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

November 2019

SPECIFICATION No SS-57/19
280MVA, 400 / 157.5 / 30kV THREE-PHASE AUTOTRANSFORMERS

I. SCOPE

The scope of the present specification is to describe IPTO's requirements regarding design features, technical characteristics and testing of three phase, 400/157.5/30kV autotransformers rated at 280MVA.

II. KEY WORDS

Autotransformers, transformers.

III. USE

The autotransformers are installed in EHV substations for the transformation of the 400KV network voltage to 150KV and 30KV levels, covering the load requirements of the 150KV transmission network and the compensation requirements of the 400KV lightly loaded overhead transmission lines, respectively.

IV. ELECTRICAL SYSTEM CHARACTERISTICS

IV.A. 400KV NETWORK

1. Nominal Voltage : 400KV
2. Maximum Operating 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. Basic Insulation level : 1550KV (peak)
8. Switching impulse withstand voltage : 1175KV (peak)
9. Variations of nominal frequency : ±0.2Hz
10. Available auxiliary DC supply voltage : 220V DC from substation batteries
11. Available auxiliary AC supply voltage : 3 – phase, 4 – conductors 230/400V A.C.
12. Power frequency withstand voltage (1min) : 680KV (r.m.s.)

13. Method of earthing (grounding) : Effectively earthed
14. Ratio Z_0/Z_+ range : 1 – 3

IV.B. 150KV NETWORK

1. Nominal Voltage : 150KV
2. Maximum Operating Voltage : 170KV
3. Minimum permissible operating voltage : 135KV
4. Number of phases : 3
5. Number of conductors : 3
6. Short Circuit level : 31KA
7. Basic Insulation level : 750KV (peak)
8. Power frequency withstand voltage (1min) : 325KV (r.m.s.)
9. Nominal frequency : 50Hz
10. Variations of nominal frequency : ±0.2Hz
11. Method of earthing (grounding) : Effectively earthed
12. Ratio Z_0/Z_+ range : 1 - 3
13. Available auxiliary D.C. supply voltage : 110V D.C. from substation batteries
14. Available auxiliary A.C. supply voltage : 3 – phase, 4 – conductors 230/400V

IV.C. 30KV NETWORK

1. Nominal System Voltage : 30KV
2. Maximum Operating Voltage : 36KV
3. Number of phases : 3
4. Number of conductors : 3
5. Short Circuit level : 20KA
6. Basic Insulation level : 250KV (peak)
7. Power frequency, withstand voltage (1min) : 95KV (r.m.s.)
8. Nominal frequency : 50Hz
9. Method of earthing (grounding) : Unearthed (Earthing of neutral of connected reactor via V.T. of $30/\sqrt{3}/0.1/\sqrt{3}$ KV ratio, 200VA burden, class 3P).
10. Available auxiliary D.C. supply voltage : 220V from substation Batteries
11. Available auxiliary A.C. supply voltage : 230/400V

V. OPERATING AMBIENT CONDITIONS

Installation	: Outdoors
Minimum ambient temperature	: -25 °C
Maximum ambient temperature	: 40 °C
Monthly average ambient temperature (hottest month)	: 30 °C
Yearly average ambient temperature	: 20 °C

Altitude	: Up to 1000 m above sea level
Other climatic conditions	: Snow, Ice and fog

VI. STANDARDS

All the technical, nominal characteristics and testing of autotransformers shall conform to the IEC 60076 series of standards, as well as the EN 50629 standard.

VII. REQUIRED DESIGN CHARACTERISTICS OF THE AUTOTRANSFORMER

1. Type

Three-phase oil autotransformer with tertiary winding, suitable for outdoor installation.

2. Voltage ratings and number of phase windings

- Primary : 400 kV, 3 - phases
- Secondary : 157.5 kV, 3 - phases
- Tertiary : 30 kV, 3 - phases

3. Symbolism of autotransformers windings connection

YNa0d1

4. Nominal apparent power (capacity) ratings

Nominal simultaneous continuous capacity, with OFAF cooling, for temperature rise limits according to par.VII.10 and for ambient conditions according to par.V:

- Primary, 280 MVA
- Secondary, 280 MVA
- Tertiary, 60 MVA

5. Type of magnetic core and electrical conductors

The type of autotransformers core will be core - form or shell - form. For the first type, the core shall consist of 3 or 5 limbs while for the shell type the core shall consist of 3 or 7 limbs. The core will be manufactured from silicon steel laminations. The conductors of all windings shall be made from copper.

6. Operation with existing auto-transformers

The auto-transformers shall be suitable for operation with 280 MVA existing auto-transformers and for this reason the on load tap-changer (OLTC) must have the following tap voltages:

Tap Position	HV (kV)	MV (kV)	
1		180.12	
2		178.06	
3		175.95	
4		173.81	
5		171.62	
6		169.38	
7		167.11	
8		164.79	
9		162.42	
10		160.00	+10 steps
11	400	157.54	principal tap
12		155.02	- 8 steps
13		152.45	
14		149.83	
15		147.15	
16		144.41	
17		141.61	
18		138.75	
19		135.82	

The tap position No. 15 will be the maximum current tapping for the HV and MV terminals. At tap positions No.1 – 15, the HV and MV sides will have rated power equal to 280 MVA. At tap positions No.16 – 19, the MV side will have rated current equal to the one at tap No. 15. Consequently, the HV and MV sides will have reduced rated power at tap positions No.16 – 19. From the above mentioned tapping voltages it follows that at tap position N.19, the HV and MV sides will have 258.44 MVA rated power. The LV side will have rated power equal to 60 MVA at the whole tap position range.

7. **Insulation Levels**

- HV line terminals	420kV	SI/LI/LIC/AC	: 1175/1425/1570/630 kV
- HV Bushings	420kV	SI/LI/AC	: 1175/1550/695 kV
- MV line terminals	170 kV	SI/LI/LIC/AC	: 620/750/825/325 kV
- MV Bushings	170 kV	LI/AC	: 750/355 kV
- HV/MV Neutral terminal	123KV	LI/AC	: 550/230 kV
- Neutral Bushing	123KV	LI/AC	: 550/255kV
- LV line terminals	52kV	LI/LIC/AC	: 250/275/95 kV
- LV Bushings	52kV	LI/AC	: 250/105 kV

8. **Short circuit withstand capability**

Auto-transformer shall be capable of withstanding under service conditions for 2 (two) seconds, on any tap-setting, short circuit at the terminals of any winding without being damaged due to excessive forces or thermal effects. The thermal ability of the autotransformers to withstand short circuit shall be demonstrated by calculation, in accordance with IEC 60076-5. The dynamic ability of the autotransformers to withstand short circuit shall be demonstrated by calculation or by the performance of a special test, in accordance with IEC 60076-5. For the above calculations and the test, the network short circuit levels and Z_0/Z_+ ratio ranges will be taken into account, as they are stated in par. IV. The fault will be fed simultaneously from both 150kV and 400kV networks, whereas the 30kV network has not voltage sources other than the autotransformer under study. The following short circuit cases will be taken into account, following IEC 60076-8:

- Three-phase faults at HV, MV or LV terminals (3 cases)
- Single-phase to earth faults at HV or MV terminal (2 cases)
- Two-phase to earth faults at HV or MV terminals (2 cases)

The short-circuit values will be calculated at the principal tapping No.11 and the two extreme tappings No.1 and 19.

9. Winding insulation category and connections

9.1. The primary (series) and secondary (common) windings shall be star-connected, with neutral brought out through a fully insulated bushing grounded directly at the grounding grid of the substation. The series and common windings shall be of non-uniform insulation category.

9.2. The tertiary winding will be delta connected. The tertiary winding will be so designed as to withstand without damage a three phase short circuit. The normal load of the tertiary winding will be one 50Mvar shunt reactor and the 1200kVA auxiliary power transformers of the substation. The tertiary winding will be of uniform insulation category.

10. Temperature rise limits

10.1 The temperature rise at top oil level will be up to 60 K.
10.2 The average winding temperature rise will be up to 65 K.
10.3 The temperature rise at the hot-spot of the windings will be up to 78 K.

The limits of the temperature rise will be verified by the execution of the corresponding type test.
The autotransformer thermal model constants, following IEC 60076-7, will be calculated and provided in attachment “A” of this specification.

11. Over-voltage capability

The autotransformers shall have a continuous over-voltage capability of 10% at no load and 5% at rated MVA, at nominal frequency, without damage to any part of the autotransformer.

12. Over-load capability

The autotransformers shall have long-time emergency overloading capability at all tap positions, according to the following values, following IEC 60076-7:

- Current at HV and MV terminals :	130% of rated tapping current
- Current at LV terminals :	100% of rated tapping current
- Voltage at all terminals :	100% of rated tapping voltage
- Ambient temperature :	20°C (equal to yearly average)
- Hot-spot temperature at all windings :	≤ 140 °C
- Top-oil temperature :	≤ 115 °C

The manufacturer shall take all measures necessary, so that during above overloading conditions the following apply:

- No excessive hot-spots due to stray magnetic fields occur in metallic parts or conductors outside of the windings.
- Main and OLTC conservators are suitable for the increased oil expansion.
- All autotransformer components, including winding supports and spacers, are suitable for the increased loading and temperature.

During actual conditions of long-time emergency overloading, if the ambient temperature exceeds 20°C or the voltage exceeds the rated value, it may be necessary for the current to be limited to lower values than the above mentioned, in order the above stated temperature limits to be respected, as described in IEC 60076-7. Another limiting factor is the moisture in oil and the corresponding acceleration of insulation ageing. For the above reasons, application of emergency overloading is not recommended without the use of a suitable autotransformer on-line monitoring system.

During overloading the voltage shall not exceed 105% of rated tapping voltage. The protection relays shall ensure clearing of pass-through short circuit currents in considerably less time than 2 sec. The protection relays shall also allow the overloading currents without tripping. The oil and winding temperature indicator tripping values shall be set in higher values before overloading, in order to allow the increased temperature.

13. Limits of insulations resistance at 20^0C

a.	For series - common windings (400KV - 150KV) :	5 GΩ
b.	For tertiary winding (30KV) :	3 GΩ

14. Short-circuit impedance

-	400kV to 157.5kV	: 19.6% at principal tap of OLTC.
-	400kV to 30kV	: as high as possible and not less than 51.5% at

principal tap of OLTC.

- 150kV to 30kV : as high as possible and not less than 26.9% at principal tap of OLTC.

The short-circuit impedance values in percentage (%) are referred to 280 MVA power and to rated tapping voltage. They are corrected to 75°C.

15. **Limits of magnetizing current values**

The magnetizing current of the auto-transformer, with the OLTC at the principal tap, will not exceed the following values for the primary voltages given below:

Primary voltage	Magn. current in % of nominal current
380 kV	0.10% |
400 kV	0.15% | tolerance + 30%
420 kV	0.35% |

The limits of the magnetizing current values will be verified by the execution of the corresponding routine test.

16. **Audible noise**

The average sound pressure level of the auto-transformer with the cooling equipment in service should not exceed the value of 85 dB(A).
The determination of the average sound pressure level and the measurement methods will be in accordance with IEC 60076-10 and will be verified by the measurements of the relevant test.

17. **Harmonics**

The maximum harmonic content, produced by the subject auto-transformer on the 400kV side, shall be given in detail by the Bidders, for various operating conditions and will be confirmed by the execution of the corresponding test.
In case that the execution of the test can't be performed, a written confirmation shall be given.

Harmonics of no-load current for voltage ratio 400/157.53kV shall be limited as follows:

- third harmonic $\leq$ 15% of no load current
- fifth harmonic $\leq$ 20% of " " "
- seventh harmonic $\leq$ 13% of " " "

18. **Guaranteed losses**

The Bidder must clearly indicate in his technical and economic offer the following guaranteed losses:

a. No-load loss at rated voltage and principal tapping. The value shall not exceed 72 kW.
b. Load loss at rated current on HV – MV sides (280 MVA loading), no current on LV side, at principal tapping and corrected to 75°C conductor temperature. The value shall not exceed 620 kW.

c. Load loss at rated current on LV side and corresponding current on HV side (60 MVA loading), no current on MV side, at principal tapping and corrected to 75°C conductor temperature. The value shall not exceed 140 kW.
d. Load loss at rated current on LV side and corresponding current on MV side (60 MVA loading), no current on HV side, at principal tapping and corrected to 75°C conductor temperature. The value shall not exceed 140 kW.
e. Cooling loss during no-load autotransformer operation, with only the first control group of coolers in operation, according to par.IX.1.i.
f. Total cooling loss, with all fans and pumps in operation, excluding standby cooler. The value shall not exceed 24 kW.
g. Total losses, which will be comprised by the no-load loss of the above par. (a) and the load loss at 280/280/60 MVA loading. This load loss will be calculated from the load losses of the above par. (b), (c) and (d), following the method described in IEC 60076-8.

Also the Bidder must clearly indicate in his technical and economic offer the peak efficiency index (PEI), according to EN 50629, which shall not be less than 99.770% (T2 limit). PEI will take into account only the losses of above par. (a), (b) and (e).

19. **Transport acceleration**

The autotransformer 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. ON – LOAD TAP – CHANGER (OLTC)

1. Parts of the on – load tap – changer

The on – load tap changer generally shall consist of a diverter switch, transition resistors, a tap selector and a reversing change – over selector.
The whole will be operated by a driving mechanism (motor drive).
All relays, switches, fuses etc., of the OLTC shall be mounted in a weather-proof control cabinet mounted on transformer.

