Technical Specification

SECTION- SERIES REACTOR
(400 KV CLASS)

REV 01

MAY'2019

Major changes in the latest Technical Specification

Section – Series Reactor (400kV Class) REV 01

Sr. No.	Clause	Brief description of major changes
1.	7.0	*Terminals shall be provided in the Cross-arms based on the requirement as per substation layout, not in each cross arm.*
2.	14.5.3	*Insulation resistance measurement for the main winding – Deleted (Not applicable)*
3.	15.1	*All external metallic part shall be of stainless steel or painted aluminium alloy of suitable thickness – Deleted* *Each capacitor unit shall be provided with an internal discharge resistor as per IEC-60143 which within 10 minutes shall reduce the residual voltage across the capacitor to 75 Volts or less after the capacitor is de-energised. – Deleted*
4.	15.2.1	*The capacitor offered must have been also endurance tested as per IEC: 60871-2/IS: 13925 and copies of reports shall be submitted for approval.- Deleted*
5.	Annexure-A	*Temperature rise of winding and structural component are added* *Insulation class of winding is changed to H Class or better* *Sound Level is changed to 80dBA*
6.	Annexure-B	*Temperature rise test at rated continuous current- revised*

Disclaimer:

Major changes are listed above. However, for details of all major and minor modifications, please refer the complete technical specification SECTION- SERIES REACTOR (400 KV CLASS) Rev 01.

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SECTION- SERIES REACTOR (400 KV CLASS)

TECHNICAL SPECIFICATION
SECTION- SERIES REACTOR (400 KV CLASS)

1.0 General

This Specification details the requirements of air core dry type current limiting reactors, intended to limit the short circuit current / fault level during faults / disturbance in power system network.

This specification covers design, engineering, manufacture, testing at manufacturer's works, delivery at site including all materials, accessories, spares, unloading, handling, proper storage at site, erection, testing and commissioning of the equipment specified.

The scope shall include carrying out Transient simulation study (Transient Recovery voltage (TRV) & Rate of Rise of Recovery Voltage (RRRV) using standard software like PSCAD, EMTP-RV) under various operating condition for each Reactor bank associated with the switching of Series reactor and to determine the rating of Capacitor (as required) to limit the TRV and RRRV.

1.1 Application Type:

i. A current-limiting reactor for connection between two different bus system or two sections of the same bus for the purpose of limiting fault current / short circuit current is referred as ***Series Bus Reactor***

ii. A current-limiting reactor connected in series with a transmission line circuit, for the purpose of limiting the fault current / short circuit current is referred as ***Series Line Reactor***.

2.0 Normative references

Where this Specification fails to give specific guidelines or rules, preference shall be given to those published by IEC or Cigre. If these are also not available the provisions of IEEE/NEMA shall be used.

Any deviation shall be clearly brought out in the relevant bid price schedule.

Normative References

IEC 60076-6	Part 6: Reactors. Clause 8
IEC 60076-1	Part 1: General
IEC 60076-2	Part 2: Temperature Rise
IEC 60076-3	Part 3: Insulation Levels and Dielectric Tests
IEC 60076-4	Part 4: Guide to the lightning impulse and switching impulse testing –Power transformers and reactors
IEC 60076-3-1	Part 3-1: Insulation Levels and Dielectric Tests –External Clearances in Air
IEC 60076-5	Part 5: Ability to Withstand Short-circuits

IEC 60050	International Electro-technical Vocabulary
IEC 60050(421)	International Electro-technical vocabulary- Chapter 421 : Power Transformers and reactors
IEC 60060	High Voltage test techniques

3.0 Transportation

The Contractor 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 equipment. It shall be the responsibility of the contractor to coordinate the arrangement for transportation of the reactor along with all accessories including spares for all the stages from the manufacturer's work to site. The manufacturer of the reactor shall specify the maximum gravitational forces that the reactor is designed to withstand in all directions during the design review discussions. Electronic type Impact recorders (on returnable basis) shall be attached to the reactors, in all directions, at the factory and shall remain on the reactor until it is in its final destination. These indicators shall be clearly observable without disturbing transport crating.

4.0 Performance

Only air insulated dry type naturally air cooled reactor shall be supplied. The reactor banks are intended for outdoor service.

