INDEPENDENT POWER TRANSMISSION OPERATOR S.A.
TNPRD/ SUBSTATION SPECIFICATION & EQUIPMENT SECTION

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SPECIFICATION SS-52/18
8 MVAR – 50 MVAR, 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 that 1000m above sea level and for an ambient temperature ranging between -25^{o}C and +40^{o}C and shall operate satisfactorily under snow and ice conditions.

V. REQUIREMENTS FOR THE REACTOR

1. Basic Rated Quantities

a. Highest voltage for equipment (U_m) : 170kV

b. Rated voltage (U_r) : 157.5kV

c. Rated power : (as stated in the inquiry)

d. Rated current :(calculated from rated power and rated voltage)

e. Rated frequency : 50Hz

f. Maximum operating voltage (U_{max}) :105% of rated voltage

g. Rated insulation levels for windings:

	Line-end	**Neutral-end**
Lightning impulse withstand voltage 1.2/50μs wave, kV crest	750	325
Power frequency withstand voltage, kV r.m.s.	325	140

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 magnetic core of the reactor will be earthed at only one point. The core earthing will be realized through an insulated conductor, connecting the core to an earthing box, placed externally on the reactor tank. By this way the core earthing could be tested without opening the reactor tank.
5. The reactor insulating fluid shall be unused mineral oil of the “inhibited transformer oil (I)” class, in accordance with standard IEC 60296. Also it shall not contain PCBs, PCTs and corrosive sulphur. The only allowed inhibitors are DBPC and DBP with content within 0.30% – 0.40% in weight. The lowest cold start energizing temperature (LCSET) of the oil shall not exceed -30°C.
6. The conductors of all windings, as well as all connecting conductors in the tank, will be insulated by Kraft paper, made by 100% sulphate wood pulp, manufactured and tested according to IEC 60641 series of standards.
7. The reactor shall be designed and manufactured in order to withstand a constant acceleration of at least 1g in all directions during transport, additionally to gravity, without any damage.

3. Temperature Rise Limits

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

-	Average winding temperature rise	:	65 K
-	Hot-spot winding temperature rise	:	78 K
-	Top oil temperature rise	:	60 K

4. Zero-Sequence Reactance

The ratio of the zero-sequence to the positive-sequence reactance (X_0/X_+) 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 (at U_{max} voltage) continuously, without exceeding the specified temperature rise limits.

10. Audible Sound Level

The average sound pressure level of the reactors rated power from 8 Mvar up to and including 25 Mvar shall not surpass 72db(A), measured according IEC 60076-10. The average sound pressure level of the reactors rated power above 25 Mvar up to and including 50 Mvar shall not surpass 76db(A), measured according IEC 60076-10. The reactors shall be designed with a natural frequency greater than 350Hz.

VI. ACCESSORIES

1. Bushings

The design of all bushings will be in accordance with IEC 60137 and EN 50458 standards.
The bushings will be of outdoor – immersed capacitance graded oil insulated type with one end exposed in ambient air and the other end immersed in the reactor oil. The active part of the bushing will consist of an Oil Impregnated Paper (OIP) condenser type core, impregnated with oil.
The insulation housing of line bushings will be of high grade porcelain or of resin impregnated fibre tube and silicon rubber covering.
The porcelain housing will comply in all relevant respects with IEC 62155. The composite housing will comply in all relevant respects with IEC 61462. The space between the active part (core) and the insulating envelope will be oil filled (liquid-insulated bushings). Bushing of resin impregnated technology are acceptable.
The bushings are required to be of the following rating characteristics:

		Line	**Neutral**
1	Highest rated Voltage (phase to phase) (Um) (kV-r.m.s.)	170	72.5
2	Rated phase to earth operating voltage (kV-r.m.s.)	98	42
3	Rated current (Ir)(A)	800	800
4	Rated thermal short time current, 1 sec (Ith)	25Ir	25Ir
5	Rated dynamic current (Id)	2.5Ith	2.5Ith
6	Cantilever operating load (N)	2000	1000
7	Creepage distance (mm)	4250	1813
8	Angle of mounting	≤30^{o}/vertical	≤30^{o}/vertical
9	Temperature limits – class of the insulating material in contact with metal parts	105^{o}C Class A	105^{o}C Class A
10	Dielectric dissipation factor (tanδ) at 1,05Um/√3 voltage	≤0.007	≤0.007
11	Maximum value of partial discharge quantity at U_m voltage	≤10pC	≤10pC