2. Type of the on – load tap – changer

Mechanical vacuum switching type (diverter switch of vacuum type and the tap selector and the reversing change – over selector in oil).

3. Number of tapping positions and the corresponding voltage level of each tapping position.

a. Total number of tapping positions : 19 including one principal tap and +10/-8 tapping positions above / below of the principal tap.

b. Voltage level of each tapping position as indicated below with a phase-to-phase voltage range between tapping positions of 2065V to 2925V.

157.5 kV side :

1. 180.12
2. 178.06
3. 175.95
4. 173.81
5. 171.62
6. 169.38
7. 167.11
8. 164.79
9. 162.42
10. 160.00 + 10 steps
11. 157.54 Principal tap
12. 155.02 -8steps
13. 152.45
14. 149.83
15. 147.15
16. 144.41
17. 141.61
18. 138.75
19. 135.82

4. Applicable Standards

IEC 60214–1 and IEC 60214–2

5. Required operating temperatures of on – load tap – changer

Minimum	Maximum
-25° C	105° C

The tap – changer will not restrict operation of the autotransformer under long-time emergency overloading, as described in par. VII.12, during which the top-oil temperature can rise up to 115 °C.

6. Location of the tap changer components and method of installation

a. The diverter switch and the transition resistors shall be placed in their own hermetically sealed oil compartment.
   The diverter switch contacts must be of vacuum type.
b. The tap selector and the reversing change – over selector shall be placed in the autotransformer oil.
c. All OLTC components mentioned above shall be placed inside the tank of the autotransformer.

Access to the OLTC and its individual components shall be possible without disturbing connections or other parts of the autotransformer. Suitable

manholes shall be available on the autotransformer tank so that the OLTC or any of its components can be removed, on site, in case of failure.
It is of paramount importance that the removal of the OLTC or any of its components does not cause any problems to any of the autotransformer parts.

7. Oil conservator of the OLTC

a. The diverter switch and the transition resistors, shall have their own conservator (oil expansion tank).
b. The OLTC conservator shall be equipped with a magnetic oil level indicator, with one contact for annunciating low oil level alarm. The alarm limit will be set for the rated loading of the autotransformer and the ambient temperatures of par.V.
c. The OLTC conservator will be fitted with a breather, which shall contain an absorbent material (silicagel).

The oil level indicator and 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.

NOTE: The OLTC conservator can be a separate compartment of the main AT/F conservator.

8. Type of oil of the OLTC

The oil used in the diverter switch and transition resistors compartment shall be exactly the same as the one used in the transformer tank.

9. Accessories of the diverter switch and transition resistors oil compartment

The compartment shall be equipped with a drain and filling tap.

10. Rating and other characteristics of the OLTC

a. Single or three phase	: Three phase
b. Tapping arrangement	: Reversing
c. Position of tapping in winding	: Neutral – end
d. Maximum rated through current	: ≥ 800 A
e. Rated frequency	: 50Hz
f. Rated voltage	: 123KV r.m.s
g. Rated power – frequency withstand voltage (50Hz, 1 min)	: 230 KV r.m.s
h. Rated lightning impulse withstand voltage (1.2/50μs)	: 550 KV peak
i. Rated chopped lightning impulse withstand voltage (1.2/3-6μs)	: 605 KV peak
j. Rated switching impulse withstand voltage (250/2500μs)	: 460 KV peak
k. Number of electrical positions	: 19
l. Rated step voltage at 800 A through current	: ≥ 2.80 kV

11. Operations under load

The OLTC shall be able to perform 300.000 operations (tap changes) without maintenance (apart of the motor drive), under step voltage of 2.33 kV and through current equal to the rated common winding current at the principal tap (No.11).

12. Required protective devices for the OLTC

a. Oil – flow controlled relay

This oil – flow relay shall be installed in the pipe between the tap changer head and oil conservator and shall respond to a predetermined oil flow (due to low energy phenomena) and enable the autotransformer to be tripped. 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.
This oil – flow relay shall be MR or EMB make and with two (2) make contacts suitable for 220V DC, one for tripping purposes and one for alarm.

b. Pressure relief device

This pressure relief device will respond in the event of the pressure in the diverter switch compartment exceeds a predetermined value (explosive energy phenomena) and enable the autotransformer to be tripped. 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.
The pressure relief device shall be QUALITROL or MR make and with two (2) make contacts suitable for 220V DC, one for tripping purposes and one for alarm.

13. Motor Drive Unit (Driving Mechanism)

a. Control : Local/Remote. For this reason the motor drive unit panel shall be equipped with a three (3) position selector switch ´´Off–Local– Remote´´. The motor drive and control panel shall also be equipped with two (2) push buttons used in conjunction with the ´´Local ´´ position of the selector switch, for raising and lowering the voltage step of the OLTC.

b. Emergency control : Emergency control is required and for this reason the motor drive and control panel shall be equipped with an emergency push – button for emergency stopping of the motor drive.

c. Supply voltage & frequency of the motor : 3ph, 400V AC, 50Hz with tolerances of 85% to 110%.

d. Installation : Outside of the autotransformer tank and connected to the OLTC by drive shafts and gears.

e. Motor drive and control cabinet : The motor drive and control cabinet of the motor drive unit shall be of IP55 protection as per IEC 60529.

f. Motor drive and control cabinet equipment : The motor drive and control cabinet besides the "Off – Local – Remote" selector switch, the two (2) push – buttons for raise, lowering and the emergency stop push button shall contain the following:
1. A tap indicator, indicating tap position.
2. Anti–condensation heater, 230V, 50Hz controlled by thermostat
3. A counter indicating the number of tap – changers accomplished.

g. Manual operation : Operation of the tap – changer manually by a mechanical device blocking at the same time operation by the electric motor.

h. Remote control and indication : The motor drive unit shall be capable of being operated from the substation's automation control system located at the control building of the substation (raise – lowering and emergency stop). The tap position and any alarms originated from the OLTC will be signaled by voltage-free contacts, with one contact per each tap position. The tap position will be also signaled analogically by the resistance value of a potentiometer. A second analog output shall be foreseen for future use in the condition monitoring system of the autotransformer. The power supply voltage of the OLTC will be 230/400V AC. The control voltage will be 230V AC.

i. Power frequency withstand voltage : 2kV, 1 minute between all live parts of auxiliary circuits and the frame.

14. Warranty

The offered OLTC shall be MR or ABB or HYUNDAI make and a warranty period of three (3) years from the received date must be given, which shall cover any OLTC damages or damages to the autotransformer due to OLTC malfunctioning.

15. Nameplates

A. OLTC

The nameplate of the OLTC shall be included in the nameplate of the autotransformer and shall contain the following:

1. Schematic diagram of the OLTC.
2. Tap positions and corresponding voltage.
3. Tapping arrangement.
4. Rated through current for each tap position.
5. Rated voltage.
6. Rated lightning impulse withstand voltage.
7. Maximum number of operations under load.
8. Characteristics of any surge arresters, if existing, built in the OLTC

B. Motor Drive

The motor drive control cabinet shall bear a nameplate of non – corrosive material and it shall contain at least the following:

1. Manufacturer’s name
2. Type and serial number
3. Supply voltage
4. Frequency
5. Power of motor
6. Runtime per tap operation

16. TESTS

The autotransformer manufacturer is obliged to present to the IPTO inspector OLTC’s test reports while the IPTO inspector is at the manufacturer’s premises for the autotransformer inspection and testing.
The test reports which are to be presented shall include the following type and routine tests:

A. Type tests

a. Temperature rise of contacts
b. Switching tests
c. Short – circuit current test
d. Transition resistor test
e. Mechanical tests
f. Tightness test
g. Dielectric tests

B. Routine Tests

a. Mechanical test
b. Sequence test
c. Auxiliary circuits insulation test
d. Pressure and vacuum tests
e. Additional routine tests shall be carried out by the manufacturer of the autotransformer as they are indicated in paragraph X.1.11.

IX. BASIC EQUIPMENT OF AUTOTRANSFORMERS AND ACCESSORIES

1. Cooling system

a. The cooling system of autotransformer will be of Oil Forced - Air Forced type (OFAF).

b. The coolers for the autotransformers cooling shall be separately mounted and not on the autotransformer tank walls. The oil pipes between coolers and autotransformer tank will include flexible metallic links, in order to withstand any seismic stress (acceleration 0.5g horizontally and 0.25g vertically). The necessary structures for supporting the radiators, fans, etc. and all connections between the various parts shall also be furnished together with the autotransformer.

c. The autotransformer shall be equipped with 6 independent cooling units with one of them to be on standby or with 5 independent cooling units with one of them to be on standby.
Each cooling unit will be a complete assembled set ready for installation. Each cooling unit shall include radiators, fans and oil circulating pump. All cooling units shall be identical, with the same pump, fans and cooling capacity.

d. With five (5) or four (4) cooling units (depending on the total number of coolers) in service, the loss of one unit will not result in changing the auto-transformer’s capability to carry its full rated load (280 MVA) and without exceeding the allowable temperature rise limits.

e. With two (2) cooler units out of service (Five (5) or four (4) units originally in service), the autotransformer shall be able to carry 80% of its full rated load.

f. Each cooling unit shall include a fixed number of radiators, which will consist of a specific number of elements with specific dimensions, and they will be equipped with air release and a drain valves. The radiators shall be designed and tested following EN 50216-1 and EN 50216-10 standards. The test certificates shall be presented to IPTO inspector.

g. The cooling unit shall include certain number of fans with specific dimensions, mounted below the radiators or on the side of them and will be of sufficient rating for OFAF operation. The fans will be metallic and they shall be designed and tested following EN 50216-1 and EN 50216-12 standards. The test certificates shall be presented to IPTO inspector.

h. Furthermore, each cooling unit will be equipped with an oil circulating pump of suitable rating for the OFAF operation. The unit must be provided with an oil flow indicator and shut-off valves on top and bottom, so as to make possible the complete isolation of the particular cooler branch, while the

auto-transformer is under load. The pumps shall be designed and tested following EN 50216-1 and EN 50216-7 standards. The test certificates shall be presented to IPTO inspector. The start – up or shutdown of any pump must not cause malfunction of any gas or oil actuated protection device. The oil pumps must have valves at both sides to enable the easy replacement in case of damage.
The replacement or maintenance of the oil pumps should be done without to be necessary to remove the coolers.

i. The cooling system of each autotransformer should be divided into 2 (two) groups for control purposes. Relay control will be provided to start automatically the first group of cooling units as soon as the autotransformer is energized (first control group).
During the automatic operation and while the first control group is continuously actuated, if the temperature of windings exceeds a predetermined value, a command will be given via the contacts of the series winding temperature indicator and via relays for the automatic energizing of the second control group. The first control group shall include at least two cooling units, if there are six cooling units in total, or at least one cooling unit, if there are five cooling units in total.
The standby cooling unit will be not included on either control group. It will be started automatically, if there is a fault on any operating cooling unit.

j. For the selection of “automatic or manual” operation of cooling system a selector switch will be available to permit the automatic or manual operation of cooling system.
For the manual operation, the activation of the first group will be done as mentioned in paragraph (i), whereas the activation of the second one and the standby cooling unit will be done manually.

k. All the fans and pumps motors will be of the squirrel cage type, three phase 400V AC, of the enclosed design. A voltage and phase sequence monitoring relay will be included in the control cabinet, which will prevent motor operation in case of not suitable voltage supply. The relay will provide fault signaling by a voltage free contact, suitable for 220V DC, 0.5A.
The control voltage of the cooling system will be 230V AC. The signaling will be realized by voltage-free contacts.

l. All necessary automatic operation equipment for the cooling system must be assembled in a metal control cabinet with IP55 protection class located on the autotransformer.

m. The same control cabinet will be used also as a junction box for the connection of all control wiring to the various devices, which are positioned on the autotransformer (OLTC, Buchholz, thermometers, etc), excluding the explosion and fire prevention system.

2. **Autotransformer tank**

a. The autotransformer tank will be of BELL type or COVER BOLTED type.

b. The bell type tank will be connected with the autotransformer base by bolted flange.
c. The autotransformer tank will be constructed to withstand vacuum.
d. For lifting purposes, the autotransformer tank must be provided with suitable lugs.
e. Manholes should be provided on the tank cover and walls dimensioned no less than 50x50cm. At least, two manholes should be required on the tank cover for the access inside the autotransformer tank.
f. Grounding pads shall be provided near the bottom of the autotransformer tank. The tank will be grounded in two points at least diagonally. The autotransformer tank should be designed so that the losses caused by circulating eddy – currents to be minimized and also the creation of onerous temperatures at the tank surface to be avoided.
g. The magnetic core of the autotransformer will be earthed at only one point. The core earthing will be realised through an insulated conductor, connecting the core to an earthing box, placed externally on the transformer tank. By this way the core earthing could be tested without opening the autotransformer tank.
h. The cover of the autotransformer tank should be designed in such way as to avoid the stagnation of water.

