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

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TECHNICAL DESCRIPTION TD-95/6

400 KV, 30 MVAR – 100 MVAR SHUNT REACTORS

I. SCOPE

This technical description covers the characteristics, design features and testing of three-phase 400 kV, outdoor, oil-type shunt reactors.

II. KEYWORDS

Shunt Reactors, Capacitive Current Compensation, Voltage Control.

III. STANDARDS

Unless otherwise specified herein, all reactor characteristics and testing shall conform to the latest revision of IEC 60076-6, 60076-3, 60076-4 standards.

IV. OPERATING CONDITIONS

1.	Installation	:	Outdoor
2.	Ambient Temperature	:	Minimum (-25^{o}C) Maximum (+45^{o}C)
3.	Altitude	:	Up to 1000m above sea level
4.	Other Conditions	:	Snow and Ice
5.	Pollution Level	:	Moderate

V. USE

The shunt reactors are to be used on the system to compensate for capacitive current and also for compensating of reactive power.

VI. ELECTRICAL CHARACTERISTICS OF THE SYSTEM

1. Nominal Voltage : 400KV
2. Maximum System Voltage : 420KV
3. Minimum permissible operating voltage : 380KV
4. Nominal frequency : 50Hz
5. Number of phases and conductors : 3
6. Short Circuit level : 40KA
7. Rated duration of short circuit : 1sec.
8. Basic Insulation level : 1550KV (peak)
9. Switching impulse withstand voltage : 1175KV (peak)
10. Variations of nominal frequency : ±0.2Hz
11. Available auxiliary D.C. supply voltage : 220V D.C. (from substation batteries)
12. Available auxiliary A.C. supply voltage : 3 – phase, (4 – conductors 230/400V A.C.)
13. Power frequency withstand voltage (1min) : 680KV (r.m.s.)
14. Method of earthing (grounding) : Solidly grounded

VII. SHUNT REACTOR REQUIRED CHARACTERISTICS

1. Design Characteristics
   a. Type : Three-phase wye connected oil-immersed type with the neutral directly grounded.
   b. Rated Voltage (Ur) : 400 kV
   c. Highest voltage for equipment (Um): 420 kV
   d. Maximum operating voltage (Umax): 420 kV (105% of rated)
   e. Rated Power : (as stated in the inquiry)
   f. Rated Current : (calculated from rated power and rated voltage)
   g. Rated Frequency : 50 Hz

Rated insulation levels for windings and bushings :

Lightning impulse withstand voltage 1,2 / 50µs wave		
	Line	**Neutral**
Terminal	1425kV crest	550kV crest
Bushing	1550kV crest	550kV crest

Switching impulse withstand voltage		
	Line	**Neutral**
Terminal	1175kV crest	--
Bushing	1175kV crest	--

Power frequency withstand voltage (50Hz, 1min)		
	Line	**Neutral**
Terminal	630kV rms	230kV rms
Bushing	695kV rms	255kV rms

h. The reactor tank will be of COVER BOLTED type and shall be made so as to withstand full vacuum.

i. Method of cooling: Cooled by oil and air natural circulation (ONAN) with radiators.

j. Type of core: gapped iron core of 5 limbs, including side limbs. In general, the iron core shall be designed in such way so that no risk exists of ferroresonance or sub-harmonic oscillations due to system switching operations, overheating of any metal parts and natural resonance of any part of the structure at or near operating frequency.

k. 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.

2. Magnetic Characteristics

The shunt reactors must exhibit linear volt/ampere characteristic up to 120 percent (120%) of their rated voltage.

3. Zero-Sequence Reactance

The ratio of the zero-sequence to the positive sequence reactance (X_0/X_+) of the shunt reactors shall lie between 0.95 and 1.0

4. Temperature Rise Limits

The following temperature rise limits for continuous operation shall be:

- Average temperature rise of winding as determined by resistance : 65 K
- Hot-spot winding temperature rise : 78 K
- Oil (top level) as determined by thermometer : 60 K

5. Harmonics

Shunt reactors shall be designed with particular attention to the suppression of harmonics, especially the second, third

and fifth. The maximum permissible value of the third harmonic component of the reactor current shall be $\leq$ 3% of the crest value of the fundamental at rated sinusoidal voltage.