4.1 Type of operation

The series reactors shall be intended for continuous operation. The reactor shall be designed for continuous & one second short circuit current rating specified. It shall withstand the following short circuit duty cycle:

Under External fault conditions, the Series Reactor bank shall be capable of withstanding a succession of Two (2), 3-phase external faults (The Elapsed time between the successive faults shall be 1 second) considering Single pole stuck CB condition during second external fault followed by an internal fault , one second later.

The Reactor bank protection shall not trip for the external fault sequence. It should trip the associated circuit breaker at the earliest for the Reactor protection trip on internal fault.
The detailed system studies / calculations shall be carried out by the contractor to verify the thermal rating of Reactor and shall be approved by the employer.

The Reactor thermal withstand rating shall be suitable for the following sequence of events:

Time from initiation of fault (ms)	Power System event.
000	First three phase external fault (fault outside the Bus/Line on which series reactor is installed) occurs.

000 to 100	Fault continues.
100	The CB in the faulted circuit interrupts the fault.
100 to 1000	Power flow continues on the Bus / Line.
1000	Second three phase external fault.
1000 to 1100	Fault continues.
1100	Two (2) CB poles clear the fault and third CB pole is stuck.
1100 to 1300	Fault continues with single pole CB stuck condition.
1300	Fault cleared by operation of LBB protection.
2300	A three phase internal fault (just after series Reactor) occurs.
2300 + time for CB opening	Reactor bank gets isolated by CB trip operation by reactor protection trip.

Each reactor shall be designed to withstand the thermal and dynamic effects of its rated short-time current including the associated electrical stress for the rated duration. Any duty cycle at currents below the rated short-time current shall be allowed provided that the let-through specific energy of the duty cycle does not exceed the rated I^2rt.

4.2 **Simulation studies**

The scope shall include carrying out Transient simulation study (Transient Recovery voltage (TRV) & Rate of Rise of Recovery Voltage (RRRV) using standard software like PSCAD, EMTP-RV) under various operating condition for each Reactor bank associated with the switching of Series reactor and to determine the rating of Capacitor (as required) to limit the TRV and RRRV.

For Line Series reactor application type, Simulation Study shall also be carried out for efficacy of the Line protection system for the line with series reactor. Details of existing line distance protection relays, setting data and associated power system network data shall be provided by the employer during detail engineering.

5.0 Design review

Adequate safety margin with respect to thermal, mechanical, dielectric and electrical stress etc. shall be maintained during design, selection of raw material, manufacturing process etc so that the reactors provide long life with least maintenance.

Design reviews shall be conducted by Purchaser/Employer/Employer's or an appointed consultant during the procurement process for reactors; however the entire responsibility of design shall be with the manufacturer.

Purchaser/ Employer reserves right to visit manufacturers works to inspect design, manufacturing and test facilities.

5.1 Design review during detail engineering

The design review will commence after placement of award with the successful bidder and shall be finalised before commencement of manufacturing activity. These design

reviews shall be carried out in detail to the specific design with reference of the reactor under the scope of this specification.

The manufacturer shall provide all necessary information and calculations to demonstrate that the reactor meets the requirements for short circuit strength and durability. The latest recommendations of IEC and Cigre SC 12 shall be applied for short circuit withstand evaluation.

The manufacturer will be required to demonstrate the use of adequate safety margins for thermal, mechanical, dielectric and vibration etc design to take into the account the uncertainties of his design and manufacturing processes.

The scope of such design review shall include but not limited to the requirement as mentioned below.

1. Winding design
2. Short-circuit withstand capability
3. Thermal design.
4. Magnetic field consideration
5. Vibration & audible noise
6. Seismic design, as applicable
7. Insulation co-ordination
8. Corrosion protection
9. Electrical and physical Interfaces with substation
10. Earthing
11. Processing and assembly
12. Testing capabilities
13. Inspection and test plan
14. Transport and storage
15. Sensitivity of design to specified parameters
16. Spares, inter-changeability and standardization
17. Demonstration of the reactor's ability to withstand the specified pollution level
18. Maintainability

6.0 Design requirements

6.1 The reactors shall be designed single-phase, dry-type with each phase mounted vertically side by side, air-core, without magnetic shield, without taps, for outdoor installation. No tappings on reactor shall be accepted. *Maximum two number of Coil in each phase of the reactor shall be allowed, mounted one above the other.*

The reactors shall be capable of handling short circuit forces based on a pre-fault voltage of 1.1 p.u and maximum design short circuit level with an infinite bus-bar configuration.

