, by hot dip galvanizing. Bolts and Nuts below M12 (12mm.) size shall be of stainless steel. Appropriate precautions shall be taken to prevent electrolytic action between dissimilar metals
- (f) Where bolts are used on external horizontal surfaces and where water can collect, methods of preventing the ingress of moisture to the threads shall be provided.
- (g) Each bolt or stud shall project at least one thread, but not more than three threads through the nut, except when otherwise approved for terminal board studs or relay stems. If bolts or nuts are placed so that they are inaccessible by means of ordinary spanners, special spanners shall be provided.
- (h) The length of the screwed portion of the bolts shall be such that no screw thread may form part of a shear plane between members.
- (i) Taper washers shall be provided where necessary.

- (j) Protective washers of suitable material shall be provided front and back on the securing screws.

#### 5.5.19. **WIRING AND CABLING:-**

- (a) Cable box/sealing end shall be suitable for following types of cable.
  - i) 415 Volt Power 1100 Volt grade PVC Insulated aluminum conductor cable with armour.
  - ii) Control. 1100 Volt grade PVC insulated 7/0.737 mm stranded copper conductor cable with armour.
- (b) Compression type cable connector shall be provided for termination of power and control cables.
- (c) All controls, alarms, indicating and relaying devices, provided with the reactor shall be wired up to the terminal blocks inside the local control cabinets.
- (d) All devices and terminal blocks with the cooler control cabinet shall be clearly identified by symbols, corresponding to those used on applicable schematic or wiring diagrams.

#### 5.5.20. **FITTINGS:**

**5.5.20.1: Fittings For Shunt Reactor:-** The following fittings shall be provided with each reactor, covered in this specification.

- (a) Conservator for main tank with oil filling hole and cap, air-cell, vacuum application valve, vacuum equalizing valve, isolating valves, drain valve, shut off valve, magnetic oil level gauge with low level alarm contacts, dehydrating air breather .
- (b) Oil preservation equipment.
- (c) Pressure relief devices with alarm/trip contacts.
- (d) Flow sensitive conservator Isolation valve
- (e) Sudden pressure relief relay with alarm contacts.
- (f) Buchholz relay, double float/reed type with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm and trip contacts (Rating 1 Amp. 220V DC) test cock, gas collection box and gas check valve at ground level.
- (g) Air release plug.
- (h) Inspection openings and covers.
- (i) RIP Bushing with metal parts and gaskets to suit the termination arrangement.
- (j) Winding temperature indicators for local and remote mounting. One RWTI with a four-point selector switch shall be provided.
- (k) Top Oil temperature indicator with maximum pointer along with two sets of contactors.
- (l) Cover lifting eyes, reactor-lifting lugs, jacking pads, towing holes and core and winding lifting lugs.
- (m) Protected type mercury or alcohol in glass thermometer.
- (n) Bottom and top filter valves with threaded male adoptors, bottom sampling valve and drain valve.
- (o) Rating and diagram plates on reactors and auxiliary apparatus.
- (p) Earthing terminals.
- (q) Flanged bi-directional wheels.
- (r) Marshaling box.

- (s) Fibre optic sensor box
- (t) Drain valve plugs shall be provided in order that each section of pipe work can be drained independently.
- (u) Insulating Oil.
- (v) Terminal marking plate.
- (w) Jacking pads/lugs
- (x) Lifting bollards.
- (y) Haulage lugs.
- (z) Cover lifting lugs.
- (z) Valve schedule plate.
- (aa) Bushing CT
- (bb) Bushing Terminal Clamps & Connectors
- (cc) Ladder to climb up to the Reactor tank cover with suitable locking arrangement to prevent climbing during charged condition.
- (dd) Nitrogen Injection Type Fire Prevention and Extinguishing system.
- (ee) Valves, as indicated at Cl.No.5.5.2 of this Specification
- (ff) Wiring upto marshalling box with PVC SWA PVC copper cables, 1100Volts grade.
- (gg) Suitable galvanized iron or stainless steel tray for cabling on main tank for better aesthetics.
- (hh) Online insulating oil drying system.
- (ii) Online dissolved gas(Multi gas) & moisture analyzer
- (jj) Optic Fiber Temperature Sensor System as per this Technical Specification.
- (kk) Cooling equipment.
- (ll) Suitable platform or ladder for safe access of Flow sensitive non-return valve and Buchholz relay shall be provided, in case these are not accessible from Reactor top.
- (mm) Two earthing terminals each on shunt reactor tank, radiators and marshalling boxes etc.
- (nn) Neutral bus connection arrangement.
- (oo) Oil sampling bottle and oil syringe.

**5.5.20.2: Fittings For Neutral Grounding Reactor:-** The following fittings shall be provided with each NGR, covered in this specification.

- a) Conservator for NGR main tank with drain valve, isolating valve, vent pipe and prismatic oil level gauge.
- b) Pressure relief devices with trip contact
- c) Buchholz relay with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm / trip contacts.
- d) Air release plug
- e) Inspection openings and covers
- f) Bushings with metal parts and gaskets to suit the termination arrangement
- g) Oil temperature indicators
- h) Cover lifting eyes, reactor lifting lugs, jacking pads, towing holes and core
- i) and winding lifting lugs
- j) Rating and diagram plates
- k) Marshalling Box (Tank mounted)
- l) Cooling equipment as applicable
- m) Bushing Current Transformers, Neutral CT (if applicable)
- n) Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently

- o) Terminal marking plates
- p) Valves schedule plate
- q) Bottom oil sampling valve with threaded male adaptors, Drain valves, Filter valves at top and bottom, shut off valves on both sides of Buchholz relay at accessible height, Sampling gas collectors for Buchholz relay at accessible height, Valve for vacuum application etc.
- r) Suitable terminal connectors on bushings
- s) Ladder to climb up to the tank cover with suitable locking arrangement to prevent climbing during charged condition.
- t) Haulage lugs
- u) Two earthing terminals each on tank, marshalling boxes etc.

**Note:** - The fittings listed above are only indicative and any other fittings which generally are required for satisfactory operation of the above rated reactors & NGRs are deemed to be included in the scope of the supplier.

#### 5.5.21. **LIMITS OF TEMPERATURE RISE:-**

The temperature rise on any part of equipment shall not exceed the maximum temperature rise specified below under the conditions specified in test clauses. The permissible temperature rise indicated is for a maximum ambient temperature of 50 degree C. If the maximum ambient temperature rises, permissible values shall be reduced accordingly. For actual maximum temperature at the location of installation, refer perfect synopsis.

Sl. No.	<u>Nature of the part or of the liquid.</u>	<u>Maximum value of:</u>	
		Temperature.	Temperature rise at a Maximum ambient air Temp. not exceeding 50 degree C.
1	Contacts in air, silver-faced copper, Copper alloy or aluminium alloy (see Notes (i) & (ii).	95	40/45
	Bare copper or tinned aluminium alloy.	75	25
2	Contacts in oil:	90	40
	Silver-faced copper, copper alloy or Aluminium alloy [see note- (i)].	80	30
3	Terminals to be connected to external Conductors by screws or bolts silver faced (see note (iii)).	105	55
4	Metal parts acting as springs.	(See note iv).	(See note iv).
5	Metal parts in contact with insulation of the following classes:		
	Class Y: (for non-impregnated Materials).	90	40
	Class A: (for materials immersed in oil or impregnated).	100	50
	Class E: in air	120	70
	In oil	100	50
	Class B: in air	130	80
	In oil	100	50
	Class F: in air	155	105

	In oil	100	50
	Enamel: oil base	100	50
	Synthetic, in air	120	70
	Synthetic, in oil	100	50
6	Any part of metal or of insulating Material in contact with oil, except Contacts.	100	50
7	Oil	90	40

- Notes: (i) When applying the temperature rise of 45° C, care should be taken to ensure that no damage is caused to the surrounding insulating materials.
- (ii) The quality of the silver facing shall be such that a layer of silver remains at the points of contact after the mechanical endurance test. Otherwise, the contacts shall be regarded as 'bare'.
- (iii) The values of temperature and temperature rise are valid whether or not the conductor connected to the terminals is silver-faced.
- (iv) The temperature shall not reach a value where the elasticity of the material is impaired. For pure copper, this implies a temperature limit of 75°C.

#### 5.5.22. **SPECIAL TOOLS AND TACKLES:-**

One Set of hand tools of 'Taparia' or 'GEDORE' Make, packed in a carry bag/box, broadly comprising of double ended spanners (Open jaws, cranked ring, tubular with Tommy bar, each of sizes 9mm to 24mm –one set each), adjustable wrenches (8 & 12 inch –one set), gasket punches (of different sizes as used in the Reactor –one set), pliers (flat nose, round nose and side cutting one of each type), hammer with handle (one), files with handle (two), knife with handle (one), adjustable hacksaw (one), cold chisel (one), Bushing Handling & lifting tools with Nylon Rope/belt, Chain Block (2 Nos.) and D-shackle shall be supplied for each Reactor.

#### 5.5.23. **LIST OF MANDATORY SPARES FOR EACH UNIT OF REACTOR**

- (a) The supplier shall provide the mandatory spares, detailed below and shall, where considered necessary, provide a list of recommended spare parts together with their individual prices. The purchaser may order all or any of the spare parts, listed at the time of contract award and the spare parts, so required by the purchaser, shall be supplied as part of this contract. Additional spares may be ordered at any time during the contract at the rates, stated in the purchase order.

<b><u>Sl.No.</u></b>	<b><u>Description.</u></b>	<b><u>Quantity.</u></b>
1	Line Bushing(RIP) with metal parts and gaskets.	1 no
2.	Neutral Bushing(RIP) with metal parts and gaskets.	1 no
3.	Local and remote winding temperature indicators with contacts.	1 set
4.	Oil temperature indicator with contacts.	1 set
5.	Pressure relief device.	1 no
6.	Magnetic oil level gauge with low oil level alarm contacts	1 No
7.	Buchholz relay.	1 No
8.	Expansion joint (complete replacement for reactor).	1 Set.
9.	Oil sampling bottle.	3 Nos.

N.B.:-

- (a) The Supplier shall ensure that sufficient spare parts and consumable items are available for his own use during commissioning of the reactor. The spares, provided with the reactor shall not be used by the supplier without the written consent of the Purchaser and any spares, used during the commissioning of the reactor shall be replaced by the supplier at his own expense.
- (b) The Supplier shall provide a list in the schedule, of additional recommended spare parts together with their individual prices. The Purchaser may order at a later date, at a price, indicated on the schedule, such additional spare parts, listed at the time of contract award.
- (c) Spares shall be available during the life of the equipment and the Supplier shall give 12 months notice of his or any Sub-Suppliers, intention to cease manufacture of any component used in the equipment.
- (d) Any spare apparatus, parts and tools shall be subject to the same Specification, tests and conditions as similar material, supplied under this contract. They shall be strictly interchangeable and suitable for use in place of the corresponding parts, supplied with the reactor and must be suitably marked and numbered for identification and prepared for storage by greasing and painting to prevent deterioration.
- (e) All spare apparatus or materials, containing electrical insulation shall be packed and delivered in cases, suitable for storing such parts or material over a period of years without deterioration. Such cases shall have to be affixed to both the underside and topside of the lid a list detailing its contents. The case will remain as the property of the Purchaser.

#### **5.5.24 OIL SAMPLING BOTTLE:**

- (i) Oil sampling bottle suitable for collecting oil sample from reactor for dissolved gas analysis shall be supplied. Bottles shall be robust enough so that no damage occurs during frequent transportation of samples.
- (ii) Oil sampling bottle shall be made of Stainless Steel having capacity of ONE litre.
- (iii) Oil sampling bottle shall be capable of being sealed gas tight and shall be fitted with cocks on both ends.
- (iv) The design of bottle & seal shall be such that loss of hydrogen shall not exceed 5% per week.
- (v) An impermeable oil proof transparent plastic or rubber tube of about 5 mm diameter and of sufficient length shall also be provide with each bottle along with suitable connectors to fit the tube on to the oil sampling valves of the equipment and the oil collecting bottle respectively.

#### **5.5.25 NITROGEN INJECTION TYPE FIRE PREVENTION & EXTINGUISHING SYSTEM:-**

**5.5.25.1 General:-** Scope of work is to design, supply, erection, testing and commissioning of Nitrogen Injection system for protection against the reactor explosion and fire for 400 KV Reactors including all required civil works of oil sump, foundations, any other required for satisfactory working of system. The NIFPS shall be guaranteed as per clause no. 18 of GTCC.

Each oil filled reactor shall be provided with a dedicated Nitrogen Injection system for prevention against the reactor explosion which shall use nitrogen as quenching medium. The system shall prevent reactor oil tank explosion and possible fire in case of internal / external cause. In the event of fire by external causes such as bushing fire, OLTC fires, fire from surrounding equipment etc., it shall act as a fast and effective fire fighter. It shall accomplish its role as fire preventer and extinguisher without employing water or carbon dioxide. Fire shall be extinguished within reasonable time (not more than 3 minutes so as not to harm the

reactor) of system activation and within 30 seconds (maximum) of commencement of nitrogen injection. The offered NIFPS system should have been in successful operation in Indian installations for at least last five years for protection of reactors of 220 KV and higher voltage class. The list of past supplies in India along with performance certificate from Central or State Government Power sector utilities, using the above system shall be submitted along with the bid offer.

Nitrogen Injection system should be a dedicated system for each oil filled reactor. It should have a Fire Extinguishing Cubicle (FEC) placed on a plinth at a distance of 5-10 m away from reactor / reactor or placed next to the firewall (if fire fighting wall exists). The FEC shall be connected to the top of reactor / reactor oil tank for depressurization of tank and to the oil pit (capacity is approximately equal to 10% of total volume of oil in reactor / reactor tank / or existing oil pit) from its bottom through oil pipes. The FEC should house a pressurized nitrogen cylinder (s) which is connected to the oil tank of reactor / reactor oil tank at bottom. The Reactor Conservator Isolation Valve (TCIV) is fitted between the conservator tank and Buchholz relay. Cable connections are to be provided from signal box to the control box in the control room, from control box to FEC and from TCIV to signal box. Detectors placed on the top of reactor / reactor tank are to be connected in parallel to the signal box by Fire survival cables. Control box is also to be connected to relay panel in control room for receiving system activation signals.