6. Voltage Variation

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

7. Acoustic Sound Level

The average sound pressure level of the reactors shall not be greater than 80dB(A), measured according IEC 60076-10.

8. Mechanical Vibration Level

Maximum vibration amplitude (peak to peak) on all sides of the tank walls shall be 200 μm.

9. Insulating oil and paper

The reactor's insulating fluid will be unused mineral oil of the "inhibited transformer oil (I)" class, in accordance with the standard IEC 60296. 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.
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.

10. Reactor's painting

The reactor's external color including radiators should be gray of 7040 RAL type. 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 $\geq$ 60μm and 3 – 4 epoxy or polyurethane paint coats of total paint thickness $\geq$ 240μm, where the finishing coat will be of

polyurethane paint. The reactor shall be painted internally with a white colored oil resistant primer coat.

11. Transport acceleration

The reactor shall be designed and manufactured in order to withstand a constant acceleration of at least 1g in all directions, additionally to gravity, without any damage.

VIII. ACCESSORIES

1. Bushings

The design of bushings will be in accordance with IEC 60137 and EN 50458 standards.

1.1 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's oil. The active part of the bushing will consist of an Oil Impregnated Paper (O.I.P.) condenser type core, impregnated with oil.

1.2 The insulation housing of line and neutral bushings will be of high grade porcelain.
The porcelain housing will comply in all relevant respects with IEC 62155. The space between the active part (core) and the insulating envelope will be oil filled (liquid-insulated bushings).

1.3 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.)	420	123
2.Rated phase to earth operating voltage (KV - r.m.s.)	242	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.Minimum cantilever withstand load during operation (N)	≥2000	≥1000
7. Creepage distance (mm)	10500	3075
8.Angle of mounting	≤30º from vertical	≤30º from vertical
9.Temperature limits – class of the insulating material in contact with metal parts	105º C Class A	105º 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 Um operating voltage	≤10pC	≤10pC
12.Lightning impulse withstand voltage (KV)	1550	550
13.Switching impulse withstand voltage (KV)	1175	-
14. Power frequency withstand voltage - dry / wet (KV)	695 / -	255 / 230
15. Type according EN 50458	420/1550/800	123/550/800

1.4 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 -25ºC to +45ºC and an altitude not exceeding 1000m.

c. The maximum oil temperature under operating emergency conditions will be 115ºC.

d. The bushings shall have a tin plated aluminium 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.

1.5 Accessories:

Bushings will be equipped with the accessories below:

a. Magnetic 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.

1.6 Rating plates – markings

The H.V and neutral 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, SIL, P.F.
- Bushings capacitance, dielectric dissipation factor.

- Mass
- Angle of mounting

1.7 Tests

The manufacturer of the reactor is obliged to present to the IPTO inspector bushings test reports while the IPTO inspector is at the manufacturer's premises for the 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 (not for line bushings)
2. Long duration power frequency (ACLD) voltage withstand test, with partial discharges measurement (only line bushings)
3. Lightning impulse voltage withstand test
4. Switching impulse voltage withstand test, dry and wet (only line bushings)
5. Thermal stability (only line bushings, calculation or test)
6. Electromagnetic compatibility test
7. Temperature rise test
8. Thermal short – time current withstand (calculation or test)
9. Cantilever load withstand test
10. Tightness test
11. Verification of dimensions.

B. Routine tests

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

C. Special tests

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

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

2. Bushing Current Transformers

Each line bushing shall be equipped with two (2) current transformers. In addition, the neutral bushing shall be equipped with one (1) current transformer.