The insulation level shall be adequate. The contractor shall demonstrate compliance with the requirement of insulation co-ordination for the overvoltage cycle specified in Section-Surge arrestor.

Each reactor shall be supported by at least six numbers bus post insulators symmetrically arranged around the centreline. No conductive loop linking the reactor magnetic flux shall be allowed in the supporting frame.

All reactors of a particular type shall be identical and interchangeable with one another at any time. This includes reactors in different phase positions.

6.2 Construction details

The features and construction details of the reactor shall be as follows:

6.3 Supporting structure

6.3.1 Lifting Eyes

Each reactor shall be provided with removable lifting eyes. Four symmetrically placed lifting eyes shall be provided so that it will be possible to lift the complete reactor without structural damage to any part of the reactor. The factor of safety at any one point shall not be less than 2.

6.3.2 Support structure & support insulators

Reactor shall be mounted on several outdoor type bus post insulators (BPI) and mounting brackets. The reactor assembly mounted on its pedestal insulators shall provide a minimum clearance of 2.5 m between the live metal/insulator base and earth. Each reactor shall be mounted on outdoor type insulators with mechanical and electrical characteristics suitable for continuous operation under the specified conditions. The reactor shall be supplied complete with all the necessary support structures and hardware and shall be designed for mounting outdoors with its longitudinal axis vertical. Each reactor shall be supplied complete with stainless steel mounting bolts. All nuts and bolts shall be fitted with approved anti-vibration locking devices. Fences across reactor banks shall be provided if required for safe electrical and magnetic clearances for human safety.

6.3.3 Earthing Terminals

Earthing pad (complete with two (2) nos. holes, M 10 bolts, plain and spring washers) suitable for connection to 75 x 12 mm galvanised steel grounding flat shall be provided for earthing of the supporting structure such that no circulating current path exist. Each support structure (leg) should have earthing terminal.

7.0 Windings

The complete winding assembly shall be encapsulated to provide full protection against extreme weather, direct sunlight and temperature variations. The reactor shall be finished with a uniform protective coating on its exposed surfaces. The conductors shall be of either aluminium or electrolytic grade copper free from scales and burrs.

The winding hottest spot temperature rise shall not exceed 105 degree C at rated current. Average Winding temperature rise shall not exceed 80 degree C at rated current. Temperature of structural components also not exceed 105 Deg C. Insulation provided for the reactor winding shall be class H or better.

Reactor winding shall consist of a cylindrical winding made of one or several concentric layers of film/glass tape insulated conductor. All concentric layers are electrically connected in parallel by welding their top and bottom ends to metallic cross arms. Terminals shall be provided in the Cross-arms based on the requirement as per substation layout. All layers are radially spaced by several glass fiber sticks which form air ducts necessary for the cooling of the winding. Cooling is provided only by natural convection of ambient air. The coils would be made up, shaped and braced to provide for expansion and contraction due to temperature changes. All joints should be welded

An analysis shall be made of the transient voltage distribution in the windings, and the clearances used to withstand the various voltages. Adequate margins shall be provided. The rated voltage across the reactor surface and inter-turn voltage shall be below the partial discharge inception level.

8.0 Current carrying connections

All internal current-carrying joints or splices shall be welded, brazed or made by compression fitting. The applicable method shall be approved by employer during the design review.

9.0 Reactor terminals

Reactor terminals shall be designed to allow for repeatable and safe connection under site conditions to ensure the integrity of the reactor in service. Live terminals shall consist of eight-bolt terminal pads in accordance with IEC 60518. The terminals shall be made of corrosion-resistant, high-conductivity metal. Terminals other than aluminium terminals shall be completely and uniformly tinned with commercially pure tin.

10.0 Vibration and Audible Noise

The Reactor design shall be made in such a way that excessive vibration does not occur in the windings, structural supports of the windings and this will be subjected to design review. Specified sound level requirements must be demonstrated by calculation.

The reactor shall be designed such that the reactor's mechanical resonant frequency does not coincide with the system frequency or its lower order harmonics

11.0 Seismic requirements

The complete reactor installation, including post insulators and pedestals, is to withstand seismic activity pertaining to the seismic zone of the installation site (with a minimum of 0.3g seismic activity) without damage to the reactor installation. The reactor's capability to operate with the specified seismic requirements must be demonstrated by calculation in accordance with IEC 60721-2-6. The wind force shall also be considered separately.