3. **Oil conservator tank**

The autotransformer must be equipped with a conservator tank to accommodate the changes in oil volume caused by the changes of the ambient temperature or the autotransformer load.
The conservator tank will be composed of one piece ready for installation.
The design must be of such a type as the direct contact between air and oil to be avoided. To avoid moisture entering in the oil of the conservator tank during the oil volume fluctuations, the tank will be fitted with a breather per separate room, which shall contain an absorbent material (silicagel) and a drainage tank. The breathers shall be designed and tested following EN 50216-1 and EN 50216-5 standards. The test certificates shall be presented to IPTO inspector. Also for that reason, a dry air cushion will float on the oil surface and will increase or decrease as the oil volume changes. The dry air cushion will be in contact with the breather so that it is always at atmospheric pressure and the incoming air is always dry.
The silicagel crystals must be active in order to be able to absorb moisture and this property will be checked by periodical optical inspections of the silicagel crystals colour. Except for the oil level indicator a drain valve will be mounted on the tank.
If the conservator tank is not mounted on the autotransformer tank, but on a separate metallic support, the oil pipe between conservator tank and autotransformer tank will include a flexible metallic link, in order to withstand any seismic stress (acceleration 0.5g horizontally and 0.25g vertically).

4. **Valves**

Each auto-transformer will be equipped with the necessary quantity of valves e.g. for draining the tank, sampling oil, isolating each cooler unit etc. Oil filling valve, filtering valve and vacuum connection valve shall be provided. One oil sampling valve shall be placed at a pipe connecting the cooling system with the autotransformer tank, at the outlet side of the pumps. All vacuum valves shall be designed and tested following EN 12266-1, -2 standards. 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. **Connecting material**

All connecting material, such as bolts, nuts and lock washers must be hot-dip galvanized.

6. **Tubing**

The tubing on the body of the autotransformer must be as little as possible and must be arranged in a logical manner. Under any operating conditions, oil leaks from the tank joints or from joints of the oil circuit are not acceptable.

7. **Insulating oil and paper**

The autotransformer insulating fluid will be unused mineral oil of the “inhibited transformer oil (I)” class, in accordance with IEC 60296 standard. It shall be non-toxic and biodegradable without 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.

Under no circumstances forced oil circulation will create a static electrification hazard in any part of autotransformer.

The conductors of all windings, as well as all connecting conductors in the tank, will be insulated by thermally upgraded paper (TUP), made by 100% sulphate wood pulp, manufactured and tested according to IEC 60641 series of standards. According to IEC 60076-2, paper is considered as thermally upgraded, if it retains 50% of its original tensile strength after remaining 65000 hours in a sealed tube with mineral oil at 110°C. The paper will contain 1% – 4% of organic nitrogen, measured according to ASTM D982.

8. **Bushings**

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

8.1 All bushings of the autotransformer will be of outdoor – capacitance graded type with one end exposed in ambient air and the other end immersed in the autotransformer oil.

8.2 The active part of the bushing will consist of a condenser type core, with insulation of Oil Impregnated Paper (OIP). For the LV bushings, the active part can have alternatively insulation of Resin Impregnated Paper (RIP).

8.3 The insulation housing of HV, MV, LV and neutral bushings will be of high grade porcelain. The porcelain housing will comply in all relevant respects with IEC 62155. For the LV bushings of RIP type, the insulation housing can be alternatively of silicon rubber.

8.4 The bushings of Autotransformer are required to be of the following rating characteristics:

	HV	MV	LV	Neutral
1. Highest rated Voltage (phase to phase) (Um) (kV-r.m.s.)	420	170	52	123
2. Rated phase to earth operating voltage (kV – r.m.s.)	242	98	30	71
3. Rated current (Ir)(A)	800	1600	1600	1600
4. Rated thermal short time current, 1 sec (Ith)	25Ir	25Ir	25Ir	25Ir
5. Rated dynamic current (Id)	2.5Ith	2.5Ith	2.5Ith	2.5Ith
6. Minimum cantilever withstand load (N)	≥2000	≥2000	≥800	≥1575
7. Creepage distance (mm)	12600	4675	1300	3380
8. Angle of mounting	≤30°/vertical	≤30°/vertical	≤30°/vertical	≤30°/vertical
9.Temperature limits – class of the insulating material in contact with metal parts	105°C Class A	105°C Class A	OIP: 105°C Class A RIP: 120°C Class E	105°C Class A
10. Dielectric dissipation factor (tanδ) at $1.05Um/\sqrt{3}$ voltage	≤0.007	≤0.007	≤0.007	≤0.007
11. Maximum value of partial discharge quantity at Um operating voltage	≤10pC	≤10pC	≤10pC	≤10pC
12. Lightning impulse withstand voltage (kV)	1550	750	250	550
13. Switching impulse withstand voltage (kV)	1175	-	-	-
14. Power frequency withstand voltage dry / wet (kV)	695 / -	355 / 325	105 / 95	255 / 230
15. Type according EN 50458	420/1550/800	170/750/1600	52/250/1600	123/550/1600

8.5 Additional characteristics of bushings.

a. Seismic withstand capabilities.

The HV, MV and neutral 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 rest 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 emergency loading conditions will be 115 ^{o}C.

d. The 420kV bushings shall have a tin plated aluminium terminal of cylindrical shape with diameter of 30mm and length of about 100mm. The 170kV, neutral and 52kV 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 autotransformer manufacturer shall respect the connection details, the maximum bushing dimensions and the minimum clearance distance in oil, following EN 50458.

f. If the 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 130% of the rated tapping current at the maximum current tap No.15 for the HV, MV bushings and of at least 125% of the rated tapping current at extreme tap No.1 for the LV bushings.

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.

8.6 Accessories:

Bushings will be equipped with the accessories below:

a. Oil level indicator. For the 420kV bushings, the oil indicator will be of the magnetic type.

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.

8.7 Note

Bushings with insulating housing following IEC 61462, which consists of a resin impregnated fiber tube and silicon rubber covering can be accepted, providing if they cover the requirements of paragraph IX-8

8.8 Rating plates – markings

The H.V, M.V. and neutral bushings shall carry a rating plate including the following markings.
Markings for L.V. bushings that indicated below with ■ are adequate:

■ 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

8.9 Tests

The autotransformer manufacturer is obliged to present to the IPTO inspector bushings test reports while the IPTO inspector is at the manufacturer’s premises for the autotransformer 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 HV bushings)
2. Long duration power frequency (ACLD) voltage withstand test, with partial discharges measurement (only for HV, MV bushings)
3. Lightning impulse voltage withstand test

4. Switching impulse voltage withstand test, dry and wet (only for HV bushings)
5. Electromagnetic compatibility test (only for HV, MV and neutral bushings)
6. Thermal stability (only for HV bushings, calculation or 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 for HV 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 withstand (IEC 61463, calculation or test)
2. Artificial pollution test (IEC 60507)

NOTE: Type and special test reports may not be presented if they have been previously submitted in the technical offer and have been found to be satisfactory.

8.10 Manufacturing

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

8.11 Bushing current transformers

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

Bushing	**Ratio**	**Core 1**	**Core 2**	**Core 3**
HV	400/1-1-1A	40VA CL 0.5	30VA CL 5P20	30VA CL 5P20
MV	1000/1-1-1A	40VA CL 0.5	30VA CL 5P20	30VA CL 5P20
LV	2000/1-1A	40VA CL 0.5	30VA CL 5P20	—

The HV and LV bushings of the middle phase will be equipped with one additional current transformer (core 4 for MV, core 3 for LV) for use by the corresponding winding temperature indicator, in order to create the thermal image of the series and tertiary windings.
All current transformers will follow IEC 61869-1 and IEC 61869-2 standards. The HV and MV bushing current transformers will have an extended current rating of 1.3 times their rated current. The LV bushing current transformers will have extended current rating of 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 auto-transformers.

9. Wiring conductors

All cables which run on the autotransformer body must be placed inside cable trays.
All wiring conductors, joints and other connections shall be made of electrolytic copper. All wiring will be made by copper conductors suitably insulated. The control cables will be of 2.5mm^2 copper cross section at least.

10. Auxiliary power supply – Isolation of auxiliary equipment

Available aux. AC power supply : three phase voltage 230/400V 50Hz.
Available aux. DC power supply : 220V
All auxiliary equipment (e.g. fan motors, pump motors, OLTC motor, OLTC control panel, main control panel), which are supplied with AC auxiliary power, shall be isolated from the autotransformer body, in order not to interfere with the autotransformer tank-earth protection. All these auxiliary equipment will be connected through insulated earthing conductors with the main control panel of the autotransformer, which will be earthed to the AC network grounding, separately from the autotransformer body.

11. Painting requirements for the autotransformer

The autotransformer including coolers shall be painted externally with RAL 7040 gray color. 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 standards. 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 autotransformer shall be painted internally with a white colored oil resistant primer coat.

12. Instruments – Relays and autotransformer protection devices

12.1. Buchholz relay

An earthquake proof Buchholz relay of EMB make, double-float type, must be provided and be mounted in the pipe connecting the conservator to the autotransformer 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 relay is full of oil under normal conditions and due to the buoyancy its two float elements will be at the upper level. When a slight or incipient fault occurs inside the autotransformer, (e.g. local overheating, a small quantity of oil leakage etc.), small bubbles of gas will be created and trapped in the relay housing, causing its oil level to fall and simultaneously the above situated element to move, resulting in the closing of the alarm contacts.
In case that a serious fault occurs in the autotransformer (e.g. a leakage of large quantity of oil, short circuits, puncture of bushings), the gas generation will be violent causing a surge of oil inside the relay which will result in the movement of the second float element and the closing of the trip contacts.
The above mentioned contacts will be suitable for 220V DC voltage.
The trapped gas in the Buchholz relay will be possible to be reclaimed through a gas collection device, which will be installed on the autotransformer at a person's height and will be connected permanently with the relay through a hose.

12.2. Oil Temperature Indicator

Each autotransformer will be provided with an oil temperature indicator of bellow type, measuring the autotransformer oil temperature at its hottest part. The indicator shall be designed and tested following EN 50216-1 and EN 50216-11 standards. The test certificates shall be presented to IPTO inspector.
The thermometer bulb is enclosed in a pocket fixed on the tank at the hottest oil region. The connection between the thermometer bulb and dial indicator is made by a flexible steel capillary tube.
The measurement will be taken via a driving motion operated by the expansion of the fluid inside the bulb and afterwards through the capillary tube will be transferred to the dial pointer.
Moreover, the autotransformer oil temperature indicator will be provided with a function for the teletransmission of the measurement from the autotransformer to the substation's automation control system. This will be achieved by mounting inside the instrument a teletransmitter with transducer of analogue output current 4-20mA.
Two (2) changeover or make contacts are required to be available, one (1) for alarm and one (1) for trip, suitable for 220V DC voltage. The alarm and trip limits will be set for the rated loading of the autotransformer and the ambient temperatures of par.V.
The oil temperature indicator should be of QUALITROL make, type AKM-OTI, or MR make, type Messko-BeTech.

12.3. Winding Temperature Indicator

Each autotransformer will be provided with two (2) winding temperature indicators. One of them will measure the series winding temperature and the other the tertiary winding temperature. The winding temperature indicators will be of bellow type, functionally similar with the oil temperature indicator having in addition only the current input, connected to a bushing current transformer, in order to create the thermal image of the corresponding autotransformer winding. In this way the temperature of the winding will be measured indirectly. The indicator for the series winding will be connected to an HV bushing current transformer and the indicator for the tertiary winding will be connected to an LV bushing current transformer. The indicators shall be designed and tested following EN 50216-1 and EN 50216-11 standards. The test certificates shall be presented to IPTO inspector.

The devices will be set before delivery of the autotransformer, according to the temperature gradient between the top-oil temperature and the hot-spot winding temperature of the corresponding winding at rated current, which will be found in the temperature rise test report.
For the teletransmission of the winding temperature indication from the autotransformer to the substation’s automation control system, the instrument will include a tele-transmitter which can be connected with a transducer of analogue output current 4-20mA.
Referring to the electrical contacts, two (2) changeover or make contacts are required at least for each indicator, one (1) for alarm and one (1) for trip. In addition, for the automatic and gradual energizing of the autotransformer cooling system, two (2) changeover or make contacts are required at the series winding temperature indicator.
The alarm and trip limits will be set for the rated loading of the autotransformer and the ambient temperatures of par.V.
All contacts will be suitable for 220V D.C. voltage.
The winding temperature indicator should be of QUALITROL make, type AKM-WTI, or MR make, type Messko-BeTech.

12.4 Oil Flow Indicator.

Each cooling unit of the autotransformer oil forced cooling system will be equipped with an oil flow indicator showing the oil flow in the connecting pipe of each oil circulation pump of the cooling system. The oil flow indicators shall be designed and tested following EN 50216-1 and EN 50216-5 standards. The test certificates shall be presented to IPTO inspector.
One (1) make contact is required for alarm when the oil flow drops below a predetermined percentage value of the full flow.
The contact will be suitable for 220V DC (~ 0.5 A) voltage.

12.5. Oil level indicator.

The autotransformer will be provided with magnetic oil level indicator. 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. The indicator will be mounted on the outdoor surface of the conservator having a float located inside the conservator oil. The oil level will order the float movement which by a drive shaft will cause the movement of a pointer in the dial.
One (1) make contact will be provided for annunciating a low oil level alarm, suitable for 220 V DC (~ 0.5A) voltage. The alarm limit will be set for the rated loading of the autotransformer and the ambient temperatures of par.V.