The bushing current transformers must have the following characteristics, for shunt reactor rated power ≤65Mvar:

Bushing	**Ratio**	**Total No. of CTs Cores**	**Burden**	**Accuracy class**
Line	100 / 1A	3	30VA	5P20
	100 / 1A	3	15VA	0.5
Neutral	100 / 1A	1	30VA	5P20

The bushing current transformers must have the following characteristics, for shunt reactor rated power >65Mvar:

Bushing	**Ratio**	**Total No. of CTs Cores**	**Burden**	**Accuracy class**
Line	150 / 1A	3	30VA	5P20
	150 / 1A	3	15VA	0.5
Neutral	150 / 1A	1	30VA	5P20

- The middle phase line bushing will be equipped with one additional current transformer for use by the winding temperature indicator, to create the thermal image of the winding.
- 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.
- The three (3) line bushings current transformer cores will be used for the implementation of the overcurrent phases-earth protection scheme. The same three (3) line bushing current transformer cores and also the current transformer core at the neutral, will be used for the implementation of the Restricted Earth Fault protection scheme for high impedance operation. For that scheme, a linear stabilizing resistor and a non-linear voltage limiter resistor are also used. These CTs shall have equal ratios, identical magnetizing characteristics and also identical secondary resistances. The magnetizing current shall be of a minimum value available in order to maximize the sensitivity of the relay. The saturation (knee-point)

voltage must be the same for all CTs and twice the selected operating voltage setting of the relay that corresponds to maximum fault current.

Complete test reports including thermal and dynamic current tests as type tests and resistance measurement, ratio and phase angle tests and excitation curve tests as routine tests must be submitted.

Complete test protocols for the above bushing current transformers shall be available at the time of inspection of the reactors.

3. Supervisory and Protection Equipment.

Reactors shall be equipped with the following:

a. Earthquake proof Buchholz relay of EMB manufacture, double-float type, 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 electrically separate contacts for alarm and tripping. The trapped gas in the Buchholz relay will be possible to be reclaimed through a gas collection device, which will be installed on the transformer at a person's height and will be connected permanently with the relay through a hose.

b. 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 normally open (NO) contact is required.

c. Oil level indicator of magnetic type with alarm contacts for minimum oil level. 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.

d. Oil thermometer of bellow type, with alarm and trip contacts and also equipped with a transmitter device for remote oil temperature indication.

e. Windings thermometer of bellow type, with alarm and trip contacts and also equipped with a transmitter device for remote oil temperature indication. 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.

f. Tank pressure relief device with alarm contacts. 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.

g. Air drier with silica gel filling. The drier shall be designed and tested following EN 50216-1 and EN 50216-5 standards. The test certificates shall be presented to IPTO inspector.

NOTE: Oil and winding thermometers shall be of QUALITROL make, type AKM-OTI/WTI, or MR make, type Messko-BeTech. The pressure relief device will be of QUALITROL make, type XPRD, or MR make, type LMPRD oil-directed.

4. Additional Accessories

Reactors shall be equipped with the following accessories and features:

a. The radiators shall be tank-supported and detachable from the tank by means of shut-off valves. 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 radiator valves shall be designed and tested following EN 50216-1 and EN 50216-8 standards. The test certificates shall be presented to IPTO inspector.

b. 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.
c. All steel parts will be hot dip galvanized as per the latest ISO Standards.
d. Tank oil drain valve and other valves to connect the vacuum 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.
e. Conservator or expansion tank composed of one piece ready for installation and will be equipped with a dehydrating breather containing absorbent material (silica-gel) and also a dry air cell floating on the oil surface as well as suitable drain valve.
f. Filling plug on the upper radiator header.
g. Gasketed joints for bushings, manholes and radiators shall be designed so that the gaskets will not be exposed to the weather and will be provided with mechanical stops to prevent crushing of the gasket.
h. Lifting eyes for the tank, pulling eyes for moving the reactor to any direction, lifting lugs for lifting the core and coil assembly and jacking pads for raising the complete shunt reactor.
i. Bi - directional rollers for movement on rails. The distance between rails shall be 1435mm.
j. The tank will be grounded in two points at least diagonally near the bottom.
k. Plate of non-corrosive material bearing the electrical diagram of the reactor.
l. Nameplate made of non-corrosive material bearing the rated characteristics of the reactor and other essential data.
m. Weatherproof terminal box for termination of weather resistant 600 V, color-coded or marked for identification control and signal wiring.