12.0 Fittings

12.1 The following fittings shall be provided with each reactor covered under this specification.

i) Rating plate for reactors

ii) Supporting structure, insulators, mounting brackets, nuts & bolts etc.

iii) One earthing terminal on each supporting structure of reactor

iv) Terminal connector

v) Lifting eyes

The fittings listed above are only indicative and any other fittings which are generally required for satisfactory operation of the reactors are deemed to be included.

13.0 Rating plate

Each reactor shall be provided with a rating plate of weather-proof material (Anodized aluminium or stainless steel), fitted in a visible position, showing in all cases the appropriate items indicated below. The entries on the plate shall be indelibly marked (for example by etching, engraving or stamping).

- type of reactor;
- outdoor application;
- reference to the IEC Standard 60076-6;
- manufacturer's name;
- manufacturer's serial number;
- year of manufacture;
- insulation level(s);
- rated frequency;
- highest voltage for equipment;
- rated continuous current
- rated short-time current and duration;
- rated dynamic short-circuit current;
- measured impedance value;
- thermal class of insulation;
- total mass;

14.0 Inspection and Testing

The Contractor shall carry out inspection and testing during manufacture of the equipment. An indication of inspection envisaged by the Purchaser/Employer is given below. This is however not intended to form a comprehensive programme as it is Contractor's responsibility to draw up and carry out such a programme in the form

of detailed quality plan duly approved by Purchaser/ Employer for necessary implementation.

14.1 Winding

- Sample check on winding conductor for mechanical properties and electrical conductivity.
- Visual dimensional checks on conductor for scratches, dent marks etc.
- Check for absence of short circuit between parallel strands.
- Check for brazed joints wherever applicable.
- Measurement of impedance by low voltage to be carried out when all connections are ready.
- Conductor flexibility test.
- Certification of all test results.

14.2 Assembled Reactor

- Check completed reactor against approved outline drawing provision for all fittings, finish level etc.
- Lifting test on all the assembled reactors.

14.3 Factory Tests

The reactors shall be subjected to type and routine tests in accordance with the latest issue of IEC-60076 Part-6, as appropriate to the type of reactor provided. Dynamic short circuit test is not envisaged and vendor will submit the required calculation to demonstrate the specified short circuit current withstand capability of the reactor.

The manufacturer shall be fully equipped to perform all the required tests as specified. Bidder shall confirm the capabilities of the proposed manufacturing plant in this regard. Any limitations shall be clearly stated in the bid. The contractor shall bear all additional costs related to tests which are not possible to carry out at his own works.

The contractor shall submit a Inspection and test plan (ITP) for approval. Complete test report shall be submitted to purchaser/ Employer after proper scrutiny and signing on each page by the test engineer of the contractor.

14.4 Pre-Shipment Checks at Manufacturer's Works

Check for inter-changeability of components of similar reactors for mounting dimensions.

14.5 Inspection and Testing at Site

The Contractor shall carry out a detailed inspection and testing programme for field activities, namely covering areas right from the receipt of material stage up to commissioning stage. It is Contractor's responsibility to draw up and carry out such a programme duly approved by the Purchaser/ Employer.

14.5.1 Receipt and Storage Checks

- Check and record condition of each package, visible part of the reactors etc. for any damage
- Impact recorder analysis
- Visual check for condition of winding in general.

14.5.2 Installation Checks

- Check the whole assembly for tightness, general appearance etc.

14.5.3 Commissioning Checks

- Check for cleanliness of the reactor and the surrounding.
- Tests as per Reactor manufacturer recommendation

Contractor shall prepare a comprehensive commissioning report including all commissioning test results and forward to Purchaser/ Employer for future record.

15.0 Capacitor to limit transient recovery voltage (TRV)

Based on the transient simulation studies, capacitors (typically in the range of 5 to 20nF) may be required to be connected across the reactor or phase to ground to limit the TRV and RRRV. The requirement shall be clearly spelt out in the transient simulation study report to be carried out by the contractor. The suggestive method shall be appropriate to the installation.

Rating of the Capacitor shall be decided based on the transient simulation studies and it shall be rated & designed to withstand the all current and voltage stresses imposed upon it under all operating conditions

15.1 Construction requirements

The capacitor units shall be of film-foil design housed in hermetically sealed polymer housing. The units shall utilize a non-PCB dielectric fluid, bio-degradable to non-toxic components.

