



May 2013

SPECIFICATION SS-52/13
8 MVAR, 9 MVAR 12.5MVAR, 16MVAR, 18MVAR, 20MVAR, 25MVAR
157.5kV SHUNT REACTORS

I. SCOPE

This Specification covers the design, manufacturing, testing at the manufacturer's premises and supplying of three-phase, outdoor 157,5kV shunt compensating reactors.

II. STANDARDS

Unless otherwise specified herein, all material, equipment, workmanship, design, inspection and testing of the subject reactors shall confirm to the latest applicable standards IEC 60076-6, 60076-3, 60076-4.

III. SYSTEM CHARACTERISTICS

1. Maximum system voltage : 170kV
2. Rated frequency : 50Hz
3. System short circuit level : 31.5kA at 170kV
4. Other characteristics : 3-phase, 3-wire, solidly grounded neutral.

IV. SERVICE CONDITIONS

Unless otherwise stipulated in this Specification the subject shunt compensating reactors shall be suitable for outdoor installation, at an altitude less than 1000m above sea level and for an ambient temperature ranging between -25°C and +40°C and shall operate satisfactorily under snow and ice conditions.

V. REQUIREMENTS FOR THE REACTOR

1. Basic Rated Quantities

- a. Highest voltage for equipment (Um) : 170kV
- b. Rated voltage (Ur) : 157.5kV

- c. Rated power (shall be stated in the inquiry)
- d. Rated frequency : 50Hz
- e. Maximum operating voltage (U_{max}) : 105% of rated
- f. Rated insulation levels for windings and bushings:

	Line-end	Neutral-end
Lightning impulse withstand voltage 1.2/50µs wave, kV crest	750	125
Power frequency withstand voltage, kV r.m.s.	325	50

2. Type of Construction

1. The reactor tank shall be of cover bolted type.
2. The reactor coils shall be of the three-phase, oil-immersed, naturally cooled type, with copper windings and shall be suitable for outdoor installation.
3. The core shall be of the gapped iron type with five (5) limbs, including side limbs. The overall design shall be such as to provide effective magnetic shielding.
In general, the design and construction of the reactors shall be such as to avoid detrimental effects due to vibration.
4. The reactor oil shall be mineral oil in accordance with IEC-60296, class II standard. Also it shall not contain any toxic substances such as PCBs or PCTs and be self-degrading.

3. Temperature Rise Limits

The following temperature rise limits for continuous operation concerning the winding shall be observed:

- Average temperature rise of winding, measured by resistance : 65°C
- Top oil measurement by thermometer (closed-type shunt reactors or reactors equipped with expansion tank) : 60°C
- Reference ambient temperature : 40°C

4. **Zero-Sequence Reactance**

The ratio of the zero-sequence to the positive-sequence reactance (X_0/X_1) of the subject three-phase reactor units shall lie between 0.95 and 1.0.

5. **Connection of Windings**

The reactor shall constitute a three-phase unit, star-connected, with its neutral connected directly to ground.

6. **System Switching Over-Voltages**

The subject reactors may be connected at the end of long submarine cable lines for the purpose of compensating their reactive power requirements. In this case the reactors may be subjected to switching over-voltages of a maximum amplitude of 3 p.u. (1 p.u. = $170/\sqrt{3}$).

7. **Harmonics**

The maximum allowable crest value of the third harmonic component of the reactor current shall be 3% of the crest value of the fundamental, when the reactor is energized at rated voltage with a sinusoidal wave form.

8. **Saturation**

The reactors must be designed in such a way so as to exhibit linear magnetization characteristics for voltages of at least equal to 1.2 times their rated voltage.

9. **Voltage Variation**

The reactors shall be designed to operate at 105% of the rated voltage continuously, without exceeding the specified temperature rise limits.

10. **Audible Sound Level**

The audible sound level of the reactors shall not surpass 72db(A). The reactors shall be designed with a natural frequency greater than 350Hz.