		Line	Neutral
12	Lightning impulse withstand voltage (kV)	750	325
13	Power frequency withstand voltage – dry / wet (kV)	355 / 325	155 / 140
14	Type according EN 50458	170/750/800	72.5/325/800

1.1 Additional characteristics of bushings

a. Seismic withstand capabilities.
All bushings shall be capable of withstand the following seismic stresses as per IEC-61463 and IEC-60068-3-3.
1. Horizontally (axes x and y) :0.5g (5m/s^2)
2. Vertically (axe Z) :0.25g (2,5m/s^2)
3. The frequency range should be 1Hz to 35Hz.
4. Acceptable methods of seismic qualification are:
   - Qualification by vibration test or
   - Qualification by static calculation or
   - Qualification by dynamic analysis

   Bidders are obliged to submit in their offers, test reports or calculation by dynamic analysis, or static calculation.
   Approval or not of all the above lies on IPTO's judgment.

b. Bushings shall be designed for operation at ambient temperature from -25 ^{o}C to +45 ^{o}C and an altitude not exceeding 1000m.

c. The maximum oil temperature under operating emergency conditions will be 115 ^{o}C.

d. The bushings shall have a tin plated copper terminal of cylindrical shape with diameter of 30mm and length of about 100mm.

e. In case of failure, it will be possible to interchange any bushing with another, even from another manufacturer, having the same type and designation according to EN 50458. The reactor manufacturer shall respect the connection details, the maximum bushing dimensions and the minimum clearance distance in oil, following EN 50458.

f. If the line bushings are of a drawn lead or drawn rod type, the cross-section of the lead or rod will be selected according to the instructions of the bushing manufacturer, in order the complete bushings to have a continuous current rating of at least 125% of the rated reactor current.

g. If after taking into consideration the above stated operating characteristics, the above indicated bushings rating current is

less than what it should, then bidders must offer bushings with suitable rating.

1.2 Accessories:

Line bushings will be equipped with the accessories below:

a. Oil level indicator.
b. Test socket (tanδ tap) suitable for measurement of the dielectric dissipation factor, capacitance and partial discharge value of the bushing. The test tap will be electrically isolated from the mounting flange and will be always earthed directly when it is not used.
c. Air release plug.
d. Oil expansion compensator.
e. Oil sampling and oil filling plugs.
f. Lifting lugs if required by the manufacturer and there are no other means of lifting the bushings.
g. Line-end bushings shall be equipped with spill gaps adjustable from 25” to 40” and having a 26” factory setting.

1.3 Rating plates – markings

The line bushings shall carry a rating plate including the following markings.

- Manufacture’s name.
- Year of manufacture and serial number
- Maximum operating phase – phase voltage (Um) or rated operating phase to earth voltage and rated frequency.
- Operating rated current (Ir)
- Insulation levels BIL, P.F.
- Bushings capacitance, dielectric dissipation factor.
- Mass
- Angle of mounting

1.4 Tests (of bushings)

The reactor manufacturer is obliged to present to the IPTO inspector bushings test reports while the inspector is at the manufacturer’s premises for the reactor inspection and testing.
The test reports which are to be presented shall include the following type, routine and special tests:
The tests will be in accordance with IEC 60137 standard.

A. Type tests

1. Power frequency voltage withstand test, wet

2. Long duration power frequency (ACLD) voltage withstand test, with partial discharges measurement (only line bushings)
3. Lightning impulse voltage withstand test
4. Electromagnetic compatibility test (only line bushings)
5. Temperature rise test
6. Thermal short – time current withstand (calculation or test)
7. Cantilever load withstand test
8. Tightness test
9. Verification of dimensions.

B. Routine tests

1. Measurement of dielectric dissipation factor (tanδ) and capacitance at ambient temperature
2. Power frequency voltage withstand test , dry
3. Measurement of partial discharge quantity
4. Test of tap insulation
5. Tightness test
6. Tightness test of flanges
7. Visual inspection and dimensional check

C. Special tests

1. Seismic test (IEC 61463, calculation or test)
2. Artificial pollution test (IEC 60507)

The bushings shall be manufactured from GE or TRENCH or ABB.

1.5 Bushing current transformers

The bushings will be equipped with bushing current transformers as follows.