12.6. Pressure relief device

Each autotransformer will be equipped with one at least pressure relief device of QUALITROL make, type XPRD, or MR make, type Messko-LMPRD oil-directed. The device will be mounted horizontally on the autotransformer tank and will operate by a spring mechanism automatically. The mechanism will hold pressed a stainless steel diaphragm, with one side of which to be exposed to autotransformer tank pressure. In case of internal over-pressures caused by internal failures, the diaphragm will open and regain its position as soon as the pressure in the tank drops below a set limit. There

will also be capability for manual check of the device operation. 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.
For the annunciation of its operation, the pressure relief device will be provided with two (2) make alarm contacts suitable for 220V DC voltage.

12.7. Rapid pressure rise relay.

The autotransformer will be provided with a rapid pressure rise relay of QUALITROL make, type 900, detecting the excessive gas pressures caused by internal arcing in the autotransformer tank. The available trip contacts will not be actuated by normal pressure variations caused by temperature change or other mechanical shock on the autotransformer body.

12.8 Autotransformer tank-earth (mass) protection

A C.T. shall be provided to be used for the protection of the auto-transformer against earth faults, given the fact that the autotransformer tank is isolated from earth. The necessary current transformer will be included in the supply and its secondary will be connected to a relay and its primary between tank and earth.
The current transformer will follow IEC 61869-1 and IEC 61896-2 standards and it will have the characteristics:

Output power	:	25VA
Ratio	:	200 / 5A
Class	:	10P10

The over-current relay (supplied by IPTO) which will be used in conjunction with CT will have the following characteristics:

Setting range
Stage 1
$I_E >$ (time delay) : (0.5-4) x In (in steps of 0.1A)
where In = 5A
Delay time : 0 to 20 sec.

Stage 2
$I_E >>$ (instantaneous) : (0.1-10) x In
Delay time : 0-20 sec.

12.9 On-line moisture and fault gas monitoring system

The autotransformer shall be equipped with a continuous moisture and fault gas monitoring system, type Hydran M2, manufactured by GE.
The system shall be installed on a pipe connecting the autotransformer tank with the cooling system, at the outlet side of the pumps. If this is not possible, alternatively it can be installed on the upper part of the tank. It will be installed through a valve. A second valve next to the first one, shall exist for future use (detection of more gases).
The system will include:

1. A gas-in-oil sensor to detect continuously the composite value of hydrogen (H_2), carbon monoxide (CO), acetylene (C_2H_2) and ethylene (C_2H_4), in the transformer oil.
2. Capacitive sensor to continuously monitor the moisture of the transformer oil.
3. A temperature sensor to monitor the oil temperature at the gas-in-oil sensor location.
The system shall also include two 4-20mA outputs and two alarm make contact outputs for transmission of measurements and alarms to the substation's automation and control system.

12.10 Direct winding hot-spot temperature measurement system

The autotransformer shall be equipped with a multi-channel fiber optic system of QUALITROL manufacture for hot-spot temperature measurement of all windings. The system will include a temperature monitor of type T/Guard 405, as well as fiber optic connected GaAs temperature sensors of type Neoptix T2. According to Annex E of IEC 60076-2, eleven (11) sensors will be embodied in the autotransformer windings, as follows:

Location	on central winding (central limb)	on each lateral winding
Series winding	2 sensors	1 sensor
Common winding (including regulating winding)	2 sensors	1 sensor
Tertiary winding	1 sensor	1 sensor

The GaAs sensors will be installed at the locations of each winding, where the hottest spots are expected to occur. The optical fibers will be terminated at a junction box, located on the autotransformer tank. An optical cable will connect the junction box with the temperature monitor, which will be also located on the autotransformer tank. Because of the fragility of the optical fibers, their installation in the windings shall strictly follow the guidance of their manufacturer.
The temperature monitor will provide an analogue output of 4-20mA per each temperature sensor for transmission of measurements to the substation's automation control system.

12.11 Oil temperature sensors

Two oil temperature sensors shall be installed on the autotransformer tank. One will be located on the tank cover, at the hottest oil point, near the temperature sensor of the oil temperature indicator. The other will be located at the bottom of the tank, at the coldest oil point. Additionally, two temperature sensor pockets will be located on the tank cover, at opposite sides of the other installed temperature sensor.
Two oil temperature sensors shall be installed on the cooling system. One will be located at the oil inlet pipe from the autotransformer tank and the other at the oil outlet pipe to the autotransformer tank.
All temperature sensors will be of Pt100 type, with at least three wires and they will be wired to the autotransformer control cabinet for future use. The temperature sensors will be of QUALITROL or MR make. All sensor pockets will be designed following EN 50216-5 standard.

X. TESTS

The tests will be carried out in accordance with the IEC 60076-1, -2 and -3 Standards. Any limitations regarding testing procedures (e.g test voltage, lightning impulse waveform, 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.

1.1 Measurement of winding resistance

The measurement will be performed by the supply of a direct current for each autotransformer winding and each phase. Additionally, the measurement for the common winding will be performed for all tap positions. The winding resistance will be measured after the autotransformer has been without excitation for at least 3 hours, so as the average oil temperature and the temperature of the windings to be equal. The average oil temperature is considered as the mean of the top and bottom oil temperature.

1.2 Check of voltage ratio and connection symbol

During the test performance, the voltage ratio will be measured on each OLTC tapping and the connection symbol of the autotransformer windings will be checked.

1.3 Measurement of short-circuit impedances and load losses

The measurement will be performed at rated frequency with sinusoidal voltage applied to the measured side terminals, with the terminals of the second side short – circuited and of the third side open – circuited. The short-circuit impedance and load loss measurements will be performed for the three different two – side combinations, meaning for HV – MV terminals (LV terminals open-circuited), HV – LV terminals (MV terminals open-circuited) and MV – LV terminals (HV terminals open-circuited). The short-circuit impedance and the load loss will be measured with the tap changer on the principal tapping No.11, on the two extreme tappings No.1 and 19, as well as on the maximum current tapping No.15. The supplied current through the measured side terminals will not be less than 50% of the relevant rated tapping current. The measured values of load loss will be corrected to the reference temperature of 75^{o}C and to the rated tapping current, according to the IEC 60076-1 standard. The measured values of short-circuit impedance will be corrected to the reference temperature of 75^{o}C, will be represented as percentage (%), referring to 280 MVA power and to rated tapping voltage, according to the IEC 60076-1 standard. For the measurements including the LV side, because of different rated power of the two sides, the correction will be done to the rated tapping current of the LV side and the other side will have the corresponding current. The expanded uncertainty of load loss with coverage factor k=2 will be calculated and reported by the manufacturer according to IEC 60076-19, but it shall not exceed 2%. All short-circuit impedance values will be reported as percentage (%) on 280MVA basis.

1.4 Measurement of no-load loss and current

The test will be carried out before the dielectric tests and temperature rise test. The measurement will be performed on the terminals of one of the windings, commonly LV terminals, at rated frequency and at 90%, 100% and 110% of rated tapping voltage, with the tap changer on the principal tapping No.11. The measurement will be performed also at 100% of rated tapping voltage, with the tap changer on the extreme tappings No.1 and 19, as well as on the maximum current tapping No.15. The remaining terminals will be left open-circuited. For the test voltage adjusting, two (2) voltmeters connected in parallel will be used. The one voltmeter will measure the rms value of the voltage (V) and the other one will measure the mean value of the voltage (V′).
The test voltage wave shape is satisfactory if the readings V′ and V are equal within 3%. For the no-load loss calculation, the measured value of power loss Pm will be corrected according to the following formula:

$$Po=Pm*(1+(V'-V)/V').$$

The rms value of no-load current is measured at the same time with the losses while the mean value of readings in the three phases is taken into account. The expanded uncertainty of no-load loss with coverage factor k=2 will be calculated and reported by the manufacturer according to IEC 60076-19, but it shall not exceed 2%.

1.5 Calculation of peak efficiency index (PEI) and corresponding load factor

The peak efficiency index PEI and the corresponding load factor k_{PEI} will be calculated according EN 50629. The measured load loss between HV – MV terminals (LV terminals open-circuited) at principal tapping and rated current (par.X.1.3), as well as the measured no-load loss at principal tapping and rated voltage, corrected to reference temperature (par.X.1.4), will be used for the calculation. According to EN 50629, only the part of the measured cooling loss (par.X.2.4) will be used for the calculation, which corresponds to the operating cooling units at the load factor k_{PEI}. This part is usually the same with the cooling loss at no-load operation, which corresponds to the first control group of cooling units, as described in par.IX.1.i.
The calculated values of PEI and k_{PEI} shall be included in the autotransformer routine test report.

1.6 Measurement of capacitance and dissipation factor

The measurement shall be carried out for the following connections:
a. (HV+MV)-(LV+tank) earthed
b. (HV+MV)-LV with tank only earthed
c. (HV+MV+LV)-tank earthed
d. LV-(HV+MV+tank) earthed

The test voltage shall be 10kV.
Tanδ ≤ 0.5 %.

1.7 Measurement of the insulation resistance

The measurements shall be carried out for the following connections and for two time periods (60 seconds and 15 seconds, DAR value measurement).
a. (HV+MV)-(LV+earth)
b LV-(HV+MV+earth)
c. (HV+MV)-LV
The test voltage shall be 2.5KV.

To check if the core earthing follows par.IX.2.g, an insulation resistance measurement shall be carried out between core and tank at the external earthing box, with a suitable voltage.

1.8 Tightness test for the autotransformer tank

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

1.9 Insulating oil tests

The following tests will be performed on oil sample from the autotransformer tank and the mentioned acceptance levels will apply:

1. Breakdown voltage (BDV) following IEC 60156, with value ≥ 70 kV
2. Dielectric dissipation factor (DDF) following IEC 60247 or IEC 61620, with value ≤ 0.005
3. Water content following IEC 60814, with value ≤ 40 mg/kg
4. Interfacial tension (IFT) following EN 14210 or ASTM D971, with value ≥ 40 mN/m
5. 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

1.10 Dielectric tests

1.10.1 Applied voltage test (AV)

The test will be made by the application of a single – phase AC voltage as nearly as possible on sine-wave form and not less than 40Hz. The applied voltage will be reduced to 1/3 of the test value at the beginning and at the end of the test.
The full test voltage will be applied for 1 min. between the line and neutral terminals of the under test winding connected together and the core, its frame and the tank of the autotransformer connected to earth..
For the tertiary winding test, the applied voltage will be 95kV and the HV and MV terminals, as well as the autotransformer tank, will be short – circuited and earthed.
A test voltage of 185kV will be applied to the HV – MV, line and neutral terminals of the series and common windings at the same time, with the LV terminals, as well as the autotransformer tank, short – circuited and earthed.

1.10.2 <u>Chopped wave Lightning Impulse tests on HV Line Terminals (LIC)</u>

The impulse test will be performed for each HV line terminal of the autotransformer with the following test sequence:

1. Application of one (1) reduced level, full wave impulse 1.2/50 μs (50%÷70% of 1425kV)
2. Application of one (1) full wave impulse 1.2/50μs at 1425kV
3. Application of two (2) chopped wave impulses 1.2/2-6μs at 1570kV
4. Application of two (2) full wave impulses 1.2/50μs at 1425kV

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 terminals which are not under test, including neutral terminal, shall be earthed directly or through low impedance.
During the test on one phase the tap changer will be on position No.1, for another phase on position No.10 (regulating winding not series connected) and for the third phase on position No.19.
During the test, the oscillograms of the applied voltage shape and current flowing through the tested terminal will be recorded.

1.10.3 <u>Lightning Impulse tests on MV Line Terminals (LI)</u>

The test will be performed only for the autotransformers, which will not be submitted to the LIC special test at MV terminals (par.X.3.1).
The impulse test will be performed for each MV terminal of the autotransformer with the following test sequence:

1. Application of one (1) reduced level, full wave impulse 1.2/50 μs (50%÷70% of 750kV)
2. Application of three (3) full wave impulses 1.2/50μs at 750kV

The terminals which are not under test, including neutral terminal, shall be earthed directly or through low impedance.
During the test on one phase the tap changer will be on position No.1, for another phase on position No.10 (regulating winding not series connected) and for the third phase on position No.19.
During the test, the oscillograms of the applied voltage shape and current flowing the tested terminal will be recorded.

1.10.4 <u>Switching impulse test on HV Line Terminals (SI)</u>

The test will be performed for each HV terminal of the autotransformer, with the neutral terminal earthed directly or through low impedance. The tap changer shall be on position No.1, in order for the highest possible switching impulse voltage to be transferred to the corresponding MV terminal, as close as possible to 620kV. The test voltage will be applied directly to the HV terminal under test. The other two HV terminals may be connected together, but they will not be earthed. The test sequence will consist of one (1) reduced level impulse application (50%÷70% of 1175kV) and three (3) subsequent impulses at 1175kV. The applied voltage impulse will have a time to peak of at least 100 μs, a time above 90% of test voltage of at least 200 μs and a time to zero of at least 1000 μs. During the test, the impulse voltage and the neutral current wave-shapes will be recorded.