VI. ACCESSORIES

1. **Bushings**

All bushings shall be of the outdoor fog type with leakage distance at least 4250mm and 450mm for the line and neutral terminals correspondingly. The bushings of the line-end shall be manufactured by TRENCH France or ABB of Sweden, or

ALSTOM of Italy and shall be provided with capacitance tap for power factor testing.
Line-end bushings shall be equipped with spill gaps adjustable from 25" to 40" and having a 26" factory setting.

2. **Bushing Current Transformers**

Each line-end terminal bushing shall be equipped with two current transformers having ratio 100/1A and 500/1A respectively, burden 25VA and 5P20 accuracy class for relaying and 1A secondary current.

Also, the neutral of each reactor shall be equipped with a bushing type current transformer having ratio 100/1A, burden 25VA and 5P20 accuracy class.

The transformers should be able to overload 1,2 times the rated current continuously $I_{\text{cont oper}} = I_{\text{rated}} \times 1,2$.

NOTE

Reactors of 8Mvar and 9Mvar, each line –end terminal bushing shall be equipped with two current transformers having ratio 50/1A and 500/1A respectively, burden 25VA and 5P20 accuracy class for relaying and 1A secondary current.

Also the neutral of each reactor shall be equipped with a bushing type current transformer having ratio 50/1A, burden 25VA and 5P20 accuracy class.

3. **Clamp-type Terminals**

Line-end terminals shall be equipped with flexible clamp connectors suitable for connection to horizontal copper tube of 30mm diameter.

4. **Supervisory and Protection Equipment**

- Earthquake proof Buchholz relay of EMB manufacture and type RS-2001 with electrically separate alarm and tripping contacts, which shall be applied to an 80mm diameter tube, that connects the reactor tank with the expansion tank.
- Oil level gage with low level alarm contacts.
- Oil temperature indicator (dial type thermometer) of AKM or MESSKO manufacture with alarm and trip contacts.
- Winding temperature indicator (dial type thermometer) of AKM or MESSKO manufacture with alarm and trip contacts.
- Main tank pressure relief device of QUALITROL manufacture.
- Silica gel breather on oil conservator or expansion tank.

5. Additional Accessories and Features

Reactors shall be equipped with the following accessories and features:

- 5.1. Combination of drain valve with bottom filter press connection and sampling device.
- 5.2. The oil expansion tank will include a dry air cushion, which will float in oil. The dry air cushion will be connected to the breather. The expansion tank will include also an oil drain valve.
- 5.6. Gasketed joints shall be provided for bushings, manholes and radiators and shall be designed so that the gaskets will not be exposed to the weather and will provided with mechanical stops to prevent crushing of the gasket.
- 5.7. Reactors shall be completely self contained. Conservator radiators and other accessories shall be supported by the reactor tank or sub-base and shall not require separate foundations or support.
- 5.8. Lifting hooks on tank, lifting eyes on cover and provision for jacking.
- 5.9. Tank grounding provision consisting of two copper faced steel pads.
- 5.10. Diagrammatic nameplate.
- 5.11. Nameplate
The reactor shall be provided with a durable metal nameplate made by corrosion resistant material. It shall bear the rating and other essential operating data and it shall include reference to installation and operating instructions as recommended by the manufacturer.
- 5.12. Reactor base shall include detachable rollers for skidding and rolling in a direction to either center line.
- 5.13. Provision shall be made for termination of weather resistant 600V, color-coded or marked for identification, control and signal wiring in a weatherproof terminal box. The available D.C. source for control etc. is 110V battery.
- 5.14. Reactors shall be furnished complete with oil and suitable for continuous operation.
- 5.15. Reactors shall be painted with gray color RAL 7040

VII. TESTS

1. Routine Tests

The following tests shall be made on all units ordered:

1. Measurement of winding resistance and dissipation factor ($\tan\delta$).
2. Measurement of reactance

3. Measurement of losses at 157.5 kV at 50Hz
4. Separate – source withstand voltage test 50KV for 1 min at 50Hz for the neutral – end and line-end terminals.
5. Short duration Induced over-voltage test and measurements of partial discharges according to IEC 60076-3 standard.
6. Lightning impulse test with 750KV for the line – end terminals.
Lightning impulse test with 125KV for the neutral – end terminal.