IX. NAME PLATE MARKINGS

Each reactor shall be provided with a permanent nameplate that includes the following information.

1. Relevant Standard IEC 60076

2. Manufacturer's name.
3. Serial Number.
4. Year of manufacture.
5. Number of phases.
6. Rated Power.
7. Rated Frequency.
8. Rated Voltage.
9. Rated Current.
10. Maximum operating voltage.
11. Insulation level
12. Characteristics of any surge arresters, if existing, built in the reactor
13. Guaranteed temperature rise of top oil
14. Guaranteed temperature rise of windings
15. Winding temperature indicator setting (actual temperature gradient between top-oil and hot-spot winding temperature at rated current)
16. Diagram of the winding connection.
17. Type of cooling.
18. Total mass.
19. Transportation mass.
20. Untanking mass.
21. Active part mass, if different from untanking mass
22. Type of electrical conductor (copper)
23. Conductor mass
24. Type of magnetic core material
25. Core mass
26. Type of insulating oil (inhibited transformer oil)
27. Mass of insulating oil.
28. Vacuum withstand capability of tank, conservator and radiators

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.

X. TESTS

Any rectriction concerning the test performance capability (e.g test voltage, lightning impulse waveform, reactive power, etc) will be stated along with the offer.
The following tests shall be carried out for the shunt reactors:

A. Routine Tests

Apart of the performance of the below mentioned tests, all routine test certificates of the accessories will be presented to IPTO inspector.

1. Measurement of winding resistance

2. Measurement of reactance.

3. Measurement of losses at rated current and frequency (50 Hz)
   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. Chopped Wave Lightning Impulse Tests on Line Terminals (LIC)

   The impulse test-sequence is applied to each of the line windings. The other line windings and the neutral shall be earthed directly or through low impedance. The current to earth shall be recorded during the test.
   During the full-wave impulse test and for each winding, application of chopped impulses shall be inserted, forming the test sequence as follows:

   1. Application of one reduced level, full wave impulse 1.2/50μs (50%÷70% of 1425kV)

2. Application of a 1425kV, full wave impulse 1.2/50 μs
3. Application of two 1570kV, chopped wave impulses 1.2/50 μs
4. Application of two 1425kV, full wave impulses 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%.

5. Switching Impulse Test on Line Terminals (SI)

A switching impulse test shall be carried out on all line terminals, using a voltage of 1175 kV. The test shall be carried out by applying to each phase in turn, from line winding to neutral with the neutral earthed, one reduced voltage wave and three full voltage waves. The reduced voltage wave shall have a crest value between of 50% and 70% of 1175 kV.
The test shall be performed with the waveshape 100μsec/1000μsec

6. Applied Voltage Test (AV)

A test voltage of 140 kV rms, 50 Hz shall be applied for 60 seconds between all line and neutral terminals connected together and to core, frame and tank of the reactor connected together to earth.

7. Induced Voltage Withstand Test with measurement of Partial Discharges (IVPD)

This test and measurement of partial discharges will be executed in accordance with IEC 60076-3 and with three-phase reactor to be tested either using three-phase test voltage or using single-phase test voltage for each phase separately. The one-hour line-to-neutral test voltage with partial discharge measurement will be 365 kV and the enhancement line-to-neutral test voltage will be 420 kV.
If the IVPD test is 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}.

8. 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.

9. Auxiliary Wiring Insulation Test (AuxW)

   The auxiliary wiring for auxiliary power or signalling will be tested with a 1min AC voltage of 2kV to earth. The secondary windings of bushing current transformers will be tested with a 1min AC voltage of 2.5kV to earth.

10. Check of ratio and polarity of bushing current transformers

11. Functional test of auxiliary wiring

12. 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.

