



February 2018

**SPECIFICATION No SS-88/6**  
**630 kVA, 30 / 0.4 kV THREE-PHASE TRANSFORMERS**  
**WITH ON-LOAD TAP CHANGER**

**I. SCOPE**

The scope of the present specification is to describe IPTO's requirements regarding design features, technical characteristics and testing of three-phase 30/0.4kV transformers rated at 630kVA. The transformers will be equipped with an on-load tap changer (OLTC).

**II. KEY WORDS**

Transformers, OLTC

**III. USE**

The transformers are installed in 400 kV substations for the transformation of the 30 kV voltage produced from 400/157.5/30 kV autotransformers to 400/230V, covering the load requirements of the substation.

**IV. SYSTEM CHARACTERISTICS**

**IV.1. 30kV NETWORK**

- |   |                  |
|---|------------------|
| 1. Nominal Voltage                          | : 30 kV          |
| 2. Maximum Operating Voltage                | : 36 kV          |
| 3. Number of phases                         | : 3              |
| 4. Number of conductors                     | : 3              |
| 5. Short Circuit level                      | : 20 kA          |
| 6. Basic Insulation level                   | : 250 KV (peak)  |
| 7. Power frequency withstand voltage (1min) | : 95 kV (r.m.s.) |
| 8. Nominal frequency                        | : 50 Hz          |
| 9. Method of earthing                       | : Unearthed      |

#### **IV.2. 400V NETWORK**

Three phases, four (4) wires (three phases plus neutral) distribution network of 230 V nominal voltage (400 V between phases), 50 Hz frequency, with grounded neutral.

#### **V. OPERATING AMBIENT CONDITIONS**

|   |                                |
|---|--------------------------------|
| Installation  | : Outdoors                     |
| Limits of ambient temperature                       | : -25 °C to + 45 °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 transformers shall conform to IEC 60076 standards, as well as EN 50588-1 standard.

#### **VII. REQUIRED DESIGN CHARACTERISTICS OF THE TRANSFORMER**

##### **1. Type**

Three-phase oil immersed transformer, suitable for outdoor installation.

##### **2. Voltage ratings and number of phase windings**

|                  |         |
|------------------|---------|
| - MV (primary)   | : 30 kV |
| - LV (secondary) | : 400 V |

##### **3. Winding connections (Vector group)**

The primary winding shall be delta-connected. The primary winding shall be of uniform insulation. The secondary winding will be star-connected with the neutral brought out through a fully insulated bushing. The secondary winding shall be of uniform insulation.

The winding connection and vector group of the transformer will be Dyn5.

##### **4. Nominal apparent power (capacity) ratings**

The nominal continuous capacity with ONAN cooling, for temperature rise limits according to par.VII.9 and for ambient conditions according to par.V, will be 630 kVA.

##### **5. Windings**

All windings of the transformer shall be constructed by copper (Cu).

## 6. Insulation levels

|                             |        |           |                 |
|-----------------------------|--------|-----------|-----------------|
| - MV terminals              | 52 kV  | LI/LIC/AC | : 250/275/95 kV |
| - MV bushings               | 52 kV  | LI/AC     | : 250/105 kV    |
| - LV terminals and bushings | 1.1 kV | LI/AC     | : 20/10 kV      |

## 7. Tappings at MV winding

At the MV winding there will be tappings for the range from -15% to +7.5% of the rated voltage with 2.5% steps. The transformer must have the following tap voltages:

| Tap Position |               | MV (V) | LV (V) |
|--------------|---------------|--------|--------|
| 1            |               | 32250  |        |
| 2            |               | 31500  |        |
| 3            | +3 steps      | 30750  |        |
| 4            | principal tap | 30000  | 400    |
| 5            | - 6 steps     | 29250  |        |
| 6            |               | 28500  |        |
| 7            |               | 27750  |        |
| 8            |               | 27000  |        |
| 9            |               | 26250  |        |
| 10           |               | 25500  |        |

The transformer will have rated power equal to 630 kVA at the whole tap position range. The maximum current tapping will be the position No.10, where both windings have maximum rated tapping current.