#### **5.5.25.2 Activation of the system**

The system shall work on the principle of Drain & stir. On activation, it shall drain a pre-determined quantity of oil from the tank top through drain valve to reduce the tank pressure, isolate conservator tank oil and inject nitrogen gas at high pressure from the bottom side of the tank through inlet valves to create stirring action and reduce the temperature of oil below flash point to extinguish the fire. On operation, the quantity of oil removed from the tank shall be such that adequate amount of oil shall remain to cover active part (i.e. core coil assembly).

Mal-functioning of the Nitrogen injection system could lead to interruption in power supply. The supplier shall ensure that the probabilities of chances of malfunctioning of the Nitrogen injection system are practically zero. To achieve this objective, the supplier shall plan out scheme of activating signals which should not be too complicated to make the system inoperative in case of actual need. The system shall be provided with automatic controls to prevent the explosion of reactors. Besides automatic control, remote electrical push button control at Control box and local manual control in the cubicle shall also be provided. The following electrical-signals shall be used for activating the system under prevention mode/fire extinguishing mode.

#### **5.5.25.2.a Auto Mode**

##### **For prevention:**

- Differential relay operation.
- Buchholz relay paralleled with pressure relief valve or RPRR (Rapid Pressure Rise Relay)
- Tripping of all circuit breakers (on HV & LV/IV side) associated reactor / reactor is the pre-requisite for activation of system.

##### **For extinguishing**

- Fire Detector



- Buchholz relay paralleled with pressure relief valve or RPRR (Rapid Pressure Rise Relay).

Tripping of all circuit breakers (on HV & LV/IV side) associated with reactor / reactor is the pre-requisite for activation of system.

#### **5.5.25.2.b Manual Mode (Local / Remote)**

Tripping of all circuit breakers (on HV & LV / IV side) associated with reactor / reactor is the pre-requisite for activation of system.

#### **5.5.25.2.c Manual Mode (Mechanical)**

- Tripping of all circuit breakers (on HV & LV / IV side) associated with reactor / reactor is the pre-requisite for activation of system.

The system shall be designed to be operated manually in case of failure of power supply to the system.

#### **5.5.25.3 Operation**

On receipt of all activating signals, the system shall drain - pre-determined volume of hot oil from the top of tank (i.e. top oil layer), through outlet valve, to reduce tank pressure by removing top oil and simultaneously injecting nitrogen gas at high pressure for stirring the oil at pre-fixed rate and thus bringing the temperature of top oil layer down. Reactor conservator isolation valve blocks the flow of oil from conservator tank in case of tank rupture / explosion or bushing bursting. Nitrogen occupies the space created by oil drained out and acts as an insulating layer over oil in the tank and thus preventing aggravation of fire.

- Electrical isolation of reactor shall be an essential pre-condition for activating the system, to avoid nitrogen injection in energized reactor.
- The system shall have provision of testing on live reactors to ensure healthiness at all times.
- The system shall have mechanical locking arrangement for nitrogen release system as well as oil drain to avoid unnecessary operation during maintenance and /or testing of the reactor and / or system.
- The system shall have provision to monitor nitrogen injection pressure as well as cylinder pressure.
- Pressure monitoring switch for back up protection for nitrogen release as redundancy to first signal of oil draining commencement for nitrogen release shall preferably be provided.
- System shall have individual mechanical release devices and provision for oil drain and nitrogen release to operate manually in case of operation DC supply failure.
- Nitrogen release scheme shall be designed in such a way that the nitrogen gas shall not enter the energized reactor tank even in case of passing / leakage of valve.
- Individual system component / equipment should operate on station DC voltage. AC-DC / DC-DC converter shall not be used for reliable operation.
- All outdoor panels / equipment shall be of IP-55 protection class.

#### **5.5.25.4 System components:-**

Nitrogen Injection system shall broadly consist of the following components. However, all other components which are necessary for fast, reliable and effective working of the system shall be deemed to be included in the scope of supply.

#### **5.5.25.4.a CUBICLE (FEC):-**

The Cubicle Frame shall be made of CRCA sheet of 3 mm (minimum) thick complete with the base frame, painted inside and outside with post office red colour (shade 538 of IS -5). It shall have hinged / hinged split doors fitted with high quality tamper proof lock. The doors, removable covers and panels shall be gasketed all round with neoprene gaskets. The degree of protection shall be IP55. The following items shall be provided in the Cubicle.

- Nitrogen gas cylinder with regulator and falling pressure electrical contact manometer.
- Oil drain pipe with mechanical quick drain valve.
- Electro mechanical control equipment for draining of oil of pre-determined volume and injecting regulated volume of nitrogen gas.
- Pressure monitoring switch for back-up protection for nitrogen release.
- Limit switches for monitoring of the system.
- Butterfly valve with flanges on the top of panel for connecting oil drain pipe and nitrogen injection pipes for reactor / reactors.
- Panel lighting (LED Type)
- Oil drain pipe extension of suitable sizes for connecting pipes to oil pit.
  - Space heater.

#### **5.5.25.4.b Under Ground Oil Storage Tank:-**

Each reactor unit shall be provided with an underground oil storage tank. The oil storage tank shall have Non Corrosive, water proof, epoxy coated (from Inside) mild steel (minimum thickness 6 mm) to store drained-out oil on operation of NIFPS. The tank shall be painted from outside as per Clause no. 5.4.8. The total capacity of storage tank shall be at least 10% of reactor tank oil to avoid overflowing of oil considering that drained oil volume shall be around 10% of reactor tank oil. Necessary arrangement shall be made on underground storage tank so as to take out the drained oil from the tank for further processing and use. All the pipes and physical connections from reactor to oil pit shall be in the scope of contractor.

This storage tank shall be placed in the pit made up of brick walls with PCC (1:2:4) flooring with suitable cover plates to avoid ingress of rain water. The design of tank and pit shall be finalized during detailed engineering.

#### **5.5.25.4.c Control box:-**

Control box is to be placed in the control room for monitoring system operation, automatic control and remote operation. The following alarms, indications, switches, push buttons, audio signal etc. shall be provided.

- System Oil.
- TCIV open.
- Oil drain valve closed.

- Gas inlet valve closed
- TCIV closed
- Detector trip
- Buchholz relay trip
- Oil drain valve open
- Extinction in progress
- Cylinder pressure low
- Differential relay trip
- PRV / RPRR /OSR trip
- Reactor / reactor trip
- System out of service
- Fault in cable connecting fault detector
- Fault in cable connecting differential relay
- Fault in cable connecting Buchholz relay
- Fault in cable connecting PRV / RPRR / OSR
- Fault in cable connecting reactor reactor trip
- Fault in cable connecting TCIV
- Auto / Manual / Off
- Extinction release on / off
- Lamp test
- Visual / Audio alarm for AC supply fail
- Visual / Audio alarm for DC supply fail

As far as possible, the control box should be so devised that all the reactors and reactors or group thereof should be controlled from single spot.

#### **5.5.25.4.d Reactor Conservator Isolation Valve:-**

Reactor conservator isolation valve (TCIV) is to be fitted in the conservator pipe line, between conservator and buchholz relay, which shall operate for isolating the conservator during abnormal flow of oil due to rupture / explosion of tank or bursting of bushing. The valve shall not isolate conservator during normal flow of oil during filtration or filling or refilling, locking plates to be provided with handle for pad locking. It shall have proximity switch for remote alarm, indication with visual position indicator.

The TCIV should be of the best quality as malfunctioning of TCIV could lead to serious consequence. The closing of TCIV means stoppage of breathing of reactor / reactor.

Locking plates shall be provided for pad locking.

#### **5.5.25.4.e Detectors:-**

The system shall be complete with adequate number of detectors (quartz bulb) fitted on the top cover of the reactor / reactor oil tank.

#### **5.5.25.4.f Signal box:-**

It shall be mounted away from reactor / reactor main tank, preferably near the reactor marshaling box, for terminating cable connections from TCIV & detectors and for further connection to the control box. The degree of protection shall be IP55.

#### **5.5.25.4.g Cables:-**

Fire survival cables (capable to withstand 750° C.) of 4 core x 1.5 sq. mm size for connection of detectors in parallel shall be used. The fire survival cable shall conform to BS 7629-1, BS 8434-1, BS 7629-1 and BS 5839-1, BS EN 50267-2-1 or relevant Indian standards.

Fire Retardant Low Smoke(FRLS) cable of adequate size shall be used for connection of signal box / marshaling box near reactor / reactor and FEC mounted near reactor/ reactor with control box mounted in control room.

Fire Retardant Low Smoke (FRLS) cable of 4 core x 1.5 sq. mm size shall be used for connection between control box to DC & AC supply source, FEC to AC supply source, signal box / marshaling box to reactor conservator isolation valve connection on reactor / reactor. Separate cables for AC supply & DC supply shall be used.

#### **5.5.25.4.h Pipes:-**

Pipes complete with connections, flanges, bends and tees etc. shall be supplied along with the system.

#### **5.5.25.4.i Other items to be supplied:-**

- a) Oil drain and nitrogen injection openings with gate valves on reactor / reactor tank at suitable locations.
- b) Flanges between Buchholz relay and conservator tank for fixing TCIV.
- c) Detector brackets on reactor / reactor tank top cover.
- d) Spare potential free contacts activating the system i.e. in differential relay, Bucholz relay. Pressure Relief Device / RPRR , Circuit breaker of reactor / reactor.
- e) Pipe connections between reactor / reactor and FEC and between FEC and oil pit required for collecting top oil.
- f) Cabling for detectors mounted on reactor / reactor top cover.
- g) Inter cabling between signal box, control box and FEC.
- h) Butterfly valves / Gate valves on oil drain pipe and nitrogen injection pipe which should be able to withstand full vacuum.
- i) Supports, signal box etc. which are to be painted with enameled paint.
- j) Any other item required for satisfactory operation of system.

#### **5.5.25.5 Power supply:-**

For Control Box: As per substation DC voltage.

For FEC Auxiliary: 230 V AC

#### **5.5.25.6 Modification on the reactor:-**

No modification on the reactor shall be allowed which affects its performance (i.e. efficiency, losses, heat dissipation ability etc.) safety, life etc. or its any other useful parameter. This requirement shall be of paramount importance and shall form the essence of the contract.

However, in any case, performance of reactor should not be affected in any manner by having Nitrogen Injection Fire Prevention Cum Extinguishing System (NIFPES) and the Contractor / Sub-Contractor shall give an undertaking to this effect. All pipes should be washed / rinsed with reactor oil. If any damage is done to the reactor and / or any connected equipment during installation, commissioning, full recovery therefore shall be effected from the Contractor / Sub-Contractor, of NIFPES system.

It shall be solely the responsibility of Contractor / Sub-Contractor to install, carry out pre-commissioning tests & commission NIFPES at the mentioned Sub-Station in this specification, to the entire satisfaction of the OPTCL.

#### **5.5.25.7 Interlocks:-**

It shall be ensured that once the NIFPES gets activated manually or in auto mode, all the connected breakers shall not close until the system is actually put in OFF mode. Also PRV shall get closed only if all the connected breakers are open.

#### **5.5.25.8 Tests:-**

Supplier has to carry out the type test as per relevant IS/IEC. Specifically IP 55 on FEC or have to produce the report from NABL approved Lab.

Reports of all routine test conducted as per relevant IS/IEC standards in respect of various bought out items including test reports for degree of protection for FEC / control box / signal box shall be submitted by the supplier.

The supplier shall demonstrate the entire functional tests, associated with the following as Factory Acceptance Tests:

- FEC, Control Box
- Fire Detector
- Reactor Conservator Isolation Valve

The performance test of the complete system shall be carried out after erection of the system with reactor at site.

Detailed layout drawings, equipment drawing along with 4 sets of Operation and Maintenance manual along with soft copies (In CDs) shall be submitted by the supplier along with the consignment.

The guaranteed technical particulars for the offered system are indicated in Ann-IV. Any other particulars, considered necessary in addition to those listed in that Section may be furnished by the Bidder.

#### **5.5.26 ON LINE INSULATING OIL DRYING SYSTEM (Cartridge type):-**

Each Reactor shall be provided with an on-line insulating oil drying system of adequate rating with proven field performance. This system shall be separately ground mounted and shall be housed in metallic (stainless steel) enclosure. The bidder shall submit the mounting arrangement. This on line insulating oil drying system shall be,

- i. Designed for very slow removal of moisture that may enter the oil system or generated during cellulose decomposition. Oil flow to the equipment shall be controlled through pump of suitable capacity (at least 5 LPM).
- ii. The equipment shall display the moisture content in oil (PPM) of the inlet and outlet oil from the drying system.
- iii. In case, drying system is transported without oil, the same shall be suitable for withstanding vacuum to ensure that no air / contamination is trapped during commissioning.

In case, drying system is transported with oil, the oil shall conform to OPTCL specification for unused oil. Before installation at site, oil sample shall be tested to avoid contamination of main tank oil.

- iv. Minimum capacity of moisture extraction shall be 10 Litres before replacement of cartridge. Calculation to prove the adequacy of sizing of the on line insulating oil-drying system along with make and model shall be submitted for approval of purchaser during detail engineering.
- v. The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.
- vi. The equipment shall be capable of transferring data to substation automation system conforming to IEC 61850 through FO port. Necessary interface arrangement shall be provided by the supplier for integration with automation system.  
The equipment shall be supplied with Operation Manual (2 sets for every unit), Software (if any), and Compact disc giving operation procedure, Maintenance Manual & Trouble shooting instructions.

#### **5.5.27 ON LINE DISSOLVED GAS (MULTI-GAS) AND MOISTURE ANALYSER:-**

- a. Online Dissolved Gas (Multi-gas) and Moisture Analyser along with all required accessories including in built display shall be provided with each Reactor for measurement & analysis of dissolved gases and moisture in the oil. Interpretations shall be as per IEC 60599-1999.
- b. The equipment shall detect, measure and analyse the following gases.