For reactor rated power from 8 Mvar up to and including 25 Mvar:

Terminals	Number	Ratio	Accuracy & Burden
U,V,W	1	100/1	5P20 25VA For protection
U,V,W	1	500/1	5P20 25VA For protection

Terminals	Number	Ratio	Accuracy & Burden
V	1	---	As required for winding temperature indicator supply
N	1	100/1	5P20 25VA For protection

For rated power above 25 Mvar up to and including 50 Mvar:

Terminals	Number	Ratio	Accuracy & Burden
U,V,W	1	200/1	5P20 25VA For protection
U,V,W	1	500/1	5P20 25VA For protection
V	1	---	As required for winding temperature indicator supply
N	1	200/1	5P20 25VA For protection

All current transformers will follow IEC 61869-1 and IEC 61869-2 standards. They shall have rated continuous thermal current 1.2 times their rated current.
Complete test protocols for the above bushing current transformers shall be available at the time of inspection of the transformers.
Also the secondary windings of CT's of bushings will be tested with the applying a power frequency voltage of 3kV to earth.

2. Supervisory and Protection Equipment

- Earthquake proof Buchholz relay of EMB manufacture, double-float type, which shall be applied to the tube that connects the reactor tank with the expansion tank. The relay shall be designed and tested following EN 50216-1 and EN

50216-2 standards. The test certificates shall be presented to IPTO inspector. Isolating valves will be installed before and after the relay. This relay will be of the double float type with two sets of signaling contacts one for alarm and one for trip. The trapped gas in the Buchholz relay will be possible to be reclaimed through a gas collection device, which will be installed on the tank at a person's height and will be connected permanently with the relay through a hose.

- Shutter valve, which will be mounted in the pipe between conservator and Buchholz relay, preventing the flow of the oil from the conservator to transformer tank, in case of tank rupture. One signaling contact is required.
- Oil level indicator of magnetic type, with low level alarm contacts. The indicator shall be designed and tested following EN 50216-1 and EN 50216-5 standards. The test certificates shall be presented to IPTO inspector.
- Oil temperature indicator of bellow type and, of QUALITROL manufacture, type AKM-OTI, or MR manufacture, type Messko-BeTech, with alarm and trip contacts.
- Winding temperature indicator of bellow type and of QUALITROL manufacture, type AKM-WTI, or MR manufacture, type Messko-BeTech, with alarm and trip contacts. The device will be set before delivery of the reactor, according to the temperature gradient between the top-oil temperature and the hot-spot winding temperature at rated current, which will be found in the temperature rise test report. Both temperature indicators shall be designed and tested following EN 50216-1 and EN 50216-11 standards. The test certificates shall be presented to IPTO inspector.
- Main tank pressure relief device of QUALITROL manufacture, type XPRD, or MR manufacture, type Messko-LMPRD oil-directed. The device will include a metallic cover with a drain, in order to convey the oil safely to the ground. The device shall be designed and tested following EN 50216-1 and EN 50216-5 standards. The test certificates shall be presented to IPTO inspector.
- Silica gel breather on oil conservator or expansion tank. The breather shall be designed and tested following EN 50216-1 and EN 50216-5 standards. The test certificates shall be presented to IPTO inspector.

5. Additional Accessories and Features

Reactors shall be equipped with the following accessories and features:

5.1. Drain valve and other valves for connection with oil treatment equipment and oil sampling device. The vacuum valves shall

be designed and tested following EN 12266-1, -2 standards. The test certificates shall be presented to IPTO inspector.

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.

5.3. Filling plug on the upper radiator header.

5.4. Tank shall be designed for vacuum filling.

5.5. Detachable radiators provided with valves.

5.6. The butterfly valves shall be designed and tested following EN 50216-1 and EN 50216-8 standards. The test certificates shall be presented to IPTO inspector.

5.7. 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.

5.8. All connecting material that is bolts, nuts and lock washers must be hot-dip galvanized as per latest ISO standards.

5.9. 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. The radiators support will be realized by mechanical means, separate from the connecting oil pipes to the tank. The radiators shall be designed and tested following EN 50216-1 and EN 50216-6 standards. The test certificates shall be presented to IPTO inspector.

5.10. Lifting hooks on tank, lifting eyes on cover and provision for jacking.

5.11. Tank grounding provision consisting of two copper faced steel pads.

5.12. Diagrammatic nameplate.

5.13. 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.