2. Type Tests

Temperature rise test.

The test shall be carried out at 105% of rated voltage at 50Hz.

The temperature rise of the winding measurement by resistance method shall not exceed 65° C.

The temperature rise of the oil shall not exceed 60° C.

3. Special Tests

The following tests shall be made on one unit of the order:

1. Measurement of zero–sequence reactance.
2. Chopped wave impulse test with 825KV only of line – end terminals, according to IEC 60076-3 standard.
The test sequence is the following:
 - a. One (1) full wave between 50% and 75% of 750kV with shape 1.2/50µsec.
 - b. One (1) full wave 750KV with shape 1.2/50µsec.
 - c. One (1) or more chopped waves between 50% and 75% of 750kV with shape 1.2/50µsec.
 - d. Two (2) chopped waves 825KV with shape 1.2/50µsec.
 - e. Two (2) full waves 750KV with shape 1.2/50µsec.
3. Long duration induced over-voltage test and measurements of partial discharges according to IEC 60076-3 standard.
4. Measurement of acoustic sound level.
The level of acoustic sound shall not exceed 72dB (A).
5. Measurement of vibrations at nominal voltage.
The level of vibrations shall not exceed 200µm.
6. Measurement of the current harmonics.
7. Measurement of mutual reactance.

8. Measurement of linearity of reactance at 70%, 90% and 105% of rated voltage.
9. Measurement of magnetic characteristic

VIII. DATA TO BE SUPPLIED BY BIDDER

1. Bidders attention is drawn to the importance of giving all the information requested by the SCHEDULE "A" of the present Specification.
Failure on the Bidder's part to comply in this respect will be taken as reasonable ground for the rejection of the Bid.
2. Bidders are required to submit, attached to their offers, drawings showing the outline dimensions of the reactors for erection purposes as well as any information, sketches and data necessary for a complete description of the equipment offered by them.
3. Along with the subject reactors Seller shall furnish complete instruction books for erection and maintenance.
4. The economic comparison of the offers shall be made according to the data requested by the SCHEDULE "B" of the present Specification.

IX. SPARE PARTS

Bidders should quote the following spare parts giving item prices:

Item Number	DESCRIPTION
1	One line-end bushing complete.
2	One neutral-end bushing complete.
3	Complete set of gaskets for all bushings, covers, radiator flanges, manholes and hand-holes for one reactor.
4	Set of replacement parts for each type of part likely to be damaged upon operation such as relays, instruments, safety devices, etc.

The Purchaser reserves himself the right to determine, when signing the Contract, the spare parts which Seller shall furnish on the basis of the prices set forth in his proposal.

X. PACKING

The accessories of the reactors will be packed inside robust, entirely closed, wooden boxes, of at least 20mm thickness and maximum gross weight of 5 tons.

The boxes will be of pallet type and they will be protected internally by an insulating material (e.g. nylon).

The oil will be sent inside barrels and also the instruments, control and protection equipment will be sent inside separate boxes as above.

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SCHEDULE "A"

Information by Seller

1. Type :
2. Rated power at rated voltage 157.5kV : Mvar
3. Maximum permissible operating voltage : kV
4. Rated current of the reactor at 157.5kV :
5. Applicable standards :
6. Rated frequency : Hz
7. Type of core :
8. Connection of windings :
9. Lighting impulse withstand voltage
 - a. At line-end :
 - b. At neutral-end :
10. Power frequency withstand voltages (1min, 50Hz)
 - a. At line-end : kV r.m.s.
 - b. At neutral-end : kV r.m.s.
11. Level of winding insulation :
12. Temperature rise limits
 - a. For windings :
 - b. For the oil :
13. Ratio of the zero-sequence reactance to the positive-sequence reactance (x_0/x_1) :
14. Voltage variation without exceeding the temperature rise limits :