13. Measurement of capacitance and dissipation factor

    The measurement shall be carried out between winding and earth. The test voltage will be 10kV.
    $\tan\delta \leq 0.5$ %

14. Measurement of the insulation resistance

    The measurement shall be carried out between winding and earth for two time periods (60 seconds and 15 seconds, DAR value measurement), with 2.5kV test voltage.

To check if the core earthing follows par.VII.1k, an insulation resistance measurement shall be carried out between core and tank at the external earthing box, with a suitable voltage.

15. 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.

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

17. 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 performed with equipment provided by IPTO.

B. Special Tests

The special tests shall be carried out on one (1) item of the order

1. Measurement of zero-sequence reactance.

2. Measurement of mutual reactance.

3. Measurement of harmonics of the current.

4. Measurement of magnetic characteristics.

5. Measurement of linearity of reactance at 70%, 90% and 105% of rated voltage.

6. Lightning Impulse Tests on Neutral Terminal (LIN)

   For this test, all line terminals are earthed and the impulses shall have a front time up to 13μs. The test sequence of the different impulses shall be as follows:
   - One reduced full impulse : For this test, the applied voltage wave shall have a crest value between 50% and 70% of 550 kV.
   - Three 100% full impulses : For this test the applied voltage wave shall have a crest value of 550 kV.

7. AC Withstand Voltage Test on Line Terminals (LTAC)

   The test will be performed by applying a single-phase test voltage for each phase separately. The line-to-earth voltage will be 630 kV. The test frequency and duration is the same as for the enhancement level of IVPD 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}.

8. Pressure deflection test of the tank

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

9. Vacuum deflection test of the tank

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

10. 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 30min.

11. 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)

C. **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 top-oil temperature rise shall not exceed 60 K.
The average winding temperature rise shall not exceed 65 K.
The hot-spot winding temperature rise shall not exceed 78 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.X.C.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 200μm.
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.X.C.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 80 dB(A).
The measurement will be carried out at rated voltage and frequency, right after the end of the temperature rise test (par.X.C.1), with the reactor close to service temperature. The measurement will be performed in accordance with IEC 60076-10.

XI. DATA TO BE SUPPLIED BY BIDDER AND VENDOR

1. Bidders must provide all information requested by Attachment "A" attached to this hereby technical description.

Failure on the Bidder's part to comply in this respect will be taken as reasonable ground for the rejection of the offer.

2. Bidders are required to submit, along with the offer, drawings showing the outline dimensions of the reactor for erection purposes as well as any information, sketches and data necessary for a complete description of the reactor and related equipment offered.

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).

   In addition the seller shall provide the following :
   Five (5) copies of final drawings and five (5) copies of complete instruction books for erection and maintenance, all along with the shipment of the reactors.

XII. ECONOMIC COMPARISON OF THE OFFERS

The economic comparison of the offers shall be made according to the data requested by the "SCHEDULE B" of this hereby technical description.

XIII. SPARE PARTS

Bidders should quote the following spare parts giving item prices:

Item Nr.	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 handholes 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 the right to determine, when signing the contract, the spare parts which seller shall furnish on the basis of the prices set forth in the proposal.

XIV. 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.VII.11.

ATTACHMENT "A"

400 kV, 30 MVAR – 100 MVAR SHUNT REACTORS

INFORMATION REQUIRED BY THE SELLER

1.	Applicable Standards	:	----------
2.	Type of the reactor	:	----------
3.	Rated Voltage of the reactor	:	----------kV
4.	Maximum Continuous Operating voltage of the reactor	:	----------kV
5.	Rated Power at 400 kV	:	----------Mvar
6.	Rated Frequency	:	---------- Hz
7.	Rated Current at 400 kV	:	---------- A
8.	Rated Reactance	:	----------
9.	Method of Cooling	:	----------
10.	Phase Connection	:	----------
11.	Type of core design (number and type of limbs)	:	----------
12.	Insulating oil		
	a. Type and manufacturer	:	----------
	b. Does the oil contain any PCBs, PCTs or corrosive Sulphur?	:	----------
	c. Is the oil of the "inhibited transformer oil (I)" class in accordance with IEC 60296?	:	----------
13.	Reactor identification with regard its magnetic characteristic (i.e. linear, non-linear, etc)	:	----------