5.14. Reactor base shall include detachable rollers for skidding and rolling in a direction to either center line. The distance between rails shall be 1435mm.

5.15. 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.

5.16. Reactors shall be furnished complete with oil and suitable for continuous operation.

5.17. Reactors shall be painted externally with gray color RAL 7040. The paint system will be suitable for high atmospheric corrosivity (category C4) and it will be of high durability (category H), according to ISO 12944-1, -2, -5. The paint

system will include a Zinc-rich primer coat of thickness ≥ 60μm,3 – 4 epoxy or polyurethane paint coats and a finishing coat of polyurethane paint. The total thickness of paint shall be ≥ 240μm. The reactors shall be painted internally with a white colored oil resistant primer coat.

VII. TESTS

Any limitations regarding testing procedures (e.g test voltage, lightning impulse waveform, reactive power, etc) should be declared from the relevant bidder.

1. Routine Tests

Apart of the performance of the below mentioned tests, all routine test certificates of the accessories will be presented to IPTO inspector. The following tests shall be made on all units ordered:

1. Measurement of winding resistance

2. Measurement of reactance

3. Measurement of losses at rated current and 50Hz
   The reported losses will be corrected to reference temperature of 75°C, following the special test method, according to IEC 60076-6, Annex D. The expanded uncertainty of losses with coverage factor k=2 will be calculated and reported by the manufacturer according to IEC 60076-19, but it shall not exceed 5%.

4. Applied voltage test 140 kV for 1 min at 50Hz for the neutral and line terminals (AV).

5. Induced voltage withstand test (IVW).
   The reactor will be tested either using three-phase test voltage or using single-phase test voltage for each phase separately, according to the note below. The line-to-neutral test voltage will be 182 kV.

6. Induced voltage test with measurement of partial discharges (IVPD).
   The reactor will be tested either using three-phase test voltage or using single-phase voltage for each phase separately, according to the note below. The one-hour line-to-neutral test voltage with partial discharge measurement will be 147 kV and the enhancement line-to-neutral test voltage will be 170 kV. This test can substitute the IVW test, but in this case the enhancement line-to-neutral test voltage will be 182 kV.

7. Lightning impulse test with 750KV for the line terminals (LI).

8. AC Withstand Voltage Test on Line Terminals (LTAC)
   This test will be performed by applying a single-phase test voltage for each phase separately, according to the note below. The line-to-earth voltage will be 325 kV. The test frequency and duration is the same as for the IVW test.
   Alternatively to performing the LTAC as a routine test, the switching impulse test (SI) of par.VII.3.3 can be performed as a routine test and the LTAC as a special test.

9. Dissolved gas analysis (DGA)
   After the completion of all HV dielectric tests, oil samples will be taken and submitted to dissolved gas analysis (DGA). The oil sampling and the DGA will be performed according IEC 61181 and IEC 60567.

10. Auxiliary wiring insulation test (AuxW).
    2 kV for auxiliary power and signaling circuits, 2.5 kV for secondary windings of CTs, 1 min, 50 Hz.

11. Check of ratio and polarity of bushing current transformers

12. Functional test of auxiliary wiring

13. Tightness test
    Gas pressure of at least 30kPa over the normal oil pressure will be applied for 24h in the conservator, with the reactor in assembled state. No leaks shall be observed. The pressure at the tank bottom shall be recorded during the test with a calibrated manometer.

14. Measurement of capacitance and dissipation factor at 10 kV.
    $\tan\delta \leq 0.005$

15. Measurement of winding insulation resistance at 2.5 kV (60s and 15s DAR value). Also insulation resistance measurement between core and tank at the external earthing box (par.V.2.4).

16. Painting check
    The external painting thickness will be checked using magnetic method, according ISO 2178. The external painting adhesion will be checked using cross-cut method, according ISO 2409. The types of paint system ingredients will be submitted to IPTO's inspector.