1.10.5 Induced voltage withstand test with measurement of Partial Discharges (IVPD)

1. For the test three-phase voltage shall be applied to the autotransformer.

2. The HV/MV neutral terminal shall be earthed.

3. The HV/MV line terminals shall remain floating.

4. The tap changer shall remain on principal tap position during the test.

5. The induced voltage to the HV/MV terminals will be produced by the application to the autotransformer tertiary, a sinusoidal voltage of frequency up to 100Hz. If the frequency of the test voltage is greater than 100Hz, the test duration for the enhancement voltage level (in seconds) will be given by the formula : $120(f_r/f_t)$, where f_r: rated frequency, f_t : test frequency, but not less than 15 sec.

6. The time sequence and the phase-to-earth voltage values at HV terminals during the test shall be as follows:

a. Switched on at a level not higher than 92kV.
b. Raised to 92kV with background partial discharges (PD) measurement.
c. Raised to 277kV and held there for a duration of 1 min with PD measurement.
d. Raised to 365kV (one-hour voltage level) and held there for duration of 5 min with PD measurement.
e. Raised to 420kV (enhancement voltage level) and held there for 60 seconds or according to par.5 above.
f. Reduced to 365kV (one-hour voltage level) and held there for at least 60 min to measure PD. PD level will be recorded every 5 min.
g. Reduced to 277KV and held there for a duration of 5 min with PD measurement.
h. Reduced to 92kV with background PD measurement.
i. Reduced to a value below 92kV before switching off.

Partial discharges shall be measured at all HV and MV terminals.

The test is successful if:

- No collapse of the test voltage occurs.
- The level of partial discharges does not exceed 250pC during the one-hour period.
- The partial discharge behavior shows no continuously rising tendency during the one-hour period, nor sudden sustained increase during the last 20 min of the same period. The partial discharge level during the one-hour period shall not increase more than 50pC. Occasional high bursts of non – sustained nature should be disregarded.
- The level of partial discharges does not exceed 100pC at 277kV voltage level.

As long as no breakdown occurs during the test and unless very high values of partial discharges are sustained for a long time, a failure to meet the partial discharge acceptance criteria shall not warrant immediate rejection, but lead to further investigation, following Annex A of IEC 60076-3.

1.10.6 Auxiliary Wiring Insulation Test (AuxW)

The wiring for auxiliary power, signaling and control will be tested with a 1min AC voltage of 2kV to earth. The test shall include the wiring of the OLTC motor drive. The secondary windings of bushing current transformers will be tested with a 1min AC voltage of 2.5kV to earth.

1.11 Operation test of On – Load Tap Changer

With the tap-changer fully assembled on the autotransformer, the following operations shall be performed:

a. With the autotransformer un-energized, eight (8) complete cycles of operation (a complete cycle of operation goes from one end of the tapping range to the other and back again).
b. With the autotransformer un-energized and with auxiliary voltage reduced to 85% of its rated value, one (1) complete cycle of operation.
c. With the autotransformer energized at rated voltage and frequency at no load, one (1) complete cycle of operation.
d. With the MV terminals short-circuited, the LV terminals open-circuited and rated current through the HV terminals, ten (10) cycles of tap-changer operations across the range of two steps on each side from tap position No.10, where the change-over selector operates. During this test, the tap changer will pass 20 times through the change-over position.

1.12 Check of ratio and polarity of bushing current transformers

1.13 Dissolved gas analysis (DGA)

After the completion of all dielectric tests, oil samples will be taken from the pipes connecting the autotransformer tank and the cooling system, while the oil pumps are in operation. The samples will be submitted to dissolved gas analysis (DGA). The oil sampling and the DGA will be performed according IEC 61181 and IEC 60567.

1.14 Functional check of auxiliary wiring

1.15 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.

1.16 Frequency response measurement (SFRA)

A frequency response measurement will be performed after all other routine and special tests and prior to shipment, following IEC 60076-18. In case the manufacturer does not have an SFRA device available, the measurement will be performed with a device provided by IPTO.

2. Type tests

2.1. Temperature rise test

The test will be carried out in accordance with the IEC 60076-2 standard. The temperature sensors and sensor pockets installed on the autotransformer tank and the cooling system (par.IX.12.11) will be used for the test. One cooling unit (standby unit) will be out of operation and isolated during the whole test. One temperature sensor shall be placed in distance of 0.5m from the air intake of each operating cooling unit. The hot-spot winding temperature will be measured directly on all windings, using the installed direct hot-spot temperature measurement system (par.IX.12.10). The maximum measurement of the sensors installed in any phase of the same winding will be used for the test.

The temperature rise test will be carried out before the dielectric routine and special tests. The autotransformer oil shall be thoroughly degassed before the beginning of the test, in order to reach a level of residual dissolved air below 0.5%.

The purpose of the test is the following:

a. To measure the top oil temperature rise in steady – state condition, with dissipation of maximum total losses. It shall not exceed 60 K.
b. To measure the average winding temperature rise for each winding at maximum rated tapping current and with the top oil temperature rise in conditions as mentioned in par.(a). It shall not exceed 65 K. Also to measure the average winding to oil temperature gradient.
c. To measure the hot-spot winding temperature rise for each winding at maximum rated tapping current and with the top oil temperature rise in conditions as mentioned in paragraph (a). It shall not exceed 78 K.

For this reason the test will be performed in the following steps:

1. Application of a three-phase test voltage to the HV terminals, while the MV terminals are short-circuited and the LV terminals are open-circuited. The tap-changer will be positioned at the tapping No.19, where the common winding has maximum rated current and the total losses of the autotransformer are also maximum. The measured active power will be equal to the total loss (load and no-load loss) of the autotransformer on tapping No.19, under rated tapping power at all windings. This corresponds to autotransformer loading HV/MV/LV = 258.44/258.44/60 MVA, as stated in par.VII.6. The no-load loss will be taken from the corresponding loss measurements in par.X.1.4, for tapping No.19. The load loss will be calculated following the method described in IEC 60076-8 and using the corresponding loss measurements in par.X.1.3 for tapping No.19. The test current will be above rated tapping current to the extent necessary to cover the total loss. During the test, the top oil and ambient temperature will be measured continuously and recorded at regular intervals. The test for this

step will be terminated when the rate of change of top oil temperature rise has fallen below 1 K/h and has remained there for a period of three (3) hours. The top oil temperature rise will be reported for rated autotransformer loading 258.44/258.44/60 MVA at tapping No.19. The oil temperature indicator will be calibrated at the end of this step.

2. When the top oil temperature rise has been measured, the test will immediately continue for one (1) hour with the test current reduced to rated tapping current at HV terminals, corresponding to rated 258.44 MVA loading for tapping No.19. During this time the top oil, bottom oil, and ambient temperatures, as well as the hot-spot winding temperatures of the tested series and common windings, will be measured continuously and recorded every five (5) min. At the end of the hour, the resistance of series and common windings at all phases will be measured rapidly, shortly after disconnection of the supply. The initial value of resistance at the exact disconnection time will be calculated by extrapolation method, following Annex C of IEC 60076-2. The average winding temperature rise, the average winding to oil temperature gradient and the maximum hot-spot temperature rise of series and common windings will be reported for rated autotransformer loading 258.44/258.44/60 MVA at tapping No.19, as in previous step. In order to do so, the above mentioned values of the common winding shall be corrected, following IEC 60076-2, to the rated tapping current of common winding corresponding to 258.44/258.44/60 MVA autotransformer loading at tapping No.19. The rated tapping current of common winding will be calculated following the method described in IEC 60076-8. The series winding temperature indicator will be calibrated at the end of this step.

3. When the series and common windings temperature rise have been measured, the MV terminals will be open-circuited and the LV terminals will be short-circuited. The test will immediately continue for one (1) hour with the test current at HV terminals reduced to such value, in order the tested tertiary winding to have its rated tapping current, corresponding to 60 MVA for tapping No.19. During this time the top oil, bottom oil and ambient temperatures, as well as hot-spot winding temperatures of the tested tertiary winding, will be measured continuously and recorded every 5 min. At the end of the hour, the resistance of the tertiary winding at all phases will be measured rapidly, shortly after disconnection of the supply. The initial value of resistance at the exact disconnection time will be calculated by extrapolation method, following Annex C of IEC 60076-2. The average winding temperature rise, the average winding to oil temperature gradient and the maximum hot-spot temperature rise of the tertiary winding will be reported for rated autotransformer loading 258.44/258.44/60 MVA at tapping No.19, as in previous two steps. The tertiary winding temperature indicator will be calibrated at the end of this step.

Before the beginning and after the end of the temperature rise test, oil samples will be taken from the pipes connecting the autotransformer tank and the coolers, with the oil pumps in operation. The samples will be submitted to dissolved gas analysis (DGA).

The oil sampling and the DGA will be performed according to Annex D of IEC 60076-2, IEC 61181 and IEC 60567. The rate of increase of dissolved gases during the temperature rise test shall not exceed the first series limits, as they are stated in Annex D of IEC 60076-2.

Note:
The total losses of the autotransformer shall be calculated at the extreme tappings No.1 and 19, at the principal tapping No.11 and at the maximum current tapping No.15, from the relevant load loss measurements (par.X.1.3, X.1.4), following the method described in IEC 60076-8. If the maximum total losses of the autotransformer under rated tapping power at all windings occur at a different tap position than No.19, then the test will be performed with the tap changer at this tap position with maximum total losses and with the corresponding rated tapping quantities. This means that the total losses used at the first step of test will be the maximum. Also the current used for every winding at the second and third step of test will be the rated tapping current at the same maximum loss tap position. The rated tapping power for every winding will be the corresponding at this maximum loss tap position.

2.2. Calculation of temperature rise at long-time emergency overloading

The load loss at the overloading conditions of par.VII.12 and tapping position No.19 will be calculated, as in the first step of the temperature rise test (par.X.2.1), following the method described in IEC 60076-8. The top-oil temperature rise, the average winding to oil temperature gradient and the hot-spot temperature rise will be calculated following the exponential equations method described in IEC 60076-7, using the reported values of the temperature rise test. Finally the top-oil, the average winding and the hot-spot temperatures for every winding will be reported, using on the ambient temperature stated in par.VII.12.

2.3. Determination of acoustic sound level

The test will confirm that the autotransformer corrected average sound pressure level under rated load and voltage, with all cooling equipment in operation, does not exceed 85 dB(A).
Two sound pressure measurements will be carried out and the total sound pressure level will be calculated from the addition of their results, through intermediate calculation of the sound power, according to IEC 60076-10.
The first measurement will be performed at rated voltage and no-load current, with the cooling equipment out of operation. The measurement can be carried out at the same time with the measurement of no-load loss (par.X.1.4), at the same tap position used for the temperature rise test and at a distance of 1 m from the autotransformer radiating surface, including cooling system. The second measurement will be performed at rated current on the HV – MV terminals, no current on LV terminals and short-circuit voltage, with all cooling equipment in operation (excluding the standby cooling unit). The measurement will be carried out during the second step of the temperature rise test (par.X.2.1), with the series and common windings close to service temperature, at a distance of 2 m from the autotransformer radiating surface, including cooling system. Both measurements will be performed in accordance with IEC 60076-10 and IEC 60076-10-1 standards. The total sound pressure level will be calculated at a 2 m

distance from the autotransformer radiating surface, including cooling system. The total sound power level will be reported also.

2.4. Measurement of the power taken by the fan and pump motors (cooling loss)

The measurement will be carried out so that the power requirements of the autotransformer cooling system is verified and taken into account in the losses guaranteed by the Bidder.
This measurement shall be carried out during and close to the end of the first step of the temperature rise test (par.X.2.1), with the insulating oil close to service temperature. The measurement will include all cooling units, excluding only the standby unit. The power absorbed by operation of only the first cooling control group, will be also reported.
Any possible excess of the guaranteed losses will burden (affect) not only the autotransformer under test but all pieces of the order.

3. Special tests

The special tests shall be carried out on one (1) only piece of the order.

3.1 Chopped wave Lightning Impulse tests on MV and LV Line Terminals (LIC)

The impulse test will be performed for each MV and LV line terminal of the autotransformer with the following test sequence:

1. Application of one (1) reduced level, full wave impulse 1.2/50 μs (50%÷70% of 750kV for MV terminal or of 250kV for LV terminal)
2. Application of one (1) full wave impulse 1.2/50μs at 750kV for MV terminal or at 250kV for LV terminal
3. Application of two (2) chopped wave impulses 1.2/2-6 μs at 825kV for MV terminal or at 275kV for LV terminal
4. Application of two (2) full wave impulses 1.2/50 μs at 750kV for MV terminal or at 250kV for LV terminal

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 terminals which are not under test, including neutral terminal, shall be earthed directly or through low impedance.
During the test at MV terminals, for one phase the tap changer will be on position No.1, for another phase on position No.10 (regulating winding not series connected) and for the third phase on position No.19.
During the test, the oscillograms of the applied voltage shape and current flowing through the tested terminal will be recorded.

3.2 Lightning Impulse tests on neutral terminal (LIN)

The impulse test will be performed at the neutral terminal of the autotransformer, with all other terminals earthed and the following test sequence:

1. Application of one (1) reduced level, full wave impulse 1.2/50μs (50%÷70% of 550kV)

2. Application of three (3) full wave impulses 1.2/50 μs at 550kV

The front time of the lightning impulse will be up to a maximum of 13 μs.
The tap changer shall be on position No.10 during the test, where the regulating winding is not connected in series with the common winding.