14. Ratio of zero sequence reactance to positive sequence reactance (X_0/X_+) (estimated value) : ----------

15. Average sound pressure level : ----------dB(A)

16. Mechanical Vibration Level : ---------- μm

17. Voltage Variation Capability : ----------

18. Harmonics of the current as per cent of the fundamental

2nd : ----------
3rd : ----------
5th : ----------

19. Winding temperature rise limits for 40°C ambient temperature (guaranteed values)

- Average by winding : ---------- °C

20. Oil (Top) temperature at 40°C ambient temperature : ---------- °C

21. Lightning Impulse withstand voltages:

- Line windings/bushings : -------/-----kV crest
- Neutral terminal/bushing : ------/------kV crest

22. Switching impulse withstand voltages

- Line windings/bushings : -------/-----kV crest

23. Power frequency withstand voltages (1 min, 50 Hz)

- Line windings/bushings : -------/-----kV rms
- Neutral terminal/bushing : -------/-----kV rms

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

- At rated voltage and current (guaranteed value) : ---------- kW
- At 105% of rated voltage : ---------- kW

25. Bushings

a. Line bushings
- Type : ----------
- Manufacturer : ----------
- Max. phase-phase operating voltage : ---------- kV
- Lightning impulse withstand voltage : ---------- kV
- Switching impulse withstand voltage : ---------- kV
- 50 Hz withstand voltage (1 minute) : ---------- kV
- Creepage distance : ---------- mm
- Rated current : ---------- A
- Cantilever withstand load : ---------- N

b. Neutral Bushing
- Type : ----------
- Manufacturer : ----------
- Max. phase-phase operating voltage : ---------- kV
- Lightning impulse withstand voltage : ---------- kV
- Creepage distance : ---------- mm
- 50 Hz withstand voltage (1 minute) : ---------- kV
- Rated current : ---------- A
- Cantilever withstand load : ---------- N

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

26. Bushing Current Transformer

	Line		Neutral
	CT	**CT**	**CT**
Ratio			
Burden			
Accuracy class			
Manufacturer			
Type of protection			
Secondary resistance			
Magnetizing current			
Knee-point voltage			

27. Supervisory and Protection Equipment

a. Buchholz relay
- Type : ----------
- Manufacturer : ----------

b. Oil Level indicator
- Type : ----------
- Manufacturer : ----------

c. Dial-type oil thermometer
- Type : ----------
- Manufacturer : ----------

d. Dial-type windings thermometer
- Type : ----------
- Manufacturer : ----------

e. Tank pressure relief device
- Type : ----------
- Manufacturer : ----------
- Alarm contacts : ----------

28. Are the reactor's accessories in accordance with the requirements of paragraph VIII.3, 4? : ----------

29. Is the reactor tank of cover bolted type? : ----------

30. Color of the reactor : ----------

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

32. Mechanical data

- Mass of core and coils : ---------- kg
- Mass of oil : ---------- kg
- Total mass of reactor : ---------- kg
- Tank type and method of connection to the bottom plate : ----------
- Untanking weight : ---------- kg
- Over-all height : ----------
- Total shipping weight : ---------- kg
- Oil in tank for shipping : ---------- kg
- Describe with what the reactor's tank will be filled for transport purposes : ---------- kg

33. Is there any restriction concerning the test performance capability (e.g due to the laboratory's sufficient itself)? : ----------

34. Indicate acceptance of the specified tests (Yes of No) : ----------

35. Is the packing accordily to the paragraph XIV of the specification? : ----------

36. Deviation, if any, from the present specification and the reasons thereof : ----------

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ATTACHMENT "B"

400 kV SHUNT REACTORS

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

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

1.2. 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.X.A.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.