17. Insulating oil tests
    The following tests will be performed on oil sample from the reactor tank and the mentioned acceptance levels will apply:

a. Breakdown voltage (BDV) following IEC 60156, with value ≥ 70 kV
b. Dielectric dissipation factor (DDF) following IEC 60247 or IEC 61620, with value ≤ 0.005
c. Water content following IEC 60814, with value ≤ 40 mg/kg
d. Interfacial tension (IFT) following EN 14210 or ASTM D971, with value ≥ 40 mN/m
e. Particle content following IEC 60970, with value ≤ 1000 parts/100ml with size p > 5 μm and value ≤ 130 parts/100ml with size p > 15 μm

18. Frequency response measurement

A frequency response measurement will be executed after all other routine and special tests and prior to shipment, following IEC 60076-18. In case the manufacturer does not possess SFRA testing equipment, the test will be perfomed with equipment provided by IPTO.

Note:

If the IVW and the IVPD tests are executed by applying single-phase voltage, according to IEC 60076-6, the following winding connection will be used:

- Application of a voltage 1.5 x U_{test} between the line terminal under test and the other two line terminals connected together, with the neutral terminal connected to earth. In this connection, the tested line-to-neutral voltage is U_{test}.

For the LTAC test, according to IEC 60076-6, the following winding connection will be used:

- Application of a voltage U_{test} between the line terminal under test and the other two line terminals connected together and to earth, with the neutral terminal left unconnected. In this connection, the tested line-to-earth voltage is U_{test} and the neutral-to-earth voltage is ⅓ x U_{test}.

2. Type Tests

1. Temperature rise test.

Two oil temperature sensor pockets shall be available on the reactor cover. Additionally, one oil temperature sensor pocket shall be available at the oil input and one at the oil output of the radiators. Four temperature sensors shall be placed around the perimeter of the tank, at the mid height of the radiators and 2 m away from them.

The temperature rise test will be carried out before the dielectric routine and special tests.

The test shall be carried out at 105% of rated voltage (U_{max}) at 50Hz. The values of top-oil temperature rise, average winding temperature rise and average winding to oil temperature

gradient will be reported at the test results. The value of hot-spot temperature rise will be calculated and reported also.
The average winding temperature rise shall not exceed 65 K.
The hot-spot winding temperature rise shall not exceed 78 K.
The top oil temperature rise shall not exceed 60 K.
The oil and winding temperature indicators will be calibrated at the end of the test.

2. Measurement of losses.
The measurement will be carried out at 105% of rated voltage (U_{max}), during and close to the end of the temperature rise test (par.VII.2.1), with the reactor close to service temperature. The reported losses will be corrected to rated current and reference temperature of 75°C. The expanded uncertainty of losses with coverage factor k=2 will be calculated and reported by the manufacturer according to IEC 60076-19, but it shall not exceed 5%.

3. Measurement of vibrations.
The level of vibrations shall not exceed 200 μm.
The measurement will be carried out at 105% of rated voltage (U_{max}), during and close to the end of the temperature rise test (par.VII.2.1), with the reactor close to service temperature.

4. Measurement of acoustic sound level.
The test will confirm that the reactor corrected average sound pressure level does not exceed 72 dB(A) or 76 dB(A), as specified in par.V.10.
The measurement will be carried out at rated voltage and frequency, right after the end of the temperature rise test (par.VII.2.1), with the reactor close to service temperature. The measurement will be performed in accordance with IEC 60076-10.

3. Special Tests

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

1. Measurement of zero–sequence reactance.

2. Chopped wave lightning impulse test on line terminals (LIC).
During the full-wave impulse test and for each winding, application of chopped impulses shall be inserted, forming the test sequence as follows:
   a. One (1) reduced level, full wave impulse (50% to 70% of 750kV) with shape 1.2/50μs.
   b. One (1) full wave 750KV impulse with shape 1.2/50μs.
   c. Two (2) chopped wave 825KV impulses with shape 1.2/2-6μs.
   d. Two (2) full wave 750KV impulse with shape 1.2/50μs.

The chopping time of the chopped lightning impulse will be between 2 μs and 6 μs and the following overswing will be below 30%. The current to earth shall be recorded during the test.

3. Switching impulse test with 620 kV for the line terminals (SI).

4. Lightning Impulse Tests on Neutral Terminal (LIN).
   The impulses shall have a front time up to 13 μs. The test sequence shall be as follows:
   a. One (1) reduced level, full wave impulse (50% to 70% of 325 kV).
   b. Three (3) full wave 325 kV impulses.

5. Measurement of vibrations at nominal voltage.
   The level of vibrations shall not exceed 200 μm.

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

10. Pressure deflection test of the tank
    The permanent deflection of any point of the tank walls shall not surpass 1 mm, after applying an internal pressure of at least 35 kPa above the normal operating pressure.