3.3 AC withstand voltage test on Line Terminals (LTAC)

The test will be performed for each phase separately by implementing a suitable connection of the three phase windings and applying a single-phase voltage, in order to produce an induced voltage to earth to the tested HV terminal equal to 630kV. The tap changer shall be on a suitable position, in order for a voltage as close as possible to 325kV to be produced to the corresponding MV terminal. In case of a connection implementation where the two MV terminals are earthed, all other terminals are not earthed and the voltage is applied between two LV terminals, the suitable tap position will be No.7.
The test frequency and duration will be the same as for the enhancement voltage level of IVPD test.

3.4 Measurement of zero-sequence impedances

The measurements will be performed at the rated frequency with sinusoidal voltage applied between the line terminals of one side connected together and the neutral terminal. The terminals of the other sides can be open-circuited or short-circuited.
The zero-sequence impedance will be measured for the following cases:

- voltage at HV terminals, with MV terminals open-circuited
- voltage at HV terminals, with MV terminals short-circuited
- voltage at MV terminals, with HV terminals open-circuited
- voltage at MV terminals, with HV terminals short-circuited

In all above cases the LV terminals will be open-circuited. The zero-sequence impedance will be measured with the tap changer on the principal tapping No.11, on the two extreme tappings No.1 and 19, as well as on the maximum current tapping No.15. The measured values of zero-sequence impedance will be corrected to the reference temperature of 75°C, will be represented as percentage (%), referring to 280 MVA power and to rated tapping voltage, according to the IEC 60076-1 standard. The zero-sequence impedance per phase is given by 3U/I, where U is the test voltage and I is the test current (test current per phase I/3).
The measurements will be carried out with such a test current, in order the induced current on the D connected tertiary winding to not exceed its rated value. (Proposed test current values: $I \leq 200A$ for HV terminals and $I \leq 450A$ for MV terminals.)

3.5 Determination of transient voltage transfer characteristics

The impulse voltage transfer characteristics will be determined, following Annex B of IEC 60076-3. The induced voltage at the isolated LV terminals will be measured, when an impulse voltage to earth will be applied at all HV and MV line terminals in succession.
The lightning impulse (LI) and chopped wave lightning impulse (LIC) voltage transfer will be measured, using an LV recurrent surge voltage generator and an oscilloscopic measuring device and then extrapolated to the full HV and MV impulse voltage level.

Alternatively, the measurement can be carried out during impulse voltage tests on line terminals, with LI and LIC tests at reduced levels, and then extrapolated to the full HV and MV impulse voltage level.

3.6 Pressure deflection test of the tank

The permanent deflection of any point of the tank walls shall not surpass 5 mm, after applying an internal pressure of at least 35 kPa above the normal operating pressure.

3.7 Vacuum deflection test of the tank

The permanent deflection of any point of the tank walls shall not surpass 5mm, after applying an internal vacuum.

3.8 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.

3.9 Insulating oil tests

The following tests will be performed on oil sample from the autotransformer tank and the mentioned acceptance levels will apply:

1. Inhibitor content of DBPC or DBP type following IEC 60666, with value within 0.30% – 0.40%
2. Corrosive Sulphur existence following DIN 51353, with negative result (not corrosive)
3. Potentially corrosive Sulphur existence following IEC 62535, with negative result (not corrosive)
4. PCBs existence following IEC 61619, with negative result (not detectable, < 2 mg/kg)
5. Acidity following IEC 62021-1 or -2, with value ≤ 0.10 mgKOH/g
6. Viscosity following ISO 3104, with value ≤ 12 mm^2/s at 40°C and value ≤ 1800 mm^2/s at -30°C (LCSET)

XI. EXPLOSION AND FIRE PREVENTION SYSTEM OF THE AUTOTRANSFORMER

The autotransformer shall be equipped with an explosion and fire prevention system. The system shall be the “Transformer Protector” of TPA3B type, made by SERGI.

The system will consist of the following equipment, provided by SERGI:

1. Depressurization Set (DS) for the main tank of the AT/F (one or two pieces, according to SERGI study)

2. Depressurization Set (DS) for the internal diverter switch tank of the OLTC

3. Depressurization Set (DS) for the turret of each HV bushing (three pieces in total)

4. Shutter valve at connection pipe between oil conservator and AT/F tank

5. Linear Heat Detector (LHD) for fire detection on the AT/F tank

6. Explosive Gas evacuation Set (EGES)

7. Inert Gas Injection Set (IGIS), which will be housed in cabinet and it will include an inert gas cylinder

8. Control Box for the electrical control of the system

The system will include also following materials, provided by the AT/F manufacturer:

1. Oil – Gas Separation Tank (OGST) for the separation of explosive gas from the oil

2. All necessary adaptors on the AT/F

3. All necessary piping to complete the TPA3B system.

4. All necessary steel supports

NOTE: It is desirable the OGST to be a compartment of the main AT/F conservator tank.

The IGIS shall be seated on a concrete base, placed at least 5 m away from AT/F tank and protected by a firewall from it, according to SERGI requirements. It will inject inert gas to the AT/F tank, diverter switch tank of OLTC and HV bushing turrets. The IGIS will operate automatically, either after bursting of a rupture disk in any DS, or after fire detection from LHD. To increase security in both cases, the trip signal of the autotransformer differential protection relay shall be a prerequisite for the IGIS activation. Each rupture disk will include a second electrical contact for electrical tripping, apart from the one used for IGIS operation.
The EGES shall be placed at least 5 m away from AT/F tank and at a height of at least 5 m.

XII. SPARE PARTS

Bidders should quote the following spare parts for each autotransformer, giving item prices.

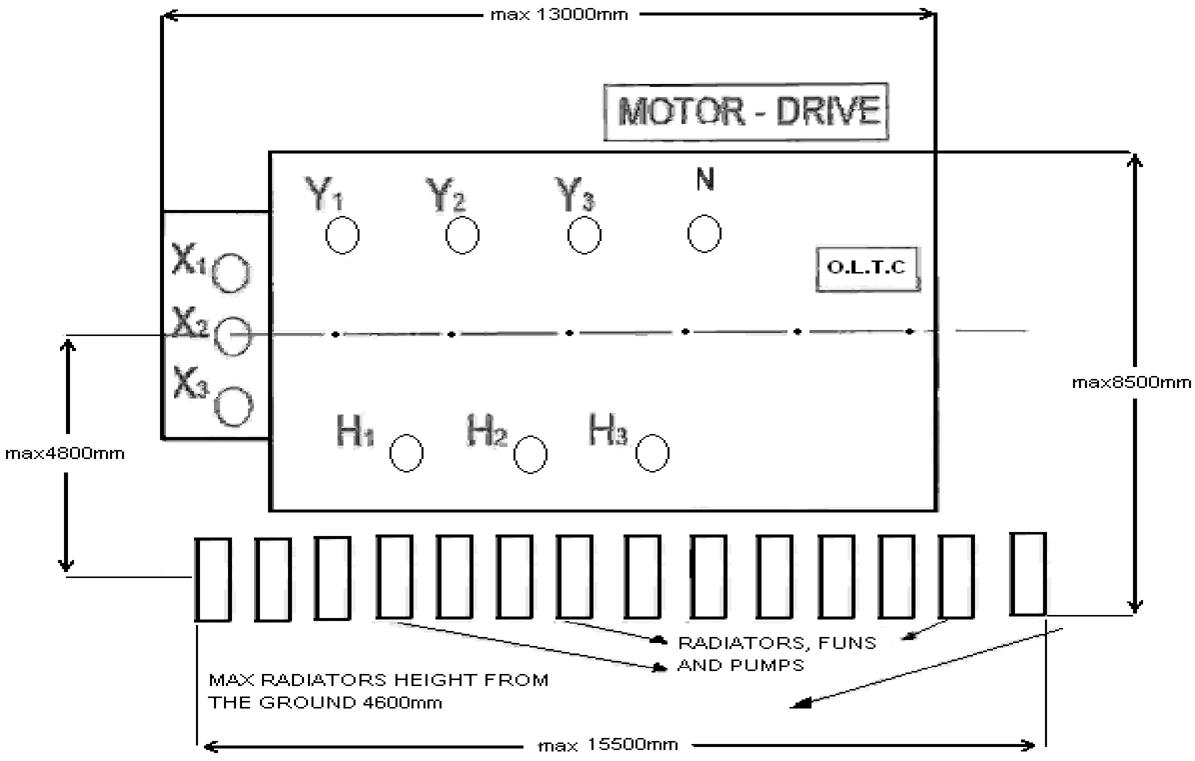
Item No	**Description**
1	One HV bushing complete
2	One MV bushing complete
3	One LV bushing complete
4	Complete set of gaskets for all bushings, covers, radiator flanges, manholes and hand-holes for one autotransformer.

5	Cooling fan and motor set
6	Cooling pump and motor set
7	Set of replacement parts for each type of part likely to be damaged upon operation of the relays, contactors, instruments, safety devices,etc.
8	Two sets of replacement parts of the OLTC likely to be damaged during operation (complete set of contacts for the diverter switch).

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 his proposal or not to purchase any spare parts at all.

XIII. OUTLINE SKETCH

The outline arrangement and overall dimensions of the autotransformer must be as indicated below. Also the outline of the autotransformer with regard the side and front view shall be as indicated in sketch SK-883B. The height of the autotransformer (bushing terminals to ground) shall not exceed 12 m.



(H)	H.V. bushings	(400KV)	(X)	L.V. bushings (30KV)
(Y)	M.V. bushings	(150KV)	(N)	Neutral bushing

XIV. AUTOTRANSFORMER MOVEMENT SYSTEM

Autotransformers shall be provided with wheels which will permit the movement of the completely filled autotransformer either in longitudinal or transverse direction. The wheels will run on rails and be able to rotate 90^0.
The dimensions for the autotransformer taxiing shall be according to the attached sketch SK-883A.

XV. TRANSPORT, LIFTING, PULLING AND LOADING REQUIREMENTS FOR THE AUTOTRANSFORMER

For the lifting, pulling, loading and transport purposes (with the autotransformer filled with nitrogen (N_2) and with the appropriate amount of oil) the autotransformer must be equipped with a lifting and pulling arrangement as it is shown in the attached sketch SK-883B. The autotransformer must also have suitable suspension lugs with their location in relation to the main body of the autotransformer must be as shown in the attached sketch SK-883C. The dimensions and lugs shown in sketch SK-883C are mandatory.
The required transport dimensions of the autotransformer are indicated in the attached sketch SK-883-D in which the outline of the tunnel is indicated with dotted line and the outline of the autotransformer is indicated with a continuous line. The autotransformer transportation weight must not exceed 260.000Kg.

XVI. DATA TO BE SUBMITTED BY BIDDERS

1. All bidders must provide all information requested in attachment “A” of this hereby specification as well as any proposed deviation from the present specification and the reason therefore. Failure on bidder’s part to comply with this request will be taken as sufficient reason for rejection of the offer.
2. All bidders must take note of attachment B of this hereby specification
3. Technical pamphlets and brochures of the offered autotransformers, which will help the technical evaluation process.
4. Technical data for the OLTC and the autotransformer accessories and systems.
5. Drawings showing the outline dimensions of the autotransformers offered and any other information deemed necessary, including terminal markings.
6. A preliminary plan for the unloading and for the transportation of the autotransformer.
7. Any type test certificates for the type and special tests specified in this hereby specification.

XVII. DATA TO BE SUPPLIED BY THE SUCCESSFUL BIDDER

The Bidder shall furnish (3) three copies for approval and (5) five copies of final drawings at or before the time of shipment of the following:

a) Assembled transformer outline drawing
b) Dimension drawings for the movement (rails) and the foundation of the autotransformer, including the explosion prevention system, showing maximum loads on each support area
c) Autotransformers operation schematics and wiring diagrams

d) Bushings outline drawings, including type and designation according EN 50458
e) Nameplate and valve plate drawings
f) Terminal designations
g) Current transformers wiring diagram
h) Current transformers characteristics
i) Cooling circuit control wiring diagrams
k) OLTC control system operation diagram and wiring diagram.
l) Calculations for the thermal and dynamic ability of the transformers under short-circuit, according to par.VII.8.
m) Wiring diagrams and instructions of the explosion prevention system
n) Transformer outline drawing showing the electrical isolation points needed for the transformer tank-earth protection, according par. IX.10 and IX.12.8.
o) Instruction manual covering installation operation and maintenance
p) A final plan for the unloading, loading and transportation of the autotransformer.
q) Layout drawing from SERGI, the explosion prevention system manufacturer, showing the implementation of the system on the specific AT/F
r) Dimension drawings for the concrete base of the IGIS cabinet of the explosion prevention system
s) Operating pressure of all pressure relief devices (main tank and OLTC)
t) Physical and chemical characteristics of the inhibited insulating transformer oil, as specified in IEC 60296, including inhibitor content (DBPC or DBP), measured according IEC 60666.
u) Physical and chemical characteristics of thermally upgraded paper (TUP), including organic nitrogen content, measured according ASTM D982.
v) One drawing showing the test arrangement during the LTAC test. The drawing shall show the specific connection of the autotransformer windings, the position of tap changer and the induced voltages on each terminal (line HV, line MV, neutral, line LV).
w) Initial calculation of the quantities used at the temperature rise test. The calculation will determine the tap position used during the test, the total autotransformer losses, the rated tapping current of the common winding and the currents used at every step of the test. The calculation will be revised before the test, using the measured values.
x) Detailed quality control plan (QCP), incorporating quality assurance (QA) and inspection and test plan (ITP).