Gases & Moisture Parameters	Typical Detection Range
H <sub>2</sub>	5 – 5,000 ppm
CH <sub>4</sub>	5 – 5,000 ppm
C <sub>2</sub> H <sub>6</sub>	5 – 5,000 ppm
C <sub>2</sub> H <sub>4</sub>	3 – 5,000 ppm
C <sub>2</sub> H <sub>2</sub>	1 – 3,000 ppm
CO	10 – 10,000 ppm
CO <sub>2</sub>	20 – 30,000 ppm
H <sub>2</sub> O	2 – 100 % RS should have facility for measurement of moisture in oil in ppm

- c. The analyser should measure (not calculate) all above gases and should have 100 % sensitivity. The equipment shall be capable of transferring data to sub-station automation system confirming to IEC 61850. Necessary interface arrangement shall be provided by the supplier for integration with automation system. The necessary type test report for such confirmations shall be submitted during detailed engineering.
- d. Equipment shall have facility to give SMS to at least three users where ever any fault gas violates the predefined limit.

- e. Equipment should work on station auxiliary supply. In case other supply is required for the equipment then suitable converter shall be included. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier.
- f. Online DGA shall be installed out door on Reactor in harsh ambient and noisy condition (Electromagnetic induction, Corona and capacitive coupling). Equipment shall be mounted separately on ground. Suitable arrangement shall be provided to support and protect the inlet and outlet piping arrangement. The connecting oil lines must be of Stainless Steel rigid pipes or flexible hoses. The equipment shall be suitable for proper operation in EHV substation (800kV) environment where switching takes place in the EHV /HV System. The suitable indications for power On, Alarm, Caution, normal operation etc. shall be provided on the front panel of the equipment. The equipment shall have IP55 Stainless Steel enclosure, suitable for 55°C ambient temperature and EMI and EMC compatibility. The Equipment must carry a minimum of five (5) years manufacturer's Warranty.
- g. The equipment shall display all the individual gas and moisture concentration on its display unit and shall have facility to download all the stored the data from the unit for further analyses. The sampling rate shall be selectable as 2 or 4 or 6 or 12 hours etc. The equipment shall have inbuilt memory to store these results for complete one year even if sampling is done at the lowest interval. The carrier and calibration gas (if applicable) shall have minimum capacity to work for at least three years without replacement. All the consumable (if any) up-to warrantee period shall be included in the scope of supply.
- h. The equipment must have an automatic Calibration facility at fixed interval. For calibration if anything required including cylinder must be mounted with the Equipment.
- i. The technical feature of the equipment shall be as under

Accuracy	± 10%
Repeatability	± 3% to 10% depending upon gases
Oil temperature range	- 20 <sup>0</sup> C to + 120 <sup>0</sup> C
External Temp. Range	-20 <sup>0</sup> C to + 55 <sup>0</sup> C (External temp range of 55 <sup>0</sup> C is important and should not be compromised due to Indian ambient & operating conditions).
Humidity range	10 to 95%
Operating Voltage	250 Vac; 50 Hz (± 20% variation)
Communications	USB & IEC 61850 compliant

- j) Software for fault indication and fault diagnostics shall include following :

Fault indication:

- IEEE, IEC or user configurable levels of dissolved gases
- Rate of change trending

Fault Diagnosis:

- Key gases

- Ratios (Rogers, IEC. etc.)
  - Duval's Triangle
- k) The equipment shall be supplied with all necessary accessories required for carrying out DGA of oil sample complete in all respect as per the technical specification. The following shall also form a part of supply.
- i) Software
  - ii) Operation Manual (2 set for every unit)
  - iii) Software manual and
  - iv) Compact disc giving operation procedures of Maintenance Manual & Trouble shooting instructions.
- l) The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.

#### 5.6 **CENTRE OF GRAVITY:**

The center of gravity of assembled reactor shall be as low and as near the vertical center line as possible. The reactor shall be stable with and without oil. The location of the center of gravity, relative to track shall be clearly marked in the outline drawing, accompanying bid.

### 6.0 **INSPECTION AND TESTING:-**

#### 6.1 **TESTING FACILITIES:-**

- a) Bidders shall submit along with the bid, the details of testing facilities, available at their works for carrying out all the routine and type tests, as specified.
- b) In case, the test facilities for any particular test are not available at the bidder's works, this shall be clearly brought out in the additional information schedule and proposed arrangement of carrying out that test shall be clearly indicated.
- c) All the measuring systems, used for the tests have certified, traceable accuracy and are subjected to periodic calibration, according to the rules of 4.11 of ISO 9001[Ref-Cl.No.10 (Tests) of IEC-60076-1]
- d) OPTCL at its discretion may use their own testing equipment(s) or third party testing equipment(s) such as Power Analyzer, D.C. Resistance meter etc. during Routine test/Type test of the Reactors at the Bidder's Works. The test results of OPTCL/Third party instrument will be accepted for the purpose of the contract. During testing & inspection of the Reactor, it shall be ensured to the Inspecting Officers that there must be direct connections from the secondary of the unit auxiliary testing transformer and from the secondaries of the testing instrument reactors to the power analyzer without any termination or any other parallel connection, what so ever. The measuring instruments with connections should be positioned in such a manner that there shall be easy access to the above instruments / equipment at the time of testing by Inspecting Officers.

#### 6.2 **GENERAL:-**

Inspection and testing shall be carried out on the reactor as detailed here and generally in accordance with IEC-60076 and IS: 2026. The Purchaser shall have the right to reject a reactor, if test results do not comply with the standards/values, specified and information /data, given in the schedules. For the purpose of determining when type tests are required, a reactor is considered to be representative of others only if it is fully



identical in design, rating and construction.

Before and after acceptance testing, samples of oil shall be taken from the reactor and analyzed for dissolved gases, using the procedures, specified in IEC Publications 567 and 599. Results of the analysis of gases, dissolved in the oil shall be immediately submitted to the Purchaser and included in the Acceptance Test Report. On completion of acceptance testing, the Supplier shall provide the Purchaser with seven copies of the complete test reports.

**Full details of the proposed methods of testing including connection diagrams shall be submitted by the Supplier for approval at least one month before testing. All tests will be witnessed by the Purchaser.**

The Purchaser shall have full access at all times to the works and all other places of manufacture of the reactors. The Supplier shall report to the Purchaser monthly or other period, as agreed between the two on manufacturing progress. The Supplier shall give the Purchaser on award of contract a complete manufacturing inspection program to allow the Purchaser, at its discretion, to inspect at all stages of reactor manufacture.

### 6.3 **STAGE INSPECTION:-**

Stage inspection on core, windings, tank and all other accessories etc. will be carried out by the Supplier in the presence of OPTCL's representative on free of cost to OPTCL before tanking of the core and windings. All the measurements will be taken on the above components, so as to ensure their compliance to the above Specification and the Guaranteed Technical Particulars. The possible routine tests like measurement of Winding resistance, loss, determination of Knee Point Voltage, determination of number of turns in the windings, tank tests etc. will be conducted during stage inspection. The purchaser's representative at his discretion may choose small strips of core for testing at CPRI/ERDA. Also, a small piece of conductor for each type of winding and core material shall be made available to the purchaser's representative. Apart from the above, the purchaser at his discretion reserves the right to carry out the stage inspection at other stages also, for which advance intimation shall be given and all necessary co-operation shall be rendered by the manufacturer.

The Supplier shall give at least 3 weeks notice in advance for deputing Inspecting Officer(s) to their works. Type Tests and routine tests on the reactor shall be conducted only if the stage inspection report and the pre-tanking tests are found to be in order as per this Specification.

### 6.4 **FINAL INSPECTION& TESTING:-**

Before offering for final inspection, type tests and routine tests, the Supplier shall furnish the factory test results (except dielectric tests) of the offered reactor(s) along with list of equipments/meters/instruments, to be used, during testing (both routine and type tests) along with calibration certificates of measuring instruments. The Purchaser may direct the Supplier for use of better equipments/meters during inspection/testing. The calibration of all the meters/instruments to be used during testing should have been done in Government approved laboratory.

#### **A. List tests to be carried out on Reactors(As per test procedure mentioned at Cl. No- 6.4.1 & 6.4.2):-**

No	Item	Test Category
1	Temperature rise test	Type

2	Measurement of zero-sequence reactance	Type
3	IP-55 Test	Type
4	Measurement of winding resistance	Routine
5	Measurement of capacitance and dielectric dissipation factor of winding	Routine
6	Measurement of capacitance and dielectric dissipation factor of Bushings	Routine
7	Measurement of Insulation Resistance & Polarisation Index	Routine
8	Impulse Test(Full wave LI, Chopped wave impulse, Switching Impulse, Full wave LI on Neutral)	Routine
9	Separate source voltage withstand test/Applied Voltage test	Routine
10	Induced over-voltage withstand test with partial discharge measurement	Routine
11	Reactance and loss measurement	Routine
12	Measurement of Mutual Reactance	Routine
13	Measurement of harmonic content of current ( Measured in Cold state)	Routine
14	Two hours excitation test	Routine
15	Vibration & Stress measurement	Routine
16	Measurement of acoustic noise level	Routine
17	Knee point voltage measurement	Routine
18	Core assembly dielectric and earthing continuity tests	Routine
19	High voltage withstand test on auxiliary equipment & wiring after assembly	Routine
20	Oil BDV test	Routine
21	DGA test before and after all the tests	Routine
22	Frequency Response analysis	Routine
23	Oil Leakage test on tank	Routine
24	Tank Vacuum Test	Routine
25	Tank Pressure Test	Routine
26	Appearance, construction & dimension check	Routine
27	Pressure Relief Device Test	Routine
28	Dew point measurement test before dispatch	Routine
29	Jacking test on tank without fitting and accessories	Routine
30	Di-penetration (DP) test after jacking test	Routine

**B. List tests to be carried out on Neutral Grounding Reactors(As per test procedure mentioned at Cl. No-6.4.1 & 6.4.2):-**

No	Item	Test Category
1	IP-55 Test	Type
2	Full wave LI Test on Neutral Terminal	Type
3	Measurement of winding resistance	Routine
4	Measurement of Impedance by V/I	Routine
5	Measurement of capacitance and dielectric dissipation factor of winding	Routine
6	Measurement of capacitance and dielectric dissipation factor of Bushings	Routine
7	Measurement of Insulation Resistance	Routine

8	Full wave LI Test on Line Terminal	Routine
9	Separate source voltage withstand test/Applied Voltage test	Routine
10	Isolation test	Routine
11	Oil Leakage test on NGR tank	Routine
12	Appearance, construction & dimension check	Routine
13	High voltage withstand test on auxiliary equipment & wiring after assembly	Routine
14	Tank Vacuum Test	Routine
15	Tank Pressure Test	Routine
16	Oil BDV test	Routine
17	Pressure Relief Device Test	Routine

#### 6.4.1 **TYPE TESTS & SPECIAL TESTS:-**

The followings shall be regarded as type tests and shall be carried out in presence of Purchaser's representative on one unit out of the lot at the discretion of the purchaser. The charges for conducting each type test shall be quoted in the relevant price schedule.

##### (a) **Temperature Rise Test:-**

Temperature rise test shall be carried out in accordance with IEC - 60076.2. This test shall be performed at Maximum continuous operating voltage  $U_{max}$  and rated frequency. The reactor shall be tested by feeding the tested losses or quoted losses at  $U_{max}$ , whichever is higher. Gas chromatographic analysis on oil shall be carried out before and after the temperature rise test and the results recorded in the test report. Sampling shall be in accordance with IEC 60567. For evaluation of the gas analysis in temperature rise test, the procedure shall be as per IS: 9434 (based on IEC: 60567) and the results will be interpreted as per IS: 10593 (based on IEC-60599). These results shall be treated as reference during future maintenance of Reactors. The calibration of OTI and WTI shall be done by reactor manufacturer and these calibrated OTI; WTI shall be used during testing of the reactor. The Sr.No. of WTI and OTI should be recorded during testing of the Reactor and only these OTI & WTI shall be supplied with the Reactor. The Optic Fiber Temperature Sensor System shall be operational during temperature tests and be demonstrated during these tests. During probe verification, the hottest probes for each phase shall be identified and temperature data for all probes (hourly readings) recorded and reported in the test report. The final hot spot temperature rise of the windings above ambient temperature after completion of last one hour before taking shut-down for hot resistance measurement shall not exceed 54 deg. C and the top oil temperature rise above ambient temperature shall not exceed 40 deg. C.

The Temperature rise test shall be done for a minimum of 24 hours with saturated temperature for at least 4 hours. DGA tests shall be performed before & after heat run test and DGA results shall generally conform to IEC 61181.

During this test, following shall be measured.

- Voltage
- Current
- Reactance & Loss
- Audible sound
- Vibration
- Colour photographs of the four sides and the top of the reactor together with the corresponding series of thermal images (colour) during starting and end of the test. It is

also recommended to take thermal images 4 more times to take care of any unforeseen situation.

- Temperature measurement with internal probes during test.
- Temperature measurement with optic fiber temperature sensor.

The heat run type test results shall serve as a “finger print” for the other units to be routine tested.

Specified winding hotspot temperatures shall not be exceeded.

The temperature rises recorded by infra red shall not be more than 10°C above top oil temperature or 15°C above the local oil temperature.

Full details of the test arrangements, procedures and conditions shall be provided with the test certificates and the following shall at least be included.

- Purchaser’s order number
- Manufacturer’s name and reactor serial number.
- Rating of Reactor
- MVA
- Voltage
- Frequency
- Rated current
- Class of cooling
- Measured loss at 75°C
- Altitude of test bay

#### **Top oil and hot spot temperature rise test:**

A log of the following parameters taken at 30 minute intervals.

- Time
- Voltage
- Current
- Total power
- Ambient temperature measured on not less than three thermometers
- Top oil temperature by both conventional thermometer and optic fiber temperature sensor.
- Cooler inlet and outlet oil temperatures
- Infra-red pictures during the heating up phases
- The hot spot temperature of core & windings by optic fiber temperature sensor.