## 8. Short circuit withstand capability

The transformer shall be capable of withstanding under service conditions for 2 (two) seconds, on any tap-setting, three-phase, phase-to-earth and two-phase-to-earth short circuit at the terminals of LV winding, without being damaged due to excessive forces or thermal effects. The thermal and dynamic ability of the transformers to withstand short circuit shall be demonstrated by calculation or the performance of a special test, in accordance with IEC 60076-5. The short-circuit current values will be calculated at the principal tapping No.4 and at the two extreme tappings No.1 and 10.

## 9. Temperature rise limits

- 9.1 The average winding temperature rise will be up to 65 K.
- 9.2 The temperature rise at top oil level will be up to 60 K.

The limits of the temperature rise will be verified by the execution of the corresponding type test.

## **10. Over-Voltage Capability**

The transformers shall have a continuous overvoltage capability of 10% at no load and 5% at rated kVA, at nominal frequency, without damage to any part of the transformer.

## **11. Short-circuit impedance**

The short-circuit impedance at principal tap and corrected to 75°C shall be 6%, with  $\pm 10\%$  tolerance.

## **12. Limits of losses**

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

- a. The no-load loss of the transformer at rated voltage and principal tapping. The value shall not exceed 675 W with zero positive tolerance, which is the  $AA_0$  limit for 36 kV transformers with OLTC, according to EN 50588-1.
- b. The load loss of the transformer at rated current and principal tapping, corrected to 75°C. The value shall not exceed 5060 W with zero positive tolerance, which is the  $A_k$  limit for 36 kV transformers, according to EN 50588-1.

## **13. Audible noise**

The sound power level of the transformer shall not exceed the value of 54 dB(A) with zero positive tolerance.

The determination of the audible noise level and the measurement method will be in accordance with IEC 60076-10 and will be verified by the measurements of the relevant test.

## **VIII. ON – LOAD TAP – CHANGER ( OLTC )**

On-load tap changer (OLTC) for voltage regulation from -7.5% to +15% in steps of 2.5%.

The OLTC shall be on the MV (primary) winding of the transformer.

A step by step device must be incorporated in the control circuit to ensure one tap-change only, even when the control switches are held continuously in the 'ON' position. The OLTC shall be equipped with auxiliary contacts for remote position indication as well as with an operation counter.

The motor drive mechanism of the OLTC shall be fed by three (3) phase voltage 230/400V, 50Hz. The motor and the OLTC mechanism shall be protected through a circuit breaker against overload, under voltage and loss of one phase

voltage. If a sudden interruption of the current feeding the motor occurs, the switch must not stay between two positions.

All relays, switches, fuses etc., of the OLTC shall be mounted in a weather-proof control cabinet mounted on transformer. The control voltage of the OLTC will be 230V AC. The signaling will be realized by voltage-free contacts. A heat resistance shall be provided in the cabinet supplied by 230V A.C. and controlled by a thermostat.

1. Parts of the on – load tap – changer

The on – load tap changer generally shall consist of transition resistors or reactors, as well as of a combined tap selector and diverter switch. The whole will be operated by a driving mechanism (motor drive).

2. Type of the on – load tap – changer

Linear type with 10 tap positions.

Mechanical oil – immersed type or vacuum/oil.

Internally mounted in the transformer tank or externally mounted in a separate tank, attached to the transformer tank.