Whatever of the above existing in electronic format will be submitted also in that form.

XVIII. RATING PLATES

The autotransformer 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 (MVA) for each autotransformer side (HV, MV, LV) and for all tap positions.
7. Rated frequency (Hz)
8. Rated voltages (V or kV) at all line terminals and for all tap positions.
9. Rated currents (A or kA) at all line terminals and for all tap positions
10. Symbol of the windings connection
11. Measured short-circuit impedance in (%) for the three possible combinations of two sides (HV, MV, LV), with the corresponding reference rated power (280MVA), for the principal and for the two extreme tap positions (No.1, 11, 19)
12. Peak efficiency index (PEI) in %, based on measurements, according EN 50629
13. Load factor k_{PEI} in (pu), at which PEI occurs
14. Measured no-load loss at principal tapping and rated voltage
15. Cooling loss at no-load operation, based on measurements
16. Measured load loss between HV – MV terminals, with LV terminal open-circuited, at principal tapping and rated current, corrected to reference temperature 75°C.
17. Rated data for all bushing current transformers
18. Type of cooling.
19. Insulation levels of all winding terminals
20. OLTC plate
21. Characteristics of any surge arresters, if existing, built in the autotransformer windings or in the tap-changer
22. Guaranteed temperature rise of top-oil with losses (load and no-load) at rated loading of all windings
23. Guaranteed average temperature rise of windings at rated current
24. Guaranteed hot-spot temperature rise of windings at rated current
25. Winding temperature indicators setting (measured temperature gradient between top-oil and hot-spot winding temperature at rated current)
26. Diagram of the windings configuration
27. Autotransformer total mass
28. Autotransformer transportation mass
29. Autotransformer untanking mass
30. Autotransformer active part mass, if different from untanking mass
31. Type of electrical conductor (copper)
32. Autotransformer conductor mass
33. Type of magnetic core material (silicon steel)
34. Autotransformer core mass
35. Type of autotransformer insulation oil (inhibited transformer oil)
36. Autotransformer oil mass
37. Vacuum withstand capability of the tank, conservator and coolers.

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

XIX. ECONOMIC COMPARISON OF THE OFFERS

The economic comparison of the offers shall be based on the autotransformer initial cost as it will be amended after taking into consideration the terms of payment and any custom duties and the cost of the guaranteed losses, that is the comparison will be carried out on the annual cost of the autotransformer as indicated in the attachment “B” of this specification.
For this reason, the paragraph 1 of the attachment “B” only must be filled and the attachment must be submitted along with all others technical information in the technical offer, while the attachment ΄΄B΄΄ must be submitted completely filled in the economic offer, as well.

XX. PACKING

The autotransformer accessories must be packed inside robust, entirely closed wooden boxes of at least 20mm thickness and maximum gross weight of five (5) tons (seaworthy packing).
The above requirement does not include the bushings of the autotransformer which must be packed separately, one bushing per one wooden box.
The boxes will be of pallet type and they will be protected internally by an insulating material (e.g.nylon).
One shock recorder will be provided and installed on each autotransformer tank by the manufacturer.
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 of the autotransformer, according to par.VII.19.

ANNEX A

(If required in the Inquiry)

Autotransformer Condition Monitoring Systems Technical Description

1. Integrated Condition Monitoring System for Autotransformers

1.1. General Requirements

The general description and requirements of the project are as follows:

1.1.1. An integrated condition monitoring system will be procured, installed and commissioned by the Contractor. The system will be installed during the manufacturing stages of the autotransformer. All necessary connections pipes, flanges, manholes, oil pockets, electrical wiring, junction and control boxes shall be incorporated in the design of the autotransformer. Only limited welding or threading operations are allowed on site.

1.1.2. The manufacturer/supplier will provide all necessary consumables and spare parts for five (5) years of operation. A guarantee for at least two (2) years of operation will be also provided for all devices and systems starting from the date of the qualitative / quantitative acceptance of the installation. The expected lifetime/MTTF of the various consumables/spare parts shall be provided analytically.

1.1.3. Each Bidder will submit a detailed technical description of the offered integrated condition monitoring system. The description will refer also in detail to the capabilities of the offered software and to the communication requirements of the system. Technical datasheets and leaflets of all offered devices will be also included. Each Bidder will submit also the list of consumables and spare parts for five years of operation of the condition monitoring system.

1.1.4. The manufacturer must have installed the condition monitoring system on at least three (3) transformers in the last three (3) years with satisfactory operation. Reference letters from the end-users must be provided. The installed monitoring systems shall comprise at minimum the fiber optics temperature sensors and the Dissolved Gas Analysis and Moisture monitor. In case that no previous or limited experience with the integrated monitoring system experience can be exhibited, the manufacturer shall provide a solemn declaration from the monitoring system vendor/manufacturer stating that he will support with know how transfer and supervision the correct installation, adjustment and functional testing of the integrated monitoring system in all stages of the manufacturing process as well as during commissioning (if necessary).

1.1.5. The wiring drawings, layout drawings and detailed data sheets of the integrated condition monitoring system and of all its components will be submitted to IPTO for approval along with mechanical and electrical drawings of the Autotransformer. The IP rating for all cubicles or cabinets shall be at least 65.

1.1.6 Operation and maintenance manuals shall be delivered for all systems and devices.

1.2. Condition Monitoring devices

The devices and sub-systems of the integrated condition monitoring system, their interconnections and communication capabilities will be as follows:

1.2.1. A dissolved gas and moisture monitor on the transformer tank, either of GE manufacture, Kelman Transfix DGA 900 type, or of Qualitrol manufacture, Serveron TM8 type, or of Siemens manufacture, Multisense 9 type, or of Doble manufacture, Morgan Schaffer Calisto 9 type. The device shall monitor eight or nine gases and moisture dissolved in transformer oil. It shall communicate remotely through Ethernet port and locally through a serial port (preferably USB). Its auxiliary power will preferably be 220 Vdc or else 230 Vac, fed from the control cabinet of the autotransformer.

The monitor shall be connected to the main tank through two pipes with ball valves for oil inlet and outlet. Alternatively it can be connected through one pipe with ball valve, if this is specified by its manufacturer.

1.2.2. A stand-alone condition monitoring system, either of GE manufacture, MS3000 type, or of Qualitrol manufacture, QTMS type, or of Siemens manufacture, Sitram TDCM type, or of Koncar manufacture, TMS type. Other monitoring systems can be accepted as long as their capabilities are at least equivalent to one of the above mentioned systems. Their acceptance is subject to approval by IPTO.

1.2.3. The system will be housed on a separate cabinet, installed on the autotransformer tank. Its auxiliary power will preferably be 220 Vdc or else 230 Vac, fed from the control cabinet of the autotransformer.

The system will import the dissolved gas and moisture measurements through connection to the relevant monitor (par.1.2.1). It will use expert models to estimate the transformer condition from the measurements. The measurement of 8 - 9 gases will be used to perform Duval triangle analysis, key gas analysis and gas ratio analysis, correlating the gases with various disturbances, e.g. paper insulation overheating, partial discharges, electrical arcing.

The system will include Pt100 oil temperature sensors, installed in pockets designed according EN 50216-5. Two oil temperature sensors shall be installed on the autotransformer tank. One will be located on the tank cover, at the hottest oil point, near the temperature sensor of the oil temperature indicator. The other will be located at the bottom of the tank, at the coldest oil point. Two oil temperature sensors shall be installed on the cooling system. One will be located at the oil inlet pipe from the autotransformer tank and the other at the oil outlet pipe to the autotransformer tank. The sensors will have three wires at least and they will be of QUALITROL or MR manufacture. The system will include also two sensors for ambient temperature measurement, one placed in shade and one under direct sunlight.

The system will use the above data and expert algorithms to calculate the following additional data:

- calculated hot-spot temperature
- cooling system efficiency
- moisture in insulation paper
- bubbling temperature
- ageing rate
- lifetime consumption
- long-time overloading level
- short-time overloading levels / times

The system will include sensors connected to the test tap of the 400kV 157.5kV and 30kV bushings. Through these sensors, the system will measure the capacitance (C1) and dissipation factor (tanδ) for each bushing, using sum of three-phase, adjacent phase reference methods or reference signal method.

The system will import the position of OLTC, using a suitable transducer, supplied by Contractor. Additionally it will include measurement of the OLTC motor current, using a CT, and of the OLTC motor voltage. In this way it will monitor the operation of the OLTC drive. The system will calculate also the cumulative switched current. It will use an expert algorithm to assess the used and remaining contact life in the OLTC and estimate the

remaining operations until next service or contact replacement. To configure the mentioned expert algorithm, IPTO will provide (if necessary) the OLTC data regarding contact wear versus current, as requested by the Contractor.
The system will have adequate storage capability for archiving of the measured data. All data will be stored in an RDBMS SQL server database.It will communicate remotely through an Ethernet port and locally through a serial port (preferably USB). The remote communication will be realized preferably through an embedded web server. Alternatively, to the web server, the Contractor will provide one license for client desktop software. The functionality of the web server or client software will include data visualization, measurement trends, condition estimations, downloading of data archives, report generation, remote setting. Additionally, the system will include communication capability through IEC 61850 protocol to the substation automation system for alarms transmitting.
The system will be commissioned on site, in presence of a technician from the manufacturer (GE, Qualitrol, Koncar,Siemens).

280MVA, 400 / 157.5 / 30kV THREE-PHASE AUTO-TRANSFORMERS

ATTACHMENT "A"

INFORMATION BY SELLER

1.	Type of auto-transformer (short description)	
	Nominal voltage	:……………………………..
	Number of phases	:……………………………..
	Connections symbolism	:……………………………..
	Rated power	:……………………………..
2.	Core type	:…………………………………
	a. Flux density at rated voltages (at no load and principal tap position)	:…………………………………
		…………………………………
	b. Number of core limbs	:…………………………………
3.	Insulation levels	:…………………………………
		…………………………………
		…………………………………
		…………………………………
		…………………………………
		…………………………………
		…………………………………
		…………………………………
		…………………………………
4.	Maximum permissible short circuit duration	:…………………………………
		…………………………………
5.	Over-voltage capability	
	a) at no load	:…………………………………
	b) at 280 MVA	:…………………………………
6.	Long-time emergency overload capability	
	Maximum current at HV – MV terminals	:……………………% of rated
7.	Autotransformer connection.	: …………………………………
8.	Insulation category of windings (uniform or non-uniform)	: …………………………………
		…………………………………
9.	Temperature rise limits	: …………K for windings
		: …………K for oil
		: …………K for winding hot-spot

10. Thermal model constants
(calculated values following IEC 60076-7):

a. Top-oil to ambient temperature rise with losses (load + no-load) at rated loading of all windings - $\Delta\theta_{or}$: ………………………… K
b. Average winding to oil temperature gradient at rated current - g_r : ………………………… K
c. Hot-spot to top-oil temperature rise at rated current - $\Delta\theta_{hr}$: ………………………… K
d. Hot-spot factor - H : …………………………
e. Exponential power of total losses versus top-oil temperature rise (oil exponent) - x : …………………………
f. Exponential power of current versus winding temperature rise (winding exponent) - y : …………………………
g. Average oil time constant - τ_o : ………………………… min
h. Winding time constant - τ_w : ………………………… min
i. Constant k_{11} : …………………………
j. Constant k_{21} : …………………………
k. Constant k_{22} : …………………………

11. Losses and PEI data
(The guaranteed losses shall be as indicated in paragraph VII-18)

11.1. No Load losses and exciting current at principal tap:

Voltage level	No load loss (kW)	Exciting current (% of rated current)
a) 380 kV	……………………	…………………
b) 400 kV	……………………	…………………
c) 420 kV	……………………	…………………

11.2. Load losses at principal tap and reference temperature 75°C:

Load on HV and MV side (MVA) (HV = MV)	Load loss (kW) with no load on LV side
280	…………………….
210	…………………….
140	…………………….
70	…………………….