#### **Winding temperature rise test:**

- Record the weight of conductor in each winding and the losses in watts per kilogram, the ‘cold’ resistance of each winding and the simultaneous top oil and ambient air temperatures, together with the time required for the effect to disappear.
- Record of thermal time constant of the winding
- Log the half- hourly readings of parameters as for the top oil temperature rise test.
- Provide a table of readings, after shut-down of power, giving the following information;
  - Time after shut-down
  - Time increment
  - Winding resistance: Record of resistance values for minimum 20 minutes.
  - Resistance increment
  - X, where X is the time after shut-down divided by the thermal time constant of the winding and

➤  $Y$ , where  $Y = Y = 100 (1 - e^{-x})$

- (Any graphical/computer method used to determine the temperature of a winding by extrapolation to the instant of power shut-down shall produce a linear curve.)
- Provide a record of all calculations, corrections and curves leading to the determination of the winding temperatures at the instant of shut-down of power.
- Record any action taken to remedy instability of the oil surge device.

Temperature measurements as per special probes or sensors placed at various locations shall also be recorded.

(b) **Measurement of Zero Sequence Reactance:-**

The test shall be generally performed as per IEC 60076-1. This measurement shall be carried out at a voltage corresponding to a neutral current equal to the rated phase current.

(c) **IP-55 Test:-**

Cooler control cabinet for the reactor shall be tested for IP-55 protection in accordance with IS-2147/IEC-529.

**N.B.:-** 1) Any other test as per IS / IEC with amendments if any, shall also be carried out with no extra cost to OPTCL.

2) The reactor offered or higher capacity (Both MVAR & voltage rating) should have been tested as per the above type tests [6.4.1(a) to (c)] and Lightning Impulse tests, as prescribed in this specification in presence of authorized representative(s) of Government Utilities. The bidder shall furnish such type & special test reports including Lightning Impulse Test Report (with chopped Impulse) (indicating therein the type and design details) along-with the offer without which the tender may be rejected. These tests should have been conducted not before five years from the date of opening of bid.

6.4.2. **ROUTINE TESTS:-**

The followings shall be regarded as routine tests and shall be conducted on each reactor in the presence of purchaser's representative(s). No extra cost shall be paid for these tests.

(a) **Measurement of winding resistance(Reactor & NGR).**

After the Reactor has been under oil without excitation for at least 3 h, the average oil temperature shall be determined and the temperature of the winding shall be deemed to be the same as the average oil temperature. The average oil temperature is taken as the mean of the top and bottom oil temperatures.

In measuring the cold resistance for the purpose of temperature-rise determination, special efforts shall be made to determine the average winding temperature accurately. Thus, the difference in temperature between the top and bottom oil shall not exceed 5 K. To obtain this result more rapidly, the oil may be circulated by a pump.

(b) **Measurement of capacitance and dielectric dissipation factor of winding (Reactor & NGR).** (Before and after the series of dielectric tests).

Reactor shall be tested in GST mode only between winding to tank for the measurement of capacitance & tan delta of winding to earth by applying 2kV and 10kV. Tan delta of winding shall not exceed 0.5% at ambient temperature. No temperature correction factor shall be applied.

- (c) **Measurement of capacitance and dielectric dissipation factor of Bushings (Reactor & NGR).** (Before and after the series of dielectric tests).  
Bushings shall be tested in UST mode by applying 10kV and 2kV. Tan delta of bushing shall not exceed 0.4% at ambient temperature. No temperature correction factor shall be applied.
- (d) **Measurement of Insulation Resistance & Polarisation Index(Reactor & NGR):-**  
Measurement of D.C. insulation resistance between each winding to earth and between windings shall be carried out at 5000V DC. The polarisation index is a ratio of insulation resistance value at the end of 10 min test to that at the end of 1 min test at a constant voltage. It is recommended that PI value shall be better than or equal to 1.5, but less than or equal to 5.
- (e) **Impulse Test(Reactor & NGR as per test plan):**
- (i) Full Wave Impulse Voltage withstand Test: - The test voltage shall be applied to each line. The applied voltage shall be the relevant lightning impulse voltage, specified in the schedule of requirements.
  - (ii) Chopped wave impulse voltage withstand test: - The test voltage shall be applied to each line terminal. The applied voltage shall be 110% of the specified relevant lightning impulse voltage.
  - (iii) Switching Impulse Tests on each HV phase terminals as per relevant IEC shall be carried out.
  - (iv) An Lightning impulse test on reactor neutrals as per IEC-76-3 Clause 12.3.2 shall be carried out.
- Tests (i) and (ii) shall be combined in a single sequence as follows for each line terminal:-
1. One reduced full impulse.
  2. One 100% full impulse.
  3. One or more reduced chopped impulse(s).
  4. Two 100% chopped impulses.
  5. Two 100% full impulses.
- The sequence for test (iii) & (iv) shall be as follows:-
1. One reduced full impulse at 50-75% of full level.
  2. Three 100% full impulses.
- (f) **Separate source voltage withstand test/Applied Voltage Test(Reactor & NGR):-** The applied voltage shall be that specified in relevant IEC.
- (g) **Induced over-voltage withstand test with partial discharge measurement:-** Test shall be carried out as per IEC-76-3, clause 11.4 (Method 2).  
Partial discharge shall be determined using a broad band instrument during the whole application of long duration induced AC voltage test (ACLD) as per IS: 2026 (Part-3):2009 and IEC 60076-3. The voltage time envelope shall be as described in clause 11.4 of IEC 76-3. The apparent charge (q) shall be in accordance with IEC 60076-3.
- (h) **Reactance and loss measurement:-**
- a. The type tested unit shall be measured in the cold and hot state.
  - b. In other units, measurement shall be carried out in the cold state and corrected as per factors derived from the type tested unit.
  - c. Measurement shall also be carried out during 2-hour excitation test.
  - d. The following details shall be recorded under the heading of losses on the test certificate:

- Voltage reading
- Current reading
- CT & PT Ratio
- Tan delta
- the power reading
- total losses measured
- Total losses corrected to 75°C winding temperature
- the frequency reading
- the instrument constants and corrections (if any)
- The magnetization curve of the reactor (Type Tested unit)

**(i) Measurement of Mutual Reactance**

The measurement shall be made at rated voltage in accordance with IEC-60076-6 with latest amendment, if any.

**(j) Measurement of harmonic content of current ( Measured in Cold state):-**

The harmonics of the current in all three phases are measured at rated voltage, by means of a harmonic analyser. The magnitude of the relevant harmonics is expressed as a percentage of the fundamental component. For more information on the magnetic characteristic, see Annex B of IEC 60076-6. The harmonics of the applied voltage shall be adequately measured at the same time.

**(k) Two hours excitation test:-**

- Each reactor to be excited at 1 p.u. for 2 hours except type tested unit.
- Measure reactance, loss and vibration
- DGA rate interpretation shall be as per IEC/ CIGRE/ IEEE guidelines
- Test shall be performed before partial discharge test

**(l) Vibration & Stress measurement:-**

After all dielectric tests, reactor shall be energised at rated voltage and mark atleast 4 points on each side wall where vibration is more. Stress will be measured on the same points. Similar process shall be followed for 1.05Ur voltage.

The test conditions, method of measurement and maximum vibration level shall be as per IEC: 60076-6 (2007) with amendments thereof, if any.

(Vibration & stress measurement in Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units)

**(m) Measurement of acoustic noise level (Measured in Cold and Hot state of temperature rise test ):-**

Test shall be performed as per clause 7.8.12 of IEC 60076-6 and IEC 60076-10.

**(n) Knee point voltage measurement of reactor (Measured in Cold state):-**

The test shall be carried out as per IEC 60076-6 clause B.7.1 “DC current charging – discharging method (theory)” or applying AC voltage from 50%, 75%, 100%, 125%, 150%, 175% & 200% of rated voltage and measure the current at various voltages, determine the Knee point voltage and calculate the tolerance of reactance as per Cl.No- 5.5.8.k of this specification.

**(o) Core assembly dielectric and earthing continuity tests:-**

The insulation of the magnetic circuit and between the magnetic circuit and the core clamping structure, including core-bolts, bands and/ or buckles shall withstand the application of a test voltage of either 2 kVac or 3 kV dc for 60 seconds.

The insulation of core to tank, core to yoke clamp (frame) and yoke clamp (frame) to tank shall be able to withstand a voltage of 2 kV (DC) for 1 minute. Insulation resistance shall be minimum 1 GΩ for all cases mentioned above.

The continuity of the single-point earthing shall be verified before despatch. The results of the works tests shall be recorded on the test certificate, and shall include the resistance reading obtained from a measurement made between the core and core clamping structure by means of at least 1.5 kV ac or 2 kV dc. During erection, the supplier shall repeat this measurement at site. The records of these tests shall also be included in the test report.

**(p) High voltage withstand test on auxiliary equipment & wiring after assembly(Reactor & NGR).:-**

All auxiliary circuits shall be subjected to application of 2KV (rms) withstand test voltage. Correct operation of all auxiliary control circuits will be tested.

**(q) Oil BDV test(Reactor & NGR).**

**(r) DGA test before and after all the tests**

**(s) Frequency Response analysis:-**

The test shall be performed on each phase of the Reactor by taking open circuit response of complete winding as HV to neutral terminal and vice versa. The response shall be compared with other units of same design for reference. The supplier shall conduct the test at the time of final testing of the reactor and record the amplitude and phase shift results on CDS for subsequent analysis. The test shall also be carried out by the supplier before commissioning at site and compare this result with the results, obtained before dispatching the reactor and submit the report along with the above results in CDs for future analysis. Each reactor is subjected to FRA test and frequency responses, recorded as above and analysed in any of the following:-

- i) Shift in the response of the winding.
- ii) Differences between the responses of all the phases of the reactor.

FRA shall also be carried out without oil in main tank for reference purpose.

**(t) Oil Leakage test on tank(Reactor & NGR).:-**

All tanks and oil-filled compartments shall be tested for oil tightness by completely filling with oil of viscosity, not greater than that of insulating oil, conforming to IEC:60296 at the ambient temperature and applying a pressure, equal to the normal head of oil plus 35KN/Sq.m. (5 Psi), measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 hours for oil and 01 hour for air, during which time, no leakage shall occur. Bidder shall arrange for witnessing the leakage test of each tank.

**(u) Tank Vacuum Test(Reactor & NGR).:-**

All reactor tanks shall be subjected to full vacuum and tested at an internal pressure of 3.33 KN/Sq.m. (25 Torr) for one hour. The permanent deflection of plates after the vacuum has been released shall not exceed the values, specified below and the performance of the reactors shall not be affected in any way.

Horizontal length of flat plate (mm.)	Permanent deflection (mm.)
Upto and including 750	5.0
751 to 1250	6.5
1251 to 1750	8.0
1751 to 2000	9.5
2001 to 2250	11.0
2251 to 2500	12.5



2501 to 3000	16.0
Above 3000	19.0

**(v) Tank Pressure Test(Reactor & NGR):-**

All reactor tanks of each size together with its radiators, conservator vessel and other fittings shall be subjected to a pressure, corresponding to twice the normal head of oil or to the normal pressure plus 35KN/Sq.m. whichever is lower. The applied pressure shall be measured at the base of the tank and maintained for one hour. The permanent deflection of flat plates after excess pressure has been released shall not exceed the values, specified in (u) above.

**(w) Appearance, construction & dimension check(Reactor & NGR).**

**(x) Pressure Relief Device Test(Reactor & NGR):-**

The pressure relief device of each size shall be subjected to increasing oil pressure. It shall operate before reaching the test pressure, specified at Cl.No.5.4.4 of this specification. The operating pressure shall be recorded. The device shall seal off after the excess pressure has been relieved. The following functional checks shall be conducted as acceptance tests on each of the pressure relief devices.

- i) Air- Pressure Test.
- ii) Liquid Pressure Test.
- iii) Leakage Test.
- iv) Contact Test.
- v) Di-electric Test.

**(y) Dew point measurement test before despatching:-**

Positive Gas pressure is generally maintained at 0.175 Kg/m<sup>2</sup> during transportation and during storage. To ensure the same, dew point measurement shall also be carried out at site. The procedure and acceptance limits are as per CBIP Manual Pub. No.295 (2006) or latest.

**(z) Jacking test on reactor tank without fitting and accessories.**

**(aa) Di-penetration (DP) test after jacking test.**

**(bb)Routine tests on neutral grounding reactor:-** In addition to the routine tests listed above, the volt-current characteristics test shall also be carried out on each neutral grounding reactor preferably at least upto short time rated current. Calculated value of hot spot temperature shall be furnished by the Contractor. Further, Lighting impulse voltage withstand test and ohmic value measurement shall also be carried out.

**6.4.3 TESTS ON SITE:-**

The following site tests shall be performed on all units:-

- a) General mechanical checks.
- b) Core and winding insulation tests (Earth fault check on arrival at site).
- c) Buchholz device tests.
- d) Silicagel breather check.
- e) Temperature instrument calibration and tests.
- f) Electric strength tests on insulating oil.
- g) Bushing tests.
- h) Winding resistance
- i) Correct operation of all C.Ts
- j) On-load tests.
- k) Capacitance & Tan-Delta of Winding & Bushing
- l) DGA
- m) SFRA

## **7.0 TEST REPORTS:-**

- (a) Two (2) sets of certified test reports and oscillograms shall be submitted for approval prior to the despatch of the equipment. The equipment shall be despatched only when all the required type and routine tests have been carried out and test reports have been approved by the Purchaser.
- (b) Each test report shall contain the following informations:-
  - (i) Complete identification, date, including serial number of the reactor.
  - (ii) Method of application, where applied, duration and interpretation of test results for each test.
- (c) Two (2) copies of the test reports for the tests carried out on the ancillary apparatus be furnished to the Purchaser for approval prior to despatch.
- (d) All auxiliary equipment/accessories shall be tested as per the relevant standards for the tests, as mentioned in this Specification. Test Certificates for the same shall be submitted to the Purchaser in four copies for scrutiny and record.

## **8.0 LIST OF REACTOR ACCESSORIES AND TEST CERTIFICATES REQUIRED FOR THEM:-**

Before offering for stage inspection of the Reactor, the supplier shall have to furnish the test certificates for the Reactor accessories, as enumerated below, wherever required.