11. Vacuum deflection test of the tank
    The permanent deflection of any point of the tank walls shall not surpass 1 mm, after applying an internal vacuum.

12. Vacuum tightness test
    After applying vacuum in the tank, the mean rate of internal pressure rise shall not surpass 0.2 kPa/h over a period of 30 min.

13. Insulating oil tests
    The following tests will be performed on oil sample from the reactor tank and the mentioned acceptance levels will apply:
    a. Inhibitor content of DBPC or DBP type following IEC 60666, with value within 0.30% – 0.40%
    b. Corrosive Sulphur existence following DIN 51353, with negative result (not corrosive)
    c. Potentially corrosive Sulphur existence following IEC 62535, with negative result (not corrosive)
    d. PCBs existence following IEC 61619, with negative result (not detectable, < 2 mg/kg)

e. Acidity following IEC 62021-1 or -2, with value ≤ 0.10 mgKOH/g
f. Viscosity following ISO 3104, with value ≤ 12 mm^2/s at 40°C and value ≤ 1800 mm^2/s at -30°C (LCSET)

VIII. DATA TO BE SUPPLIED BY BIDDER AND VENDOR

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. Providing that a contract has been awarded, the Vendor shall furnish three (3) copies of the following drawings for approval and before the construction of the reactors :
   a. Assembled reactor outline drawing.
   b. Reactor outline drawing for transport, showing centre of gravity
   c. Bushing outline drawings, including type and designation according EN 50458.
   d. Name plate drawing.
   e. Bushing current transformer control wiring diagrams.
   f. Bushing current transformer characteristic curves showing open circuit secondary saturation, ratio and phase angle correction.
   g. Wiring diagram of the reactor itself.
   h. Operating pressure of the pressure relief device
   i. Physical and chemical characteristics of the insulating oil, as specified in IEC 60296
   j. Detailed quality control plan (QCP), incorporating quality assurance (QA) and inspection and test plan (ITP).

   Along with the subject reactors, Vendor shall furnish three (3) copies of complete instruction books for erection and maintenance and three (3) copies of final drawings.
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	D E S C R I P T I O N
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. RATING PLATES

The transformer will be provided with a rating plate of a non-corrosive material, fitted in a visible location showing the items indicated below:

1. Relevant Standard IEC 60076
2. The manufacturer's name
3. Serial number
4. Year of manufacture
5. Number of phases
6. Rated power (Mvar)
7. Rated frequency (Hz)
8. Rated voltage (KV)
9. Rated current (A)
10. Maximum operating voltage (U_{max})
11. Type of cooling.
12. Reactor total mass
13. Reactor transportation mass
14. Reactor untanking mass
15. Reactor active part mass, if different from untanking mass
16. Type of electrical conductor (copper)
17. Reactor conductor mass
18. Type of magnetic core material
19. Reactor core mass
20. Type of insulating oil (inhibited transformer oil)
21. Reactor oil mass
22. Insulation levels
23. Characteristics of any surge arresters, if existing, built in the reactor
24. Guaranteed temperature rise of top oil
25. Guaranteed temperature rise of windings

26. Winding temperature indicator setting (measured temperature gradient between top-oil and hot-spot winding temperature at rated current)
27. Diagram of the windings configuration
28. Vacuum withstand capability of the tank and conservator.

The reactor will be also provided with a plate indicating the designation, position, scope of use, type and dimensions of all valves of the reactor tank and oil conservator. The plate will indicate also the state (opened, closed) for each valve during normal operation or vacuum drying conditions.
In addition to the above mentioned plates with the above information, the reactor shall also carry nameplates with technical characteristics of auxiliary equipment, such as bushings, CTs, cooling system and OLTC according to the individual Standards.

XI. PACKING

The accessories of the reactors will be packet 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.
For each shipment lot of reactors, at least one shock recorder will be provided and installed by the manufacturer on a reactor tank. For each contract, shock recorders will be installed on the 30% at least of the number of provided reactors.
The shock recorders will be of digital type and they will include GPS and time tagging of the recordings. They will be of type SMT HYBRID – MONILOG ENDAL or SHOCKWATCH – SHOCK LOG 298 or MESSKO – CARGOLOG or of an equivalent type, subject to IPTO's approval.
The alarm limit of shock recorders will be set below 1g acceleration, which is the design withstand limit, according to par.V.2.7.