11.3. Load loss at principal tap and 75°C with 60 MVA on HV and LV side and no load on MV side :………………… kW

11.4. Load loss at principal tap and 75°C

with 60 MVA on MV and LV side
and no load on HV side :………………… kW

11.5. Total losses at principal tap and 75°C
with 280 MVA on HV – MV side
and 60 MVA on LV side
(no-load + load loss) :………………… kW

11.6. Total cooling system loss
(all cooling units in operation,
excluding standby cooler) :………………… kW

11.7. Cooling system losses at AT/F no-load operation
(only the first cooling control group in operation) :………………… kW

11.8. Efficiency Index (EI) at principal tap:

Load on HV and MV side in MVA (HV = MV)	Efficiency Index with no load on LV side
280	…………………%
210	…………………%
140	…………………%
70	…………………%

11.9. Peak efficiency index (PEI)
according EN 50629 :…………………%

11.10. Load factor at HV – MV terminals
at which PEI occurs, at 280 MVA base :………………… pu

12. Impedances in (%) at principal tap, at 280 MVA power and rated voltage, corrected to 75°C:

12.1. Positive sequence impedances

a) HV / MV :…………………………………
b) HV / LV :…………………………………
c) MV / LV :…………………………………

12.2. Zero- sequence impedances

a) HV (MV open-circuited) :…………………………………
b) HV (MV short-circuited) :…………………………………
c) MV (HV open-circuited) :…………………………………
d) MV (HV short-circuited) :…………………………………

13. Average sound pressure level
- Autotransformer without cooling (no-load) :…………………………dB(A)

- With all coolers at rated power and voltage (excluding standby cooler) :…………………………dB(A)

14. Harmonics of no-load current for principal tap (400/157.5/30kV):
    a. Third harmonic :………% of no-load current
    b. Fifth harmonic :………% of no-load current
    c. Seventh harmonic :………% of no-load current

15. On - load tap changer (OLTC)

    a.Manufacturer and type of the OLTC : ……………………………..

    b. List all parts of the OLTC : ……………………………..
    ………………………………
    ………………………………
    ………………………………
    ………………………………

    c. Is the OLTC of vacuum switching type? : ……………………………..

    d. Number of tapping positions : ……………………………..
    ………………………………

    e. Operating temperature
    Minimum : ………………………………
    Maximum : ……………………………...

    f. Is the tap selector and the reversing change – over selector in their own not oil – tight compartment? : ………………………………
    ………………………………..
    ………………………………..

    g. Is the diverter switch and the transition resistors in their own oil – tight compartment? : ………………………………
    ……………………………….

    h. Is the OLTC equipped with its own conservator ? : ……………………………..

    i. Is the oil of OLTC free from PCBs or PCTs, suitable for transformers and in accordance with IEC 60296? : ………………………………

    j. Is the conservator equipped with oil level indicator and breather? : ………………………………
    ………………………………

k. Is the diverter switch and transition resistors compartment equipped with a filling and a drain tap ? : ………………………………
………………………………..

l. Does the OLTC consist of a three – phase unit ? : ………………………………

m. Is the OLTC equipped with its own oil-flow relay? : ………………………………
Describe where it is installed : ………………………………
Type and manufacturer : ………………………………

16. Tapping arrangement : ………………………………

17. Position of regulating winding : ………………………………

18. Maximum rated through current of OLTC : ………………………………

19. Maximum rated step voltage of OLTC : ………………………………

20. Rated frequency of OLTC : ………………………………

21. Rated Voltage of OLTC : ……………………………...

22. Supply voltage for the control circuits of the motor drive unit : ……………………………...

23. Rated power frequency withstand voltage : ………………………………

24. Rated lightning impulse withstand voltage : ……………………………...

25. Describe the oil – flow controlled relay and where it is installed : ………………………………
………………………………..
………………………………..
………………………………..

26. Number of make output contacts of the oil – flow controlled relay : ………………………………

27. Describe the pressure relief device and where it is installed : ………………………………
………………………………
………………………………
………………………………

28. Number of make output contacts of the pressure relief device : ………………………………

29. Time response of the pressure relief device : ………………………………

30. Pressure or vacuum values for the diverter switch compartment and transition resistors : ………………………………

31. Time response of the oil – flow controlled relay : ………………………………

32. Is the motor drive unit suitable for Local/Remote operation? : ……………………………….
………………………………..
………………………………..

33. Is the motor drive unit equipped with emergency stop? : ……………………………….
…………………………………

34. Indicate installation position of the motor drive unit : ……………………………….
…………………………………
…………………………………

35. Supply voltage of the motor drive unit motor : …………………………………

36. Frequency of the motor of the motor drive unit : …………………………………

37. IP class protection of the motor drive unit panel : …………………………………

38. Is the motor drive control cabinet equipped with :

a. Local/Remote selector switch : ………………………………..

b. Three (3) Push – buttons for raising, lowering and emergency stop : ……………………………….

c. A device indicating tap position : ……………………………….

d. Tap counter : ……………………………….

e. Anti - condensation heaters controlled via thermostat : ……………………………….

f. Supply voltage of the
anti – condensation heaters : ………………………………..

39. Can the motor drive unit be controlled remotely ? : ……………………………….
………………………………..

40. Can tap position, number of operations and any alarms be displayed at a remote distance ? : ……………………………….

41. Power frequency withstand voltage of the auxiliary circuits of the motor drive unit : ……………………………….

42. Warranty terms of OLTC : ……………………………….
………………………………...
…………………………………
…………………………………

43. Cooling system

a) Type of cooling system : …………………………………
b) Are the coolers separately mounted and not on the tank walls? : …………………………………
c) Is the autotransformer equipped with six (6) independent cooling units with one of them on standby? : …………………………………
d) Does the cooling system meet the requirements of paragraph IX.1.d? : …………………………………..
e) Does the cooling system meet the requirements of the paragraph IX.1.e? : …………………………………..
f) Does the cooling system meet the requirements of the paragraph IX.1.f? : …………………………………..
g) Does the cooling system meet the requirements of the paragraph IX.1.g, h, i, j, k, l and m? : ………………………..
h) Cooling unit data
1. Number of fans per cooling unit : …………………………
2. Rated power of the fan motor : ………………………W
3. Power of the fan motor when running : ………………………W
4. Number of pumps per cooling unit : …………………………
5. Rated power of the pump motor : ………………………W
6. Power of the pump motor when running : ………………………W
7. Oil flow of unit when running : ……………………lt/min

44. Autotransformer tank
    a. Type : …………………………
    b. Material of the tank : …………………………
    c. Is the autotransformer tank in accordance with the requirements of paragraphs IX.2.b, c, d, e, f and g? : …………………………

45. Autotransformer conservator tank
    a. Type : …………………………
    b. Is the conservator composed of one piece? : …………………………
    c. Describe the method of protection against moisture: : …………………………
    ……..……………………
    d. Does the conservator meet all requirements of paragraph IX.3; : ……………………………….

46. Pressure relief device for the autotransformer tank
    - Type : ……………………………….
    - Location of installation : ……………………………….
    - Alarm contacts : ……………………………….
    ……..…………………………

47. Valves
    - Type : ……………………………….
    ……..…………………………
    - Use : ……………………………….
    ……..…………………………
    ……..…………………………

48. Oil of the autotransformer :……………………………….
    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? :……………………………….

49. Bushings

		H.V	M.V	L.V.	Neutral
a.	Type	....	....	....	……..
b.	Manufacturer	....	....	....	……..
c.	Max phase-phase operating voltage (rms)	....	....	....	……..
d.	Rated phase to earth operating voltage (rms)	....	....	....	……..
e.	Rated current (A)	....	....	....	……..
f.	Rated thermal current (A)	....	....	....	……..
g.	Rated dynamic current (A)	....	....	....	……..
h.	Cantilever withstand load (N)	....	....	....	……..
i.	Creepage distance	....	....	....	……..
j.	Angle of mounting	....	....	....	……..
k.	Thermal limits – class	....	....	....	……..

l.	Dielectric dissipation factor	....	....	....	……..
m.	Partial discharges at max operating phase-phase voltage	....	....	....	……..
n.	Insulation levels	....	....	....	……..
o.	Cross-section of drawn lead or rod	....	....		……..
o.	Seismic withstand capability	....	....	....	……...
p.	Do the bushings meet the requirements of paragraph IX-8.5 and 8.6?	....	....	....	……..
q.	Are the bushings interchangeable with any other having the same type, according EN 50458?	....	....	....	……..

50. Bushings current transformers
(Ratio, accuracy class, burden)
- HV : …………………………
…………………………
- MV : …………………………
…………………………
- LV : …………………………
…………………………

51. Are all cables which run on the autotransformer inside cable trays? : …………………………

52. Type of material of the winding conductors : …………………………

53. Type and manufacturer of Buchholz : …………………………
- Location : …………………………
- Characteristics of alarm contacts : …………………………
- Characteristics of trip contacts : …………………………

54. Type and manufacturer of oil temperature indicator. : …………………………
- Characteristics of alarm contacts and trip contacts : …………………………
- Measurements teletransmission capability : …………………………

55. Type and manufacturer of winding temperature indicator. : …………………………
- Characteristics of alarm contacts and trip contacts : …………………………
- Measurements teletransmission capability (Yes or No) : …………………………

56. Type and manufacturer of oil flow indicator. : …………………………
- Characteristics of alarm contacts and trip contacts : …………………………

57. Type and manufacturer of oil level indicator. : ……………………………
- Characteristics of alarm contacts and trip contacts : ……………………………

58. Autotransformers mass protection system
- Current transformer (ratio, burden, class) : ……………………………

59. Type and manufacturer of rapid pressure rise relay : ……………………………
- Location of installation : ……………………………
- Characteristics of alarm contacts : ……………………………

60. Type and manufacturer of on-line moisture and dissolved gas monitoring system §12.9 : ……………………………

61. Net weights and dimensions
- Transportation weight : ……………………..… kg
- Core (steel) : ……………………..… kg
- Coils (copper) : ……………………..… kg
- Tank and fittings : ……………………..… kg
- Oil : ……………………..… kg
- Total weight : ……………………..… kg
- Untanking weight : ……………………..… kg
- Active part weight : ……………………..… kg
- Overall height (including bushings) : ………………………m
- Height over tank : ………………………m
- Projected floor dimensions:
  Length : ………………………m
  Width : ………………………m
- Description of the movement system : ……………………………
  ..……………………………
- Description of the unloading and transportation way : ……………………………
  ..……………………………

62. Tests (acceptance of the specified tests) (Yes or No) : ……………………………

63. Type and manufacturer of the explosion and fire prevention system (description) : ……………………………
..……………………………
..……………………………
..……………………………

64. Type and manufacturer of the direct hot-spot temperature measurement system and number of sensors per winding (description) : ……………………………
..……………………………

....

65. Color of the autotransformer : ....

66. Corrosivity category and durability category of the autotransformer's painting, according ISO 12944 : ....

67. Describe with what the autotransformer tank will be filled for transport purposes : ....
....

68. Type of material, manufacturer and country of origin of the autotransformer core material : ....
....

69. Does the autotransformer layout follow the drawing of par.XIII? : ....

70. Does the autotransformer tank layout follow the drawings SK-883B, C and D, as well as par.XV ? : ....

71. Does the autotransformer accessories packing follow par.XX? : ....

72. Is the Condition Monitoring System according to Annex A? (If required in the Inquiry) : ....

280MVA, 400 / 157.5 / 30kV THREE-PHASE AUTOTRANSFORMERS

ATTACHMENT "B"
CAPITALIZATION OF LOSSES

INFORMATION BY SELLER

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

1. Autotransformer initial cost and losses:

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

b. No-load loss at rated voltage and principal tapping
(guaranteed value) : P_0 = ………………. kW

c. Load loss at rated load 280 MVA on HV and MV sides
(HV = MV), no load on LV side, at principal tapping
and at reference temperature 75°C, (guaranteed value) : P_{HM} = ……………… kW

d. Load loss at load 60 MVA on HV and LV sides
(HV = LV), no load on MV side, at principal tapping
and at reference temperature 75°C, (guaranteed value) : P_{HL} = ……………… kW

e. Load loss at load 60 MVA on MV and LV sides
(MV = LV), no load on HV side, at principal tapping
and at reference temperature 75°C, (guaranteed value) : P_{ML} = ……………… kW

f. Cooling loss at autotransformer no-load operation, with
only the first cooling control group in operation
(guaranteed value) : P_{C0} = ……………… kW

g. Total cooling loss, with all cooling units in operation,
excluding standby cooler (guaranteed value) : P_{CS} = ……………… kW

2. Autotransformer total ownership cost

The capitalized losses (CL) and the total cost of ownership (TCO) of the autotransformer will be calculated from the above mentioned data and the following mathematical types. As an intermediate step, the calculation of the total load loss P_k of the autotransformer is necessary, at rated load 280 MVA on HV and MV sides, rated load 60 MVA on LV side, at principal tapping and at reference temperature 75°C. The following type for this calculation is based on the method described in IEC 60076-8. In all types, all losses are expressed in kW and all costs are expressed in €.

$P_k = 0.977 \cdot P_{HM} + 0.5 \cdot (P_{HL} + P_{ML})$

Total load loss P_k = ………………… kW

$CL = 6805 \cdot (P_0 + P_{C0}) + 1467 \cdot (P_k + P_{CS} – P_{C0})$

Capitalized losses (CL) = ……………………… €

TCO = IC + CL

Total ownership cost (TCO) = ……………………… €

3. Penalty for losses excess

With regard to load and no-load losses, an autotransformer is considered as successfully inspected if the losses measured during inspection (relevant routine tests, par.X.1.3, X.1.4 and type test, par.X.2.4) do not exceed the losses guaranteed by Seller (par.VII.18), by more than the maximum accepted tolerance of 15% for no-load, load and cooling losses, as well as 10% for the total losses, according to IEC 60076-1. Also the peak efficiency index (PEI), calculated from measured values, shall not exceed the minimum T2 PEI limit (par.VII.18) with no tolerance, which is 99.770%, according to EN 50629. Otherwise the autotransformer is rejected. The measurement uncertainty is not taken into account, according to IEC 60076-19 and EN 50629.

On each successfully inspected autotransformer, 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 loss values, whereas CL' is calculated from the same mathematical type as CL and the measured loss values 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.