15. Harmonics of reactor current at rated voltage
- a. Third harmonic :
 - b. Fifth harmonic :
 - c. Seventh harmonic :
16. Noise levels at rated voltage :
17. Vibration levels at rated voltage :µm
18. Normal frequency of reactor :
19. Total losses and impedance
- a. At rated voltage 157.5kV : kW
 - Ω/phase
 - b. At 105% rated voltage : kW
 - Ω/phase
20. Cooling method :
21. Have the reactors been designed to employ linear magnetization characteristics with voltage equal to 1.2 of their rated voltage?:
22. Bushings
- a. Line-end bushings
 - Type and manufacturer :
 - Lightning withstand level :
 - 1 minute - 50Hz Power frequency withstand voltage : kV r.m.s.
 - Minimum creepage distance : mm
 - Range of spill-gap settings : mm
 - b. Neutral-end bushing
 - Type and manufacturer :
 - Lightning withstand level :
 - 1 minute - 50Hz Power frequency withstand voltage : kV r.m.s.
 - Minimum creepage distance : mm

23. Bushing current transformers
- a. Line-End
- Ratio :
 - Continuous operations current :
 - Burden :VA
 - Accuracy class :
- b. Neutral-End
- Ratio :
 - Continuous operation current :
 - Burden :VA
 - Accuracy class :
24. Type and manufacturer BUCHHOLZ
- Installation :
 - Characteristics of alarm contacts :
 - Characteristics of tripping contacts :
25. Is the reactor equipped with oil level gauge with low level alarm contacts? :
26. Type and manufacturer of the oil temperature measurement instrument :
- Characteristics of alarm contacts :
 - Characteristics of tripping contacts :
27. Type and measurement of the winding temperature measurement instrument
- Characteristics of alarm contacts :
 - Characteristics of tripping contacts :
28. Type and manufacturer of the pressure relief device :
29. Is the reactor tank of cover bolted type? :
30. Accessories and features of the reactors according to paragraph VI-5 :
31. Reactor oil
- a. Type and manufacturer :
 - b. Does the oil contain PCBs or PCTs? :
 - c. Is it in accordance with IEC-60296, class II standard :
32. Are the line-terminal bushings equipped with flexible clamp connectors appropriate for connection to 30mm diameter

- copper tubes? :
- 33. Has the reactor Silica Gel breather on the oil conservator or the expansion tank? :
- 34. Color of the reactor :
- 35. Approximate mechanical data
 - a. Transfer weight : kg
 - b. Total weight : kg
 - c. Core and coils : kg
 - d. Case and fittings : kg
 - e. Oil : kg
 - f. Untanking weight (heaviest piece) : kg
 - g. Overall height : m
 - h. Height over case : m
 - i. Untanking height (with bushings) : m
- 36. Acceptance of specified tests :
- 37. Is the packing according to the paragraph X of the specification? :
- 38. Deviations if any from the present specification and the reasons thereof :

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SCHEDULE "B"

EVALUATION OF LOSSES

1. Reactor first cost and losses
 - a. The reactor first cost
 (The reactor first cost will be computed by the Purchaser who will consider the Seller C+F price, as amended after the evaluation of the proposed terms of payment) : K = €.
 - b. Total losses at rated voltage
 157.5kV (guaranteed value) : C = kW
2. Reactor annual cost
 - a. Reactor carrying charges
 (at 9.37 per cent) : $\frac{9.37K}{100} = \dots\dots\dots \text{€}.$
 - b. Capacity loss(.116,7€/kW-year) : 116,7..€ x C..... €.
 - c. Energy loss (0,0438€. per kWh) : 0,0438€xC x 7500 = €.
 - d. Total annual cost : (the sum) = €.
3. Penalty for excess losses
 With regard to total losses, a reactor is considered as successfully inspected if the losses ascertained during inspection do not exceed the maximum tolerance of 15% which is specified in the IEC Standards, versus the losses guaranteed by Seller.
 Otherwise the reactor shall be rejected. On each successfully inspected reactor, any difference in the losses versus the guaranteed ones (without tolerance), shall be negative or zero. If such difference is positive, i.e. the losses ascertained during inspection exceed the guaranteed ones (without tolerance) penalty shall be imposed on Seller consisting of:

...4751€ per kW of total losses in excess.