<b>Sl. No.</b>	<b><u>Accessory</u></b>	<b><u>Ref. Standard</u></b>	<b><u>Test Certificates required.</u></b>
1.	RIP Bushing	IS-2099	<ul style="list-style-type: none"><li>1. Appearance, construction and dimensional check.</li><li>2. Test for leakage of internal filling at a pressure of 1.Kg/Cm<sup>2</sup> for 12h.</li><li>3. Insulation resistance measurement with 2 KV megger.</li><li>4. Dry power frequency voltage withstand test.</li><li>5. Dry power frequency voltage withstand test for test tap insulation.</li><li>6. Partial discharge measurement</li><li>7. Measurement of tan delta and capacitance.</li><li>8. Thermal stability</li><li>9. Measurement of PD</li><li>10. Switching Impulse Voltage withstand test</li></ul>
2.	Winding temperature indicator.		<ul style="list-style-type: none"><li>1 Calibration test.</li><li>2 Dielectric test at 2 KV for one minute.</li><li>3 Accuracy test for indication and switch setting scales.</li><li>4 Test for adjustability of switch setting.</li><li>5 Test for switch rating.</li><li>6 Measurement of temperature rise with respect to the heater coil current.</li></ul>
3.	Oil temperature indicator.		<ul style="list-style-type: none"><li>1 Calibration test.</li><li>2 Dielectric test of 2 KV for one minute.</li><li>3 Accuracy test for indication and switch setting scales.</li><li>4 Test for adjustability of switch setting.</li></ul>

			5 Test for switch rating.
4.	Pressure Relief Valve.		1 Functional test with compressed air to check bursting, pressure indication, flag operation and switch operation. 2 Dielectric tests at 2 KV for one minute. 3 Switch contact testing at 5A, 240V AC.
4.	Buchholz ` Relay.	IS-3637	1. Leak test with reactor oil at a pressure of 3 Kg. /Cm <sup>2</sup> for 30 minutes at ambient temperature for relay casing. 2. Insulation resistance measurement with 500 V Megger. 3. Dielectric test at 2 KV for 1 minute. 4. Elements' test at 1.75 Kg/ Cm <sup>2</sup> for 15 minute using reactor oil at ambient temperature. 5. Loss of oil and surge test. 6. Gas volume test. 7. Mechanical strength test. 8. Velocity calibration test. 9. Appearance, construction and dimensional check. 10. IP- 55 on Terminal Box
5.	Oil level Indicators.		1 Test for oil levels. 2 Switch operations for low level alarm. 3 Switch contact test at 5A, 240V, A.C. 4 Dielectric tests at 2 KV for 1 minute. 5 Appearance, construction and dimensional check.
6.	Pressed Steel Radiators.		1. Air pressure test at 2 Kg/ Cm <sup>2</sup> under water for 15 minutes. 2. Appearance, construction and dimensional check. 3. Quality of hot dip galvanization along with thickness of galvanization
7.	Bushing current transformer.	IS-2705	1. Appearance, construction and dimensional check. 2. Polarity check. 3. Measurement of insulation resistance. 4. High voltage power frequency test. 5. Determination of ratio error and phase angle of measuring and protection BCTS. 6. Determination of turns ratio error for PS Class BCTS. 7. Inter-turn insulation withstand test. 8. Excitation current characteristic test. 9. Secondary winding resistance measurement. 10. Knee-point voltage measurement for PS Class BCT.
8.	Pressure check.		1. Appearance, construction and dimensional

gauges/  
differential  
pressure  
gauges.

2. Calibration test.
3. Alarm contact setting test.

9. Air Cell

Oil side coating, Air side undercoating, Air side outer coating and coated fabric as per IS-3400 /BS-903/IS-7016.

10. Test reports of Valves as per Cl.4. 6.4 of CBIP publication No -317.

11. Test reports of all other accessories as per relevant standard.

**9.0 INSPECTION:-**

**9.1 GENERAL:-**

- (i) The purchaser shall have access at all times to the works and all other places of manufacture where the reactor is being manufactured and the supplier shall provide all facilities for unrestricted inspection of the supplier's works, raw materials, manufacture of all the accessories and for conducting necessary tests, as detailed herein.
- (ii) The supplier shall keep the purchaser informed in advance of the time of starting and of the progress of the manufacture of the equipment in its various stages so that arrangements could be made for inspection.
- (iii) No material shall be despatched from its point of manufacture unless the material has been satisfactorily inspected and tested.
- (iv) The acceptance of the equipment shall in no way relieve the supplier of his responsibility for meeting all the requirements of this specification and shall not prevent subsequent rejection of such equipment, if found to be defective later.

**9.2 INSPECTION PROGRAMME:-**

- (a) The supplier shall chalk out a detailed inspection and testing programme for manufacturing activities for the various components. An indicative programme of inspection as envisaged by the purchase is given below. This is not however intended to form a comprehensive programme, as it is supplier's responsibility to draw up and carry out such a programme, duly approved by the Purchaser. Stage inspection on core and winding will be carried out before tanking of core. For this, the supplier shall give at least ten days notice in advance. **The purchaser reserves the right to carry out the stage inspection, final inspection & testing by a third party.**
- (b) Additional tests, if required, are deemed to be included in the scope of work.
- (c) Stages of inspection and purchaser's participation would be defined and tied up at the time of award of contract within 15 days of issue of the Purchase order.
- (d) The supplier shall arrange all his tests in such a fashion that the inspection and testing shall not exceed 5 (five) days for the above reactor.
- (e) On site testing, if any discrepancies will occur, the supplier will be asked immediately for its rectification and the supplier shall depute his representative for rectification without any delay.
- (f) At the time of final inspection, the supplier shall identify each & every item/accessories of the particular Reactor under testing. Unless all the items are identified, the manufacturing will not be treated as complete. Serial No. of bushings, WTI, OTI and other details shall be entered into the Test reports to ensure that these items are not being applied to the subsequent Reactor units while testing. Various tests as per the

specification shall be performed in the presence of OPTCL Engineers or when the inspection waiver has been given, in such a case, the testing as per the specification shall be done at the manufacturers works and same should be confirmed by documentary evidence by way of Test Certificate, which shall be got approved by OPTCL.

- (g) In case, for any reason(s), inspection is not completed or the equipment is not found to be complete with all accessories as per confirmation, given with the inspection call, the purchaser reserves the right to recover the complete cost of deputation of inspection team to the works of the manufacturer.
- (h) The supplier shall submit the test certificates of the bought-out items and Raw materials at the time of the routine testing of the fully assembled equipment.
- (i) It may be noted that "No change in any accessory or associated equipment after passing all the tests successfully shall be allowed and if this is subsequently detected, it shall be binding on the supplier to replace with the same item with which the initial tests were conducted at his works, failing which the entire test shall become null & void. The purchaser at his discretion may consider for rejection of the units, thus supplied. The entire cost for replacement of such rejected units, thus supplied and for repeating acceptance tests shall be borne by the suppliers.

#### 9.2.1 **TANK AND CONSERVATOR:-**

- (a) Certification of chemical analysis and material test of plates.
- (b) Check for flatness.
- (c) Electrical interconnection of top and bottom by braided tinned copper flexible
- (d) Welder's qualification and welding procedure.
- (e) Testing of electrodes for quality of base materials and coatings.
- (f) Inspection of major weld preparation.
- (g) Crack detection of major strength weld seams by dye penetration test.
- (h) Measurement of film thickness of:
  - (i) Oil insoluble varnish.
  - (ii) Zinc chromate paint.
  - (iii) Finished coat.
- (i) Check correct dimensions between wheels, demonstrate turning of wheels through 90 degree and further dimensional check.
- (j) Check for physical properties of materials for lifting lugs, jacking pads etc. All load bearing welds including lifting lug welds shall be subjected to N.D.T.
- (k) Leakage test of the conservator.
- (l) Quality of spray galvanization of tank bottom with thickness of galvanization
- (m) Certification of all test results.

#### 9.2.2 **CORE:**

- (a) Sample testing of core material for checking specific loss, bend properties, magnetization characteristics and thickness.
- (b) Check on the amount of burrs.
- (c) Bow-check on stampings.
- (d) Check for overlapping of stampings, corners of the sheets are to be apart.
- (e) Visual and dimensional check during assembly stage.
- (f) Quality of core packets
- (g) Quality of spacers
- (h) Check for inter laminar insulation between core sections, before and after pressing.

- (i) determination of knee point voltage.
- (j) Visual and dimensional checks for straightness and roundness of core, thickness of limbs and suitability of clamps.
- (k) High voltage test (2 KV for one minute) between core, its bolts and clamps.
- (l) Certification of all test result.

#### 9.2.3 **INSULATING MATERIAL.**

- (a) Sampling check for physical properties of materials.
- (b) Check for dielectric strength.
- (c) Visual and dimensional check.
- (d) Check for the reaction of hot oil on insulating materials.
- (e) Dimensional stability test at high temperature for insulating material.
- (f) Tracking resistance test on insulating materials.
- (g) Certification of all tests results.

#### 9.2.4 **WINDING:**

- (a) Sample check on winding conductor for mechanical properties and electrical conductivity.
- (b) Check insulating distance between high voltage connection, cables and earth and other live parts.
- (c) Check for proper cleanliness and absence of dust.
- (e) Visual dimensional checks on conductor for scratches, dent marks etc.
- (f) Sample check on insulating paper for PH value, electric strength & bursting strength.
- (g) Check for the bonding of insulating paper on the conductor.
- (h) Check for absence of short circuit between parallel strands.
- (i) Check for brazed joints wherever applicable.
- (j) Conductor flexibility test.
- (k) Certification of all test results.

#### 9.2.5 **CHECKS BEFORE DRYING PROCESS:**

- (a) Check condition of insulation on the conductor and between the windings.
- (b) Check insulation distance between high voltage connections, cables and earth and other live parts
- (c) Insulation of core shall be tested at 2 kV/minute between core and Yoke clamps, Yoke clamps to tank and Core to Tank
- (e) Check for proper cleanliness and absence of dust etc.
- (f) Certification of all test results

#### 9.2.6 **CHECKS DURING DRYING PROCESS:**

- (a) Measurement and recording of temperature, vacuum and drying time during vacuum treatment.
- (b) Check for completeness of drying by measuring IR value and TAN DELTA. Polarisation index of the winding i.e., ratio of IR value taken at 10 minutes to 1 minute shall be taken. The P.I. Value should not be less than '1.5' or more than '5'.
- (c) Certification of all test results.

#### 9.2.7 **ASSEMBLED REACTOR:**

- (a) Check completed reactor against approved out line drawings, provision for all fittings,

finish level etc.

- (b) Test to check effective shielding of the tank
- (c) Jacking test with oil on the assembled reactors.
- (d) Dye Penetration (DP) test shall be carried out after jacking test.

#### 9.2.8 **OIL:**

Site test shall be performed on oil samples before and after filling in the reactor. Oil parameters shall conform to relevant IEC & IS prior to filling at site and oil samples taken from the tank top, bottom and cooling system after filling shall possess characteristics as per above standards. The supplier shall warrant that oil furnished is in accordance with the relevant clause of this specification. The purchaser at his discretion may send oil sample(s) to Govt. approved laboratory for determination of quality of oil including confirmation on percentages of naphthenic and paraffinic content, as specified at Cl. No.5.5.16 (a) of this Specification.

#### 9.2.9 **Bought Out Items:**

The makes of all major bought-out items shall be subject to purchaser's approval. The supplier shall also prepare comprehensive inspection and testing programme for all bought-out/sub-contracted items and shall submit the same to the purchaser for approval. Such programme shall include the following components.

- (a) Buchholz Relay.
- (b) Axles and wheels.
- (c) Winding temperature indicators for local and remote mounting.
- (d) Oil temperature indicators.
- (e) Bushings.
- (f) Bushing current transformers.
- (g) Marshalling box.
- (h) Cooling equipment.
- (i) Terminal connectors.
- (j) Pressure relief device

The above list is not exhaustive and the supplier shall also include other bought-out items in his programme.

#### 9.2.10 **TYPE TESTS ON FITTINGS:**

All the following fittings shall conform to type tests and the type test reports shall be furnished by the contractor along with the drawings of equipment/ fittings. The list of fittings and the type test requirement is:

- 1) Bushing (Type Test as per IEC:60137 including Snap back/Seismic test for 400 kV and above voltage class bushing)
- 2) Buchholz relay (Type Test as per IS: 3637 and IP-55 Test on terminal box )
- 3) Marshalling box (IP-55 test)
- 4) Pressure Relief device Test  
The pressure Relief Device of each size shall be subjected to increase in oil pressure. It shall operate before reaching the test pressure specified in reactor tank pressure test above. The operating pressure shall be recorded. The device shall seal off after excess pressure has been released.  
The terminal box / boxes of PRD shall conform to degree of protection of IS 13947 / Equivalent IEC standard.
- 5) Sudden Pressure Relay Test

- 6) Magnetic Oil Level gauge & Terminal Box for IP-55 degree of protection.
- 7) Air Cell (Flexible air separator) - Oil side coating, Air side under Coating, Air side outer coating and coated fabric as per IS: 3400/ BS: 903/ IS: 7016
- 8) OTI & WTI

### **9.3 PRE-SHIPMENT CHECK AT SUPPLIER'S WORKS:**

- (a) Check for proper packing and preservation of accessories like radiators, Bushings, dehydrating breather, rollers, Buchholz relay, control cubicle, connecting pipes, conservator etc.
- (b) Check for inter-changeability of components of similar reactors for mounting dimensions.
- (c) Check for proper provision of bracing to arrest the movement of core and winding assembly inside the tank.
- (d) Gas tightness test to conform tightness and record of dew point of gas inside the tank.
- (e) Derivation of leakage rate and ensure adequate reserve gas capacity.
- (f) Items must be clearly identified by assigning a number, which needs to be tallied with challan.

### **9.4 INSPECTION AND TESTING AT SITE**

The Contractor shall carry out a detailed inspection and testing programme for field activities covering areas right from the receipt of material stage up to commissioning stage. An indicative programme of inspection as envisaged by the Purchaser is given below. However, it is contractor's responsibility to draw up and carry out such a programme duly approved by the Purchaser. Testing of oil sample at site shall be carried out as per specification.

### **9.5 RECEIPT AND STORAGE CHECKS**

- (a) Check and record condition of each package, visible parts of the reactor etc. for any damage.
- (b) Check and record the gas pressure in the reactor tank as well as in the gas cylinder.
- (c) Visual check for wedging of core and coils before filling up with oil and also check conditions of core and winding in general.
- (d). Check and record reading of impact recorder at receipt and verify the allowable limits as per manufacturer's recommendations.