Each capacitor unit shall be designed to allow for expansion and contraction due to all ambient and loading conditions expected during the life of the unit.

In addition to the normal load requirements and voltages at protective level, the capacitor shall be capable of withstanding the over-voltages associated with the installation.

The capacitor shall be suitable for outdoor installation with maximum ambient temperature of 50 Degree Centigrade.

Paint shade shall be RAL 7032

15.2 TESTS

15.2.1 Type test

The Capacitor shall comply with the requirements of type test as per IEC 60358-1 and type test reports shall be submitted for approval.

15.2.2 Acceptance & routine test

The equipment shall be subjected to routine and acceptance tests as per relevant IS/IEC.

Annexure – A

1.0 Technical Particulars / Parameters of Series Reactor

The parameters pertaining to the reactors furnished under this specification are listed below:

Sr. No.	Parameter	Unit	Series Bus Reactor	Series Line Reactor
1.1.	Type		air core dry type	air core dry type
1.2.	Service condition		Outdoor	Outdoor
1.3.	Rated voltage/phase	kV	$420/\sqrt{3}$	$420/\sqrt{3}$
1.4.	Rated frequency	Hz	50	50
1.5.	Single / Three Phase Design		(SINGLE)	(SINGLE)
1.6.	Rated Reactance per phase	Ohm	12	12
1.7.	Tolerance on rated reactance	%	+2.5, -0.0	+2.5, -0.0
1.8.	Rated continuous current	Amps.	2500	3000
1.9.	Rated Short circuit current	Amps.	14000	14000
1.10.	Rated short-circuit current duration	second	1	1
1.11.	Rated MVAR per phase		75	108
1.12.	Winding Hottest spot temperature rise	^{0}C	≤ 105	≤ 105
1.13.	Average winding temperature rise	^{0}C	≤ 80	≤ 80
1.14.	Temperature of structural component	^{0}C	≤ 105	≤ 105
1.15.	Insulation class of winding	-	H or better	H or better
1.16.	Rated one minute power-frequency withstand voltage to earth	kV	630	630
1.17.	Rated switching impulse withstand voltage to earth	kVp	1050	1050
1.18.	Rated lightning impulse withstand voltage to earth	kVp	1550	1550
1.19.	Sound Level	dBA	< 80	< 80
1.20.	Paint shade	-	RAL 7032	RAL 7032

Note:

a) The reactors (of the same phase or adjacent phases) shall have no or negligible mutual inductance.

b) Reactor shall also be designed to withstand the short circuit duty cycle specified in the specification.

Annexure -B

The contractor shall submit Inspection and test plan (ITP) for approval. A typical test plan is indicated below. The following tests shall be performed according to IEC Standard 60076-6; for each test, reference is made to the corresponding Standard Clause. Complete test report shall be submitted to purchaser/ Employer after proper scrutiny and signing on each page by the test engineer of the contractor.

Test Plan

No.	Test Description	Routine / Type
1.	Measurement of winding resistance (IEC 60076-1);	Routine
2.	Measurement of impedance at rated continuous current (Cl. 8.9.5 of IEC 60076-6);	Routine
3.	Measurement of loss at ambient temperature (Cl. 8.9.7 of IEC 60076-6)	Routine
4.	Winding overvoltage test dry (Cl. 8.9.9 of IEC 60076-6)	Routine
5.	Switching impulse test (Cl. 8.9.16 of IEC 60076-6)	Type
6.	Measurement of acoustic sound level (Cl. 8.9.14 of IEC 60076-6)	Type
7.	Separate source a.c. withstand voltage test dry & wet (Cl. 8.9.8 & 8.9.20 of IEC 60076-6)	Type
8.	Temperature rise test at rated continuous current (Cl. 8.9.11 of IEC 60076-6)	Type
9.	Wet winding overvoltage test (Cl. 8.9.19 of IEC 60076-6)	Type

Temperature rise test at rated continuous current (8.9.11)

The test shall be carried out in general accordance with IEC 60076-2. For dry-type reactors, the temperature class limits as stated in IEC 60076-11 apply. This test shall be performed at rated continuous current I_r and rated frequency.

In exceptional cases, for example extremely large rated power, it may be difficult to meet this test condition. In these cases, the test may be performed at a reduced current value but not less than 0.7Ir.

Manufacturer shall submit details of test equipment available for carrying out the above test.