8 MVAR – 50 MVAR, 157.5kV SHUNT REACTORS

ATTACHMENT "A"

Information by Seller

1.	Type		:	……..
2.	Rated power at rated voltage 157.5kV		:	…….…… Mvar
3.	Maximum continuous 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 rms
	b.	At neutral-end	:	…… kV rms
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_+) (estimated value)		:	……..
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. Average sound pressure level : ……dB(A)

17. Vibration levels at rated voltage : ……µm

18. Normal frequency of reactor : ……..

19. Total losses
(at reference temperature 75°C)

a. At rated voltage and current : …… kW
(guaranteed value)

b. At 105% of rated voltage (U_{max}) : …… kW

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 : ……..
- Max. phase-phase operating voltage : ……kV rms
- Rated current : ……A
- Lightning withstand level : …… kV
- 1 minute - 50Hz Power frequency withstand voltage : …… kV rms
- Minimum creepage distance : …….. mm
- Cantilever withstand load : …….. N
- Range of spill-gap settings : …….. mm

b. Neutral-end bushing
- Type and manufacturer : ……..
- Max. phase-phase operating voltage : ……kV rms
- Rated current : ……A
- Lightning withstand level : ……..
- 1 minute - 50Hz Power frequency withstand voltage : …… kV r.m.s.
- Minimum creepage distance : …….. mm
- Cantilever withstand load : …….. N

c. Are the bushings interchangeable with any other having the same type, according EN 50458? : ……..

23. Bushing current transformers

a. Line-End
- Ratio : ……..
- Continuous thermal current : ……..
- Burden : ……VA
- Accuracy class : …….

b. Neutral-End
- Ratio : ……..
- Continuous thermal 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 manufacturer 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, PCTs or corrosive sulphur? : ……..
c. Is the oil of the “inhibited transformer oil (I)” class in accordance with IEC 60296? : ……..

32. Are the terminals of line bushings

made of 30 mm diameter copper rods? : ……..

33. Has the reactor Silica Gel breather on the oil conservator or the expansion tank? : ……..

34. Color of the reactor : ……..

35. Corrosivity category and durability category of the reactor's painting, according ISO 12944 : ……..

36. 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

37. Acceptance of specified tests : ……..

38. Is the packing according to the paragraph XI of the specification? : ……..

39. Deviations if any from the present specification and the reasons thereof : ……..
……..
……..

8 MVAR – 50 MVAR, 157.5kV SHUNT REACTORS

ATTACHMENT "B"

CAPITALIZATION OF LOSSES

For the capitalization of losses, the method of EN 50629, Annex E is used, adapted for reactors.

1. Reactor initial cost and losses:

   a. Reactor initial cost (The reactor total initial cost will be calculated by the Purchaser according to the Special Terms of the Inquiry – evaluation of the Bids) : IC = …….. €

   b. Total losses at rated voltage and current, at reference temperature 75°C (guaranteed value) : P_k = …… kW

2. Reactor total ownership cost:

   The capitalized losses (CL) and the total cost of ownership (TCO) of the reactor will be calculated from the above mentioned data and the following mathematical types. In these types, the losses are expressed in kW and the costs are expressed in €.

   $CL = 5827 \cdot P_k$
   Capitalized Losses (CL) = …… €

   TCO = IC + CL
   Total ownership cost (TCO) = …… €

3. Penalty for losses excess:

   With regard to total losses, a reactor is considered as successfully inspected if the losses at rated current and reference temperature 75°C ascertained during inspection (relevant routine test, par.VII.1.3) do not exceed the losses guaranteed by Seller, by more than the maximum accepted tolerance of 10%, according to IEC 60076-6. Otherwise the reactor shall be rejected. The measurement uncertainty is not taken into account, according to IEC 60076-19.

   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, meaning the losses ascertained during inspection exceed the guaranteed ones (without tolerance), a penalty shall be imposed on the Seller consisting of the difference CL' – CL. CL is

calculated from the mathematical type stated above and the guaranteed losses value, whereas CL' is calculated from the same mathematical type as CL and the measured losses value during inspection.

If the difference CL' – CL is negative the Seller is not entitled to any additional payment, whereas if this difference is positive the penalty shall be imposed.