### **9.6. INSTALLATION CHECKS**

- (a) Inspection and performance testing of accessories.
- (b) Check whole assembly for tightness, general appearance etc.
- (c) Oil leakage test
- (d) Capacitance and tan delta measurement of bushing before fixing/connecting to the winding, contractor shall furnish these values for site reference.
- (e) Leakage check on bushing before erection.

### **9.7 RECOMMENDED COMMISSIONING CHECKS:**

- (a) Check the colour of sillicagel breather.
- (b) Check the oil level in the breather housing, conservator tanks, cooling system, condenser bushing etc.
- (c) Check the bushing for conformity of connection to the lines etc. and tan delta test for bushings at 10 KV (min.)
- (d) Check for correct operation of all protection devices and alarm/trip.



- (i) Buchholz Relay.
- (ii) Excessive winding temperature.
- (iii) Excessive oil temperature.
- (iv) Low oil flow.
- (v) Low oil level indication.
- (e) Check for the adequate protection of the electric circuit supplying the accessories.
- (f) Check resistance of all windings.
- (g) Insulation resistance measurement of:
  - (i) Control wiring.
  - (ii) Main windings.
- (h) Check for cleanliness of the reactor and the surroundings.
- (i) Continuously observe the reactor operation for 24 hours.
- (j) Check the operation with respect to temperature rise, noise level etc.
- (k) Capacitance & Tan delta measurement of windings and bushings.
- (l) Frequency response analysis (FRA). FRA equipment shall be arranged by the supplier.
- (m) DGA of oil just before commissioning and after 24 hours energisation at site.
- (n) Supplier shall prepare a comprehensive commissioning report including all commissioning test results as per Pre-Commissioning Procedures and forward to Purchaser for future record.

#### **10.0 QUALITY ASSURANCE PLAN:**

The Bidder shall invariably furnish following information alongwith his offer, failing which the offer shall be liable for rejection.

- (i) Statement giving list of important raw materials, names of Sub-suppliers for the raw materials, list of standards according to which the raw materials are tested, list of tests normally carried out on raw material in presence of Bidder's representative, copies of test certification.
  - (ii) Information and copies of test certificates as in (i) above in respect of bought out items.
  - (iii) List of manufacturing facilities available.
  - (iv) Level of automation achieved and list of areas where manual processing exists.
  - (v) List of areas in manufacturing process, where stage inspections are normally carried out for quality control and details of such tests and inspection.
  - (vi) Special features provided in the equipment to make it maintenance free.
  - (vii) List of testing equipments available with the Bidder for final testing of equipment specified and test plant limitation, if any, vis-à-vis the type, special, acceptance and routine tests specified in the relevant standards. These limitations shall be very clearly brought out in 'Schedule of Deviations'.
- 10.1 The supplier shall within 30 days of placement of order, submit the following informations to the purchaser.
- (i) Name of the raw materials as well as bought- out accessories and the names of sub-suppliers selected from those furnished along-with the offer.
  - (ii) Type test certificates of the raw material and bought out accessories.
  - (iii) Quality Assurance Plan (QAP) withhold points for purchaser's inspection. The QAP and hold points shall be discussed between the purchaser and the supplier before the QAP is finalised. The QAP shall include all the quality checks as stipulated in this specification.
- 10.2 The supplier shall submit the routine test certificates of bought out items and raw materials at the time of routine testing of the fully assembled reactor.

## **11.0 DOCUMENTATION:**

- 11.1 All drawings shall conform to relevant International Standards Organisation (ISO) specification. All drawing shall be in ink and suitable for micro filming. All dimensions and data shall be in S.I. Units.
- 11.2 The Bidder shall furnish along-with the bid dimensional drawings of reactor, core & winding assembly along with separate drawings for core, core packets spacers and windings and all other accessories. These drawing shall include the following information.
- (a) Dimensions.
  - (b) Tolerances on dimensions.
  - (c) Material designation used for different components with reference to standards.
  - (d) Fabrication details such as welds, finishes and coatings.
  - (e) Catalogue or part members for each component and the total assembly with bill of materials.
  - (f) Identification marking.
  - (g) Weight of individual components and total assembled weight.
- 11.3 The supplier shall, within 15 (fifteen) days of placement of order submit the final version of following drawings/ documents in AutoCAD format and two sets in hard copy for purchaser's approval. All Drawings and Designs in complete shape (not in a piece-meal manner) as per the specification and without any deviation should be submitted within 15 (Fifteen) days of placement of Purchase Order.
- a) Outline dimensional drawings of reactor and accessories. The clearances between Voltage terminals and ground should be shown.
  - b) Table of fittings for OGA.
  - c) Combined Rating and Diagram plate. It should contain various weights (core, winding, oil etc.), C.T. ratio (WTI CT, OTI CT, all bushings CT) HV Bushing.
  - d) HV Bushing.
  - e) HVN Bushing.
  - f) Twin Bi-directional Roller. Detailed drawing showing wheel loading and its center of gravity.
  - h) Valve schedule plate
  - i) Detailed Foundation drawings along with structural drawings showing design criteria and loadings.
  - j) Oil filling Instruction plate.
  - k) On line Drying System
  - l) GA of Marshalling Kiosk.
  - m) Assembly of core with details of radially laminated core packets, spacers along with dimensions and weights etc.
  - n) Details of winding arrangement, conductor cross-section & weights etc.
  - o) CT rating plate.
  - p) Schematic diagram showing the flow of oil in the cooling system as well as each limb and winding Longitudinal and cross-sectional view showing the duct sizes, cooling pipes etc. for the reactor/ heat exchanger, drawn to scale shall be furnished.
  - q) Inter connection-cabling diagram between reactor and all panels.
  - r) Complete bill of materials.
  - s) Detailed dimensions, assembly and description of auxiliaries.
  - t) Constructional details of tank including material, dimensions thickness,

reinforcing members, used, if any along with the measures taken to reduce vibration.

- u) Galvanizing and painting procedure.
- v) Factory Test procedures, lay-out of testing equipment/circuits and Test schedules for tests.
- w) Commissioning test procedure and report.
- x) Operation and Maintenance Manual.
- y) QAP during manufacturing and during erection of the reactor.
- z) Nitrogen injection system for protection against Fire & Explosion
- aa) Any other drawings(s) as required by the purchaser.
- bb) Dehydrating Breather
- cc) Optic fiber temperature sensor
- dd) RIP Bushing
- ee) On line insulating oil drying system
- ff) On line Dissolved Gas (Multi Gas) & Moisture Analyzer

The purchaser shall communicate his comments/ approval on the drawings/documents to the supplier within reasonable period. The supplier shall, if necessary, modify the drawings and resubmit two copies of the modified drawings for purchaser's approval within one week from the date of comments.

#### **11.4 DESIGN REVIEW:-**

- 11.4.1. The Reactors shall be designed, manufactured and tested in accordance with the best International Engineering Practices under strict Quality Control to meet the requirements, stipulated in the Technical specification. Adequate safety margin with respect to thermal, mechanical, di-electric, electrical stresses and electrical clearances shall be maintained during design, selection of raw materials, manufacturing process etc. so that the Reactor provides long life with least maintenance.
- 11.4.2. Raw material and sub-vendors used by reactor manufacturer shall be declared before commencement of manufacturing. The validity of Type tests of Reactor shall be 5 years as on the originally scheduled date of bid opening, provided that offered reactor design is identical to the type tested reactor and same active materials (CRGO, Conductor and Insulation) of same grade & from the same sub-vendors are used. In case of any change of either active materials or sub-vendors, the type tests shall be carried out by the supplier at no extra cost to Purchaser. Reactor type test report from the same manufacturing plant shall only be acceptable.
- 11.4.3 The design review will commence after placement of award with successful Bidder and shall be finalized before final drawing approval. The supplier shall depute their design engineer(s) to OPTCL for design review and finalization of drawings. However, the entire responsibility of design shall rest with the manufacturer.
- 11.4.4 The representative of the purchaser may visit to the manufacturer's works to inspect design, manufacturing and testing facilities.
- 11.4.5 The design review shall be conducted generally following the "Guidelines for conducting design reviews, prepared by CIGRE SC12 working Group 12.22 and as per Appendix-VI(Design Review parameters) of CBIP Publication No – 317.
- 11.4.6 The manufacturer will be required to demonstrate the use of adequate safety margin for thermal, mechanical, dielectric stress and vibration etc. to take into account the uncertainties of his design and manufacturing processes.

11.4.7 The scope of such a design review shall at least include the followings:-

**Design Review Document for Shunt Reactor**

<b>Sr. No.</b>	<b>Description</b>
1.	Core and Magnetic Design
2.	Over-fluxing and Linear characteristics
3.	Inrush-current characteristics while charging
4.	Winding and winding clamping arrangements
5.	Short-circuit withstand capability considering inrush current.
6.	Thermal design including review of localised potentially hot area
7.	Cooling design
8.	Overload capability
9.	Eddy current losses
10.	Seismic design, as applicable
11.	Insulation co-ordination
12.	Tank and accessories
13.	Bushings
14.	Protective devices
15.	Radiators
16.	Sensors and protective devices– its location, fitment, securing and level of redundancy
17.	Oil and oil preservation system
18.	Corrosion protection
19.	Electrical and physical Interfaces with substation
20.	Earthing (Internal & External)
21.	Processing and assembly
22.	Testing capabilities

23.	Inspection and test plan
24.	Transport and storage
25.	Sensitivity of design to specified parameters
26.	Acoustic Noise
27.	Spares, inter-changeability and standardization
28.	Maintainability
29.	PRD and SPR (number & locations) and selection
30.	Conservator capacity calculation
31.	Winding Clamping arrangement details with provisions for taking it "in or out of tank"
32.	Conductor insulation paper details
33.	Location of Optical temperature sensors
34.	The design of all current connections
35.	Location & size of the Valves
36	Any other design review as deemed to be necessary

Note: Design review document for NGR shall be decided during detailed engineering.

11.5 The supplier shall also furnish two copies of bound manuals for each reactor covering erection, commissioning, operation and maintenance instructions and all relevant information and drawings pertaining to the main equipment as well as auxiliary devices. Marked erection drawings shall identify the component parts of the equipment as shipped to enable purchaser to carry out erection with his own personnel. Each manual shall also contain one set of all the approved drawings, type test reports as well as acceptance reports of the corresponding consignment despatched.

11.6 The manufacturing of the equipment shall be strictly in accordance with this Specification, approved drawings and no deviation shall be permitted without the written approval of the purchaser. All manufacturing and fabrication work in connection the equipment prior to the approval of the drawings shall be at the supplier's risk.

However, approval of the drawings by the purchaser shall not relieve the supplier of his responsibility and liability for ensuring correctness and correct interpretation of the latest revision of applicable standards, rules and codes of practices. The Reactor shall conform in all respects to high standards of engineering, design, workmanship and latest revisions of relevant standards at the time of ordering and the purchaser shall have the power to reject any material, which in his judgement is not in full accordance therewith.

### **11.7 TEST REPORTS:**

- (i) Two copies of type test reports shall be furnished to the purchaser. One copy will be returned duly certified by the purchaser to the supplier.
- (ii) Two copies of routine test reports shall be furnished to the purchaser. One copy will be returned duly certified by the purchaser and only thereafter shall the materials be despatched.
- (iii) All records of routine test reports shall be maintained by the supplier at his works for periodic inspection by the purchaser.
- (iv) All test reports for tests conducted during manufacture shall be maintained by the supplier. These shall be produced for verification as and when requested for by the purchaser.

### **12.0 TRANSPORTATION, PACKING AND FORWARDING:-**

- 12.1 The supplier shall despatch the reactor, filled with oil or in an atmosphere of nitrogen or dry air at positive pressure. In the former case, the supplier shall take care of the weight limitation on transport and handling facility at site. In the latter case, necessary arrangement shall be ensured by the supplier to take care of pressure drop of nitrogen or dry air during transit and at site of installation. The nitrogen or dry air cylinder, provided to maintain positive pressure can be taken back by the supplier after oil filling. A gas pressure-testing valve with necessary pressure gauge and adapter valve shall be provided. Reactor shall also be fitted with at least two Electronic Impact Recorders (on returnable basis) during transportation to measure the magnitude and duration of the impact in all three directions. The acceptance criteria and limits of impact in all three directions, which can be withstood by the equipment during transportation and handling, shall be submitted by the supplier during detailed engineering. The recording shall commence in the factory before dispatch and must continue till the unit is received/installed at destination sub-station. The data of electronic impact recorder(s) shall be downloaded at site and a soft copy of it shall be handed over to Engineer-in-charge. Further, within three weeks, the supplier shall communicate the interpretation of the data.
- 12.2 The equipment shall be suitable for vertical/horizontal transport as the case may be and suitable to withstand handling during transport and outdoor storage during transit. The supplier shall be responsible for any damage to the equipment during transit, due to improper and inadequate handling during transfer, loading and unloading. The easily damageable material shall be carefully packed and marked with the appropriate caution symbol. Whenever necessary, proper arrangement for lifting, such as lifting hooks etc. shall be provided. Any material found short inside the packing cases shall be supplied by supplier without any extra cost.
- 12.3 Each consignment shall be accompanied by a detailed packing list containing the following information:-
  - (a) Name of the consignee.
  - (b) Details of consignment.
  - (c) Destination.
  - (d) Total weight of consignment.
  - (e) Sign showing upper/lower side of the crate.
  - (f) Handling and unpacking instructions.
  - (g) Bill of materials indicating contents of each package.
  - (h) Two sets of approved copies of drawings, instruction and commissioning manuals, approved test certificates and certificates of bought out items, approved copies of guarantee certificate.

12.4 The supplier shall ensure that the packing and bill of materials are approved by the purchaser before dispatch.

**13.0 SUPERVISION OF ERECTION, TESTING AND COMMISSIONING (ET&C):**

The erection, testing and commissioning of the reactors shall be supervised by trained personnel (Engineer) of the supplier. The Engineer shall direct the sequence of ET& C. The Engineer shall correct in the field, any errors or omissions on the part of the supplier, in order to make the equipment and material properly perform in accordance with the intent of this specification. The Engineer shall also instruct the plant operators in the operation and maintenance of the commissioned equipment. The supplier shall be responsible for any damage to the equipment, on commissioning the same, if such damage results from faulty or improper ET&C procedure. Purchaser shall provide adequate number of skilled/semi-skilled workers as well as all ordinary tools and equipment and cranes required for equipment erection, at his own expenses. Apart from the above, the purchaser shall not be responsible for any other expenses such as Engineer's salary, insurance against personal injuries to the Engineer etc. Special tools, if required for erection and commissioning, shall be arranged by the supplier at his cost and on commissioning, these shall be supplied to the purchaser, free of cost for future use. The supervision of erection, testing and commissioning charges will be borne by the Purchaser as per tender price schedule.

**14.0 QUANTITY AND DELIVERY REQUIREMENTS:**

- (i) This is set out in Annexure -I of this Specification. The firm will submit a 'PERT CHART', indicating the manufacturing, inspection, testing and delivery schedule in details immediately after receipt of the Purchase Order.
- (ii) The scope of supply shall also include supply of 2.5% extra quantity of bolts, nuts, washers, split pins, cotter pins and such other small loose items, free of cost in addition to the materials/equipment as spelt out in this specification.

## **ANNEXURE-I(Reactors)**

Name of the bidder: -

Address:-

MAXIMUM FLUX DENSITY AND CORE WEIGHT CALCULATION: -

Type and Grade of Core: -

Thickness [in mm]:-

$$E = 4.44 \times f \times B_{\max} \times A_i \times N$$

Where E = winding rated voltage / phase

f = Rated frequency

B max. = Maximum flux density in Tesla.

A<sub>i</sub> = Net iron area in sq.m = Gross iron area x stacking factor in sq.m

N = Number of winding turns/phase

$$B_{\max} = E / 4.44 \times f \times A_i \times N$$

Core weight calculation:- (Detailed calculation to be provided by the bidder)

NB: - 1 Specific loss vs. flux density graph for the type of core lamination to be used has to be furnished.

2. VA/Kg. Vs flux density graph for the core lamination to be used has to be furnished.

3. Any other factor assumed for above calculation to be explained with reasons.

4. The bidder may use its own method of calculation towards determination of maximum flux density and weight of the core. But the same shall be supported with proper explanation and justification.

Place

Date

Bidder's name:

Signature, designation, seal

**NB- The Bidders are required to up load this calculation sheet duly filling the required data, in PDF format.**



**ANNEXURE-II**  
**DETAILS OF LOSS CALCULATIONS FOR 420KV SHUNT REACTOR**

1. Name of the Firm
2. Flux density at 420KV and 50 Hz [Tesla]
3.
  - i. Core weight in Kg.
  - ii. Gross core area [mm<sup>2</sup>]
  - iii. Stacking factor.
  - iv. Building Factor
  - v. Net core iron area [mm<sup>2</sup>] [ii x iii]
  - vi. No. of winding Turns/Phase
4. [a] Specific losses [W/Kg.] at maximum flux density corresponding to 420KV and 50 HZ.  
[b] Volt ampere /Kg. at maximum flux density corresponding to 420KV and 50 HZ.
5. Calculated/guaranteed iron loss in KW at-
  - (i) Rated voltage and rated frequency.
  - (ii) Maximum system voltage and lowest system Frequency.
6. Current density (A/Sq.mm) for winding
7. Conductor size (in mm) and Area of conductor (in mm<sup>2</sup>) of winding
8. Total Bare copper conductor area (A) (Sq.mm) of winding
9. No. of winding turns/ phase
10. Internal Diameter of winding (in mm.)
11. Outside Diameter of winding (in mm.)
12. Mean Diameter (Dm) of winding (in mm.)
13. Length of copper conductor of winding (L)Mtr. =Pie x Dm x N
14. Per-phase resistance of winding (in ohms) at 75<sup>0</sup>C=0.0211XL/A
15. I<sup>2</sup>R loss (in KW) at 75<sup>0</sup>C
16. Stray losses and eddy current losses (in KW) at 75 deg.C
17. Calculated guaranteed Load losses (in KW) at 75 deg. C [I<sup>2</sup>R loss + stray losses]
18. Computed/guaranteed total loss of reactor in KW at rated Voltage and rated frequency. (Copper loss + Iron loss)
19. Copper Weight (L X A X 8.89 X 10<sup>-3</sup>)

NB: - 1 Approximate values in weight and losses etc. are not allowed.  
2 Tolerance of + 5% in weights may be quoted without any approximation

Place:

Date

Bidder's name:

Signature, designation, seal

**NB- The Bidders are required to up load this calculation sheet duly filling the required data, in PDF format.**

### **ANNEXURE-III(GTP)**

#### **A) GUARANTEED TECHNICAL PARTICULARS FOR 420 KV SHUNT REACTOR**

**[TO BE FILLED IN BY THE BIDDER, IN EXCEL FORMAT OF THE TECHNO COMMERCIAL BID SHEET]**

<b>Sl.No.</b>	<b>Description</b>	<b>Data to be filled in by the bidder</b>	
1	Manufacturer Name & Country		
2	Type of Reactor (Gapped / Air Core)		
3	Type of Gapped core Type of Reactor		
4	Standards Applicable		
5	Rated MVAR capacity		
6	No. of phases		
7	Rated Voltage (KV), Ur		
8	Maximum continuous operating voltage (Umax)		
9	Rated Frequency (Hz)		
10	Rated Current (Ampere)		
11	Tolerance on Rated Current (%)		
12	Amount of unbalanced current in each phase when connected to symmetrical voltages		
13	Connection		
14	System Earthing		
15	System Fault Level (kA)		
16	Type of cooling		
17	Maximum Temperature Rise ( $^{\circ}\text{C}$ ) over ambient temperature at maximum continuous operating voltage ( $1.05 U_r$ )		
(a)	Of Top Oil measured by thermometer & optic fibre temperature sensor		
(b)	Of Winding measured by Resistance Method		
(c)	Of winding Hot Spot measured by Optic Fiber Temperature Sensors		
18 (i)	Guaranteed maximum losses at rated voltage, rated frequency and at rated output at 75 deg C (KW)		
18 (ii)	Maximum losses at Maximum continuous operating voltage (Umax), rated frequency and at rated output at 75 deg C (KW)		
19	Noise level at rated voltage and frequency over ambient noise level (db)		
20	Insulation level (Winding & Bushing)	Winding Line / Neutral	Bushing Line/ Neutral
(a)	Lighting impulse (1.2/50 micro secs) withstand voltage (KVp)		

(b)	Power frequency withstand voltage KVRms)	
(c)	Switching surge withstand voltage (KVp)	
21	Maximum Partial Discharge Level at 1.5 Pu	
22 (a)	Range of voltage upto which impedance will be constant (p.u.)	
(b)	Impedance value at 1.0 pu (ohms)	
(c)	Impedance value at 1.5 pu (ohms)	
(d)	Tolerance on Impedance (%)	
23(a)	Ratio of Zero Sequence Reactance to Positive Reactance( $X_0/X_1$ )	
(b)	Tolerance on reactance at rated voltage & rated frequency (%)	
24	Capacitance Value (Phase to ground)	
25	Harmonic content in phase current	
26	<b>Core</b>	
a	Type of core(Gapped or Air Core)	
b	In case of Gapped core design, type of core design adopted	
c	No. of Limbs	
d	No. of core Packets Per Limb	
e	No. of CRGO Laminations Per Core Packet	
f	Type of core material & its grade	
g	Thickness of core lamination(mm)	
h	Maximum Flux Density in any part of the core and yoke at rated MVA, rated voltage	
i	No load currents at different % of rated voltage & rated frequency	
	50% rated voltage	
	75% rated voltage	
	100% rated voltage	
	125% rated voltage	
	150% rated voltage	
	175% rated voltage	
	200% rated voltage	
j	Radius of core packet	
k	Thickness of core packet(mm)	
l	Weight Per Core packet(Kg)	
m	Space Factor	
n	No. of Gaps Per Limb	
o	Length of each gap(mm)	
p	Total gap length(Meter)	
q	Effective surface area of air gap(Sq. Meter)	

r	Impregnating material for binding the laminations in the core packet	
s	Material & Dimensions of the spacers used in the gap	
t	Longitudinal elasticity of the spacer material	
u	Maximum Flux Density in the core(Tesla)	
V	Total weight of the core(Kg)	
w	Type of joint of top and bottom yokes	
<b>27</b>	<b>Windings</b>	
a	Material of winding	
b	Type of winding	
c	Conductor Cross sectional Area(Sq.cm)	
d	Current density(Amp Per Sq.cm)	
e	Type of insulation(Whether paper covered)	
f	Insulating material used for winding	
g	Insulating material used between core & winding	
h	Clearance of windings (between phases)	
i	Insulation level of winding	
j	Whether windings are pre-shrunk?	
k	Type of connection	
l	Bare conductor size (mm).	
m	Insulated conductor size (mm).	
n	No. of conductors in parallel (Nos.).	
o	No. of turns per phase	
p	No. of discs per phase	
q	No. of turns per disc	
r	Gap between discs. (mm).	
s	Inside diameter (mm).	
t	Outside diameter (mm).	
u	Axial height after shrinkage (mm).	
v	D.C Resistance of winding at 75 ° C (Ohms).	
w	Stray losses including eddy current losses in winding at 75°C (KW)	
x	Any special measures taken to reduce eddy current losses and stray losses, mention in details.	
y	Total losses at 75°C	
z	Details of special arrangement provided to improve surge voltage distribution in the Windings	
aa	Maximum Tan delta(power factor) of Windings at measured temperature.	

28	BUSHINGS	Phase	Neutral
a	Make and type		
i	Rated voltage class [KV-rms.]		
ii	Rated current [Amps.]		
b.	Lightning Impulse withstand test voltage [1.2/50 microsecond][KVP]		
c	Switching surge withstand test voltage [KVP]		
d	Power frequency withstand test voltage		
i	Wet for 1 minute [KV-rms]		
ii	Dry for 1 minute [KV-rms]		
e.	Power frequency visible corona discharge Voltage [KV-rms.]		
f	Partial discharge level [PC]		
g	Minimum creepage distance in mm		
h	Minimum creepage distance in mm [protected]		
i	Whether test-tap is provided?		
j	Quantity and grade of oil in bushing and Specification of oil used [Kg.]		
k	Weight of assembled bushing [Kg.]		
l	Minimum clearance height for removal of Bushing [mm]		
m	Under oil flashover or puncture impulse voltage [KVP]		
n.	Under oil flashover or puncture power frequency Voltage (KV-rms).		
o.	Phase to earth clearance in air of live parts at the top of bushings.		
p.	Maximum tan delta value at measured temperature		
29	<b>Minimum clearance [mm]</b>		
A	Outside Oil		
i.	Phase to phase		
ii.	Phase to ground		
iii.	Neutral to ground		
B	Inside Oil		
(i)	Winding to Core		
(ii)	Winding to top yoke		
(iii)	Winding to bottom yoke		
(iv)	Winding to Tank.		
a]	Length wise		
b]	Breadth wise		
c]	Width wise		

30	<b>Weight [Tolerance + 5%] [Approximate value is not allowed]</b>	
a	Core [Kg.]	
b	Core with clamping [Kg.]	
c	Winding insulated conductor [Kg.]	
d	Coils with insulation [Kgs,]	
e	Core and winding [Kg.]	
f	Oil required for first filling [Liter/Kg]	
g	Tank and fittings with accessories [Kg.]	
h	Untanking weight [Kg.]	
i	Total weight with oil and fittings	
31	<b>DETAILS OF TANK</b>	
a	Material for Transformer tank	
b	Type of tank	
c	Thickness of sheet [No approximate value to be mentioned]	
i	Sides [mm]	
ii	Bottom [mm]	
iii	Cover [mm]	
iv	Radiators [mm]	
v	Conservator	
d	Inside dimensions of main tank [No approximation in dimensions to be used]	
i	Length [mm]	
ii	Breadth [mm]	
iii	Height [mm]	
e	Outside dimensions of main tank [No approximation in dimensions to be used]	
i	Length [mm]	
ii	Breadth [mm]	
iii	Height [mm]	
f.	Thickness of spray galvanisation of tank bottom.	
g.	Vacuum recommended for hot oil circulation [torr]	
h.	Vacuum to be maintained during oil filling in Transformer tank [torr]	
i.	Vacuum to which the tank can be subjected without distortion (tor)	
j.	No. of bi-directional wheels provided	
k.	Track gauge required for the wheels	
i	Transverse axis	
ii	Longitudinal axis	
l	Type and make of pressure relief device	

m	No. of pressure relief device provided	
n	Minimum pressure at which PRD operates [Kpa]	
o	Maximum Vibration & Stress on tank wall at rated voltage	
p	Whether anti-vibration pads used between active part & tank bottom	
32	<b>CONSERVATOR</b>	
a	Type of conservator	
b	Total volume [Liters]	
c	Volume between the highest and lowest visible Oil levels [Litres]	
d	Power required by heaters [If provided][KW]	
e	Conservator sheet thickness (mm.)	
f	Diameter of conservator(mm)	
33	<b>DETAILS OF AIR CELL OF CONSERVATOR</b>	
a	Make	
b	Type	
c	Capacity	
d	Size	
34	<b>RADIATORS</b>	
a	Overall dimensions lxbxh [mm]	
b	Total weight with oil [Kg.]	
c	Total weight without oil [Kg.]	
d	Thickness of radiator tube [mm]	
e	Types of mounting	
f	Vacuum withstand capability	
g	Total radiating surface in sq.m	
h	Type and make of material used for the radiators	
i	Total number of radiators/Banks for Transformer and dimensions of tubes.	
j	Thickness of hot dip galvanization of radiators.	
35	<b>GAS AND OIL OPERATED RELAY</b>	
a	Make	
b	Type	
c	Size	
d	Whether supervisory alarm and trip contacts provided and their sizes and Nos.	
36[I]	<b>TEMPERATURE INDICATORS</b>	<b>OTI / WTI</b>
a	Make and type	

b	Permissible setting ranges for alarm and trip	
c	Number of contacts	
d	Current rating of each contact	
e	Whether supervisory alarm contacts provided?	
f	Size [lxbxd]	
g	Nos.	
h	Ratio and type of CT used for winding Temperature indicators.	
[II]	<b>OPTIC FIBER TEMPERATURE SYSTEM</b>	
a.	MAKE & TYPE	
b.	Whether the offered Optic Fiber Temperature System fulfills the stipulations for the same as per this Specification	
c.	Whether the end-user's certificate for offered Optic Fiber Temperature System, from Indian Utilities furnished	
d.	Whether, the Bidder has got past experience of supply of Reactors with Optic Fiber Temperature System [YES/NO]	
e.	If 'YES', please state the No. of such Reactors, supplied along with the name(s) of Organisation(s), to whom supplied with Make of the Optic Fiber Temperature System, supplied and performance of the same.	
f	Address of FO system supplier	
g	Nos. of channels	
h	Sensors per channel	
i	Channel switching frequency	
j	Sampling sensor rate	
k	Switching reliability	
l	Wave length operational length	
m	PC output interface	
n	Data display	
o	Self Diagnostic	
p	Temp range & resolution	
q	Accuracy	
r	Response time	
s	Front panel display	
t	Probe signal strength readout	
u	Input power	
v	Serial Output	



w	Fiber type	
x	Nos. of relays	
y	Temperature Data storage	
z	LED alarm indicators	
aa	System fault relay	
bb	System fault status indicator	
cc	Surge protection	
dd	Connectors	
ee	Operating temperature range	
ff	Storage temperature	
gg	Probes material & dimensions	
hh	Analog output	
ii	SCADA compatibility	
jj	Nos. of probes	
kk	Tank wall adaptor plate with cover	
ll	EMI/RMI susceptibility	
mm	Signal conditioner compatibility	
nn	Connector for tank wall feed through	
37	<b>OIL QUALITY</b>	
A	<b>Function</b>	
i	Viscosity at 100degC	
ii	Viscosity at 40degC	
iii.	Viscosity at -30degC	
iv	Appearance	
v	Pour point	
vi	Water content	
vii	a) for bulk supply	
viii	b) for delivery in drums	
ix	Electric strength (breakdown voltage)	
x	Density at 20 deg C	
xi	Dielectric dissipation factor (tan delta) at 90 deg C	
xii	Negative impulse testing KVp @ 25 deg C	
xiii	Carbon type composition (% of Aromatic, Paraffins and Naphthenic compounds )	
B	<b>Refining/Stability</b>	
i	Acidity	
ii	Interfacial tension at 27degC	
iii.	Total sulphur content	
iv	Corrosive sulphur	
v	Presence of oxidation inhibitor	
vi	2-Furfural content	

C	<b>Performance</b>	
i	Oxidation stability -Total acidity -Sludge - Dielectric dissipation factor (tan delta) at 90degC	
ii	Oxidation stability	
D	<b>Health, safety and environment (HSE)</b>	
i	Flash point	
ii	PCA content	
iii.	PCB content	
E	<b>Oil used (inhibited) for first filling, testing and impregnation of active parts at manufacturer's works shall meet parameters as mentioned below:</b>	
i	Break Down voltage(BDV)	
ii	Moisture content	
iii.	Tan-delta at 90°C	
iv	Interfacial tension	
F	<b>Each lot of the oil shall be tested prior to filling in main tank at site for the following:</b>	
i	Break Down voltage(BDV)	
ii	Moisture content	
iii.	Tan-delta at 90°C	
iv	Interfacial tension	
G	<b>After filtration &amp; settling and prior to energisation at site oil shall be tested for following:</b>	
i	Break Down voltage(BDV)	
ii	Moisture content at hot condition	
iii.	Tan-delta at 90°C	
iv	Interfacial tension	
v	<b>Oxidation Stability</b>	
	a) Acidity	
	b) Sludge	
	c) Tan delta at 90 °C	
vi	Total PCB content	
38	<b>APPROXIMATE OVERALL DIMENSIONS OF REACTOR INCLUDING COOLING SYSTEM ETC.</b>	
a	Length [mm]	
b	Breadth [mm]	
c	Height [mm]	

39 a	Minimum clearance height for lifting core and Winding from tank [mm]	
b	Minimum clearance height for lifting tank cover [mm]	
40	<b>SHIPPING DETAILS</b>	
a	Approximate weight of heaviest package [Kg.]	
b	Approximate largest Package [Kg.]	
c	Size of largest package (mm) X(mm) X (mm)	
d	Gross weight to be handled (kg)	
e	Gross volume to be handled (kg)	
f	Approx overall dimension ((lXbXh) (mm)	
g	Approx quantity of oil required for first filling	
h	Untanking height (mm)	
41	<b>Proposed method of transportation</b>	
42	<b>Size of rail recommended for the track.</b>	
43	<b>Details of CT</b>	<b>Line side/Neutral side/common neutral side</b>
a	Quantity	
b	Type and voltage class	
c	No. of cores	
d	Ratio	
e	VA burden	
f	Accuracy class	
g	Minimum knee point voltage [volts]	
h	Maximum magnetization current at minimum Knee point voltage [mA]	
i	Maximum secondary winding resistance at 75°C [ohms]	
44	<b>LIFTING JACKS</b>	
a	Governing standard	
b	No. of jacks in one set	
c	Type and make	
d	Capacity [tonnes]	
e	Pitch [mm]	
f	Lift [mm]	
g	height in closed position [mm]	
h	mean diameter of thread [mm]	
45	<b>MARSHALLING KIOSK</b>	
a	Make and type	
b	Details of apparatus proposed to be housed in the Kiosk	
c	Degree of Protection	
46	<b>Types of terminal connectors and drawing No</b>	

a	HV	
b	Neutral	
47	<b>DEHYDRATING BREATHERS</b>	
a	Make & Type	
b	Quantity	
c	Type of dehydrating agent used for breathers	
d	Quantity of dehydrating agent used for breathers(Kg)	
49	Details of painting, galvanization conforms to this Specification [Yes/No]	
50	<b>Valve sizes and numbers</b>	
a	Drain valves- mm-Nos.	
b	Filter valves- mm-Nos.	
c	Sampling valves- mm-Nos.	
d	Radiator valves- mm-Nos.	
e	Other valves- mm-Nos.	
51	Whether the Reactor, covered is fully type tested and if so, whether copies of type test certificates, enclosed with the tender.	

## **B) GUARANTEED TECHNICAL PARTICULARS FOR 145KV NEUTRAL GROUNDING REACTOR**

<b>Sl.No.</b>	<b>Description</b>	<b>Data to be filled in by the bidder</b>
1	Name of Manufacturer & Country	
2	Type of Reactor(Gapped/Air core)	
3	Standard applicable	
4	Connection	
5	<i>Rated voltage from insulation strength considerations</i>	
6	<i>Rated frequency</i>	
7	<i>No of phases</i>	
8	<i>Type of Insulation</i>	
9	<i>Max. continuous current</i>	
10	<i>Rated short time current (10 sec)</i>	
11	<i>Rated impedance at rated short time current</i>	
12	Max. temperature rise over ambient temperature of 50°C at rated voltage	
i.	of top oil measured by thermometer	
ii.	of winding measured by resistance	
13	Insulation level for winding	
i.	Lightning Impulse withstand Voltage(kVp)	
ii.	One Minute Power Frequency withstand Voltage(kVrms)	

14	Bushings	
i.	Rated Voltage(kV)	
ii.	Lightning Impulse withstand Voltage(kVp)	
iii.	One Minute Power Frequency withstand Voltage(kVrms)- <b>Dry/Wet</b>	
iv.	Type of bushing	
v.	Minimum Total Creepage Distance(mm)	
vi.	Tan Delta value of bushings (Tan delta shall be measured at ambient temperature. No temperature correction factor shall be applied)	
15	Method of grounding	
16	Minimum clearances in air (mm)	
i.	Line side	
ii.	Ground side	
17	Bushing Current Transformers	Line side/Neutral side
i.	Type	
ii.	Ratio	
iii.	Accuracy Class	
iv.	Burden	
v.	Min. Knee Point Voltage	
vi.	Max. resistance of secondary winding	
vii.	Max. Excitation current	
viii.	Application	
18	<b>Weight [Tolerance + 5%] [Approximate value is not allowed]</b>	
i.	Core [Kg.]	
ii.	Core with clamping [Kg.]	
iii.	Winding insulated conductor [Kg.]	
iv.	Coils with insulation [Kgs,]	
v.	Core and winding [Kg.]	
vi.	Oil required for first filling [Liter/Kg]	
vii.	Tank and fittings with accessories [Kg.]	
viii.	Untanking weight [Kg.]	
ix.	Total weight with oil and fittings	
19	<b>DETAILS OF TANK</b>	
i.	Material for Transformer tank	
ii.	Type of tank	
iii.	Thickness of sheet [No approximate value to be mentioned]	
iv.	<i>Inside dimension</i>	
v.	<i>Outside dimension</i>	
vi.	Maximum Vibration & Stress on tank wall at rated voltage	
20	<b>CONSERVATOR</b>	
i.	Type of conservator	
ii.	Total volume [Liters]	
iii.	Thickness of sheet	

iv.	Dimension of conservator	
21	<b>GAS AND OIL OPERATED RELAY</b>	
i.	Make	
ii.	Type	
iii.	Size	
iv.	Whether supervisory alarm and trip contacts provided and their sizes and Nos.	
22	<b>TEMPERATURE INDICATORS</b>	
i.	Make and type	
ii.	Permissible setting ranges for alarm and trip	
iii.	Number of contacts	
iv.	Current rating of each contact	
v.	Whether supervisory alarm contacts provided?	
vi.	Size [lxbxd]	
vii.	Nos.	
viii.	Ratio and type of CT used for winding Temperature indicators.	
23	<b>APPROXIMATE OVERALL DIMENSIONS</b>	
i.	Length [mm]	
ii.	Breadth [mm]	
iii.	Height [mm]	
iv.	Minimum clearance height for lifting core and Winding from tank [mm]	
v.	Minimum clearance height for lifting tank cover [mm]	
24	<b>SHIPPING DETAILS</b>	
i.	Approximate weight of heaviest package [Kg.]	
ii.	Approximate largest Package [Kg.]	
iii.	Size of largest package (mm) X(mm) X (mm)	
iv.	Gross weight to be handled (kg)	
v.	Gross volume to be handled (kg)	
vi.	Approx overall dimension ((lXbXh) (mm)	
vii.	Approx quantity of oil required for first filling	
viii.	Untanking height (mm)	
25	<b>MARSHALLING KIOSK</b>	
i.	Make and type	
ii.	Details of apparatus proposed to be housed in the Kiosk	
iii.	Degree of Protection	
26	<b>OIL QUALITY</b>	
27	<b>Valve sizes and numbers</b>	
i.	Drain valves- mm-Nos.	
ii.	Filter valves- mm-Nos.	
iii.	Sampling valves- mm-Nos.	
iv.	Other valves- mm-Nos.	
28	Whether the Reactor, covered is fully type tested and if so, whether copies of type test certificates, enclosed with the tender.	

**C) GUARANTEED TECHNICAL PARTICULARS NITROGEN INJECTION SYSTEM FOR PREVENTION OF FIRE/ EXPLOSION FOR REACTORS.**

Sr. No.	Description	Guaranteed Particulars
1	Name of Manufacture and country of origin	
2	Reference standards	
3	Details of system equipments	
4	FEC (Fire Extinguishing Cubicle)	
4.1	Dimensions (LXBXH) mm	
4.2	Weight	
4.3	Capacity of Nitrogen cylinder	
4.4	Number of cylinders	
4.5	Pressure of Nitrogen filing	
4.6	Minimum distance of FE cubicle from the reactor	
4.7	Method of mounting	
4.8	Whether the following items are provided in FE cubicle. If so furnish make, type & other details	
4.9	Contact Manometer	
4.10	Pressure Regulator	
4.11	Oil Release Unit	
4.12	Gas release unit	
4.13	Oil drain assembly	
4.14	Pressure / limit switches	
4.15	No. of contacts & spare contacts (NO & NC)	
4.16	Oil drain Valve (ABOVE FEC)	
4.17	Make	
4.18	Type	
4.19	Size	
4.20	Type of metal	
4.21	Nitrogen Injection Valve (Above FEC)	
4.22	Make	
4.23	Type	
4.24	Size	
4.25	Oil drain pipe	
4.26	Size	
4.27	Length	
4.28	Number of openings in the reactor tank	
4.29	Material	
5	Control Box	
5.1	Dimensions (LXBXH) mm	
5.2	mm	
5.3	Type & Thickness of sheet steel	
5.4	Details of components provided in the control box	
5.5	Control voltage	
5.6	Method of mounting	

5.7	Whether audio and visual alarm provided?	
6.	Reactor Conservator Isolation Valve	
6.1	Make	
6.2	Type	
6.3	Location	
6.4	Whether suitable for pipe of size 80 mm dia	
6.5	No. of contacts & spare contacts (NO & NC)	
6.6	Padlocking provision	
7	Detectors	
7.1	Make	
7.2	Type	
7.3	Quantity required	
7.4	Method of fixing	
7.5	Effective heat sensing area	
7.6	Temperature recommended for effective heat sensing	
7.7	Number of contacts NO / NC	
7.8	Necessity and condition of Refilling	
8	Whether approved by Tariff Advisory Committee of India	
9	TECHNICAL PARTICULARS FOR NITROGEN INJECTION SYSTEM FOR PREVENTION OF REACTOR EXPLOSION	
10	Power Supply	
10.1	Control box	
10.2	FEC (lighting)	
10.3	Extinction period	
10.4	On system activation	
10.5	On commencement of Nitrogen injection	
11	FEC Suitable for capacity	
11.1	Dimensions (LXBXH) mm	
11.2	Weight	
11.3	Nitrogen cylinder capacity	
12	Control Box	
12.1	Dimensions (LXBXH) mm	
12.2	Weight	
13	Detectors	
13.1	Heat sensing temperature	
13.2 Time of operation	Reactor Tank Explosion Prevention	Fire Extinction
For system activation		
For reduction of pressure in tank by Nitrogen Release		

13.3 Any other technical details not covered above.

**N.B.**

***The bidder must fill up all the points of GTP for offered item(s). Instead of indicating “refer drawing” or “as per IS/IEC”, the exact value(s) must be filled in.***