3. Number of tapping positions and the corresponding rated tapping voltage

Total number of tapping positions : 10 including one principal tap and +3/-6 tapping positions above/below of the principal tap.

| Tap Position |               | MV (V) | LV (V) |
|--------------|---------------|--------|--------|
| 1            |               | 32250  |        |
| 2            |               | 31500  |        |
| 3            | +3 steps      | 30750  |        |
| 4            | principal tap | 30000  | 400    |
| 5            | - 6 steps     | 29250  |        |
| 6            |               | 28500  |        |
| 7            |               | 27750  |        |
| 8            |               | 27000  |        |
| 9            |               | 26250  |        |
| 10           |               | 25500  |        |

4. Applicable Standards

IEC 60214-1 and IEC 60214-2

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

| Tap – changer Environment | Temperature |         |
|---------------------------|-------------|---------|
|                           | Minimum     | Maximum |
| Oil                       | -25°C       | 105°C   |

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

The diverter switch and the transition resistors or reactors shall be placed in their own compartment which shall be oil – tight. This compartment will lie inside or outside of the transformer tank.

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 transformer parts.

7. Oil conservator of the OLTC

- a. Regardless of whether the OLTC is of oil or vacuum type, the diverter switch and the transition resistors shall have their own conservator (oil expansion tank).
- b. The OLTC conservator shall be equipped with an oil level indicator.
- 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: Is also accepted one conservator with two (2) rooms, one for the transformer tank and one for OLTC.

8. Type of oil of the OLTC

The oil used in the OLTC compartment shall be exactly the same as the one used in the transformer tank.

9. Accessories of the OLTC 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 for winding of D connection
- b. Tapping arrangement : Linear
- c. Position of tapping in winding : MV winding
- d. Maximum rated through current :  $\geq 10$  A
- e. Rated voltage : 52 kV rms
- f. Rated power – frequency  
withstand voltage (50Hz, 1 min) : 95 kV rms
- g. Rated lightning impulse  
withstand voltage (1.2/50 $\mu$ s) : 250 KV peak
- h. Rated chopped lightning impulse  
withstand voltage (1.2/3-6 $\mu$ s) : 275 KV peak
- i. Number of electrical positions : 10
- j. Rated step voltage :  $\geq 900$  V

11. Operations under load

The OLTC shall be able to perform 500.000 operations (tap changes) without contact change, under step voltage of 750V and through current equal to the rated MV transformer winding current at the principal tap No.4.

12. 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 and enable the transformer 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 have 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. Supply voltage and frequency of the motor : 3ph, 400V AC, 50Hz with tolerances of 85% to 110%.
- c. Installation : Outside of the transformer 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 – changes accomplished.
- g. Manual operation : Operation of the tap – changer manually by a hand lever 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. The power supply voltage of the OLTC will be 230/400V AC. The control voltage will be 230V AC.

- i. Power frequency withstand voltage

: 2 kV, 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 transformer due to OLTC malfunctioning.

15. Nameplates

A. OLTC

The nameplate of the OLTC shall be included in the nameplate of the transformer 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.

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 transformer manufacturer is obliged to present to the IPTO inspector OLTC's test reports while the inspector is at the manufacturer's premises for the transformer inspection and testing.

The test reports which are to be presented shall include the following type and routine tests.

- Type tests
  - a. Temperature rise of contacts
  - b. Switching tests
  - c. Short – circuit current test
  - d. Transition impedance test
  - e. Mechanical tests
  - f. Tightness test
  - g. Dielectric tests
- 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 transformer and they are indicated in paragraph X.1.10.

## IX. BASIC EQUIPMENT OF TRANSFORMERS AND ACCESSORIES

### 1. Transformer tank

The transformer tank will be of COVER BOLTED type. The construction of the tank shall be robust and shall not permit oil leaks. The transformer tank shall be manufactured with folded sheets. The folded sheet shall be at least of 1.2 mm thick.

The tank shall be equipped with suitable lugs for lifting when it is empty.

The tank cover shall be removable (by screws) with suitable gasket. The connections of all components that are screwed on the cover or on the tank shall also be made through suitable gaskets.

The gasket material shall be weather-proof and oil-proof at temperatures up to 110°C.

All nuts and bolts of the tank cover shall have normal metric threads, according to ISO 4017 and ISO 898 respectively, withstand class 8.8.

### 2. Wheels, lifting lugs, jack bosses

The tank of the transformer shall be equipped at their longitudinal sides with four suitable jack bosses enabling the use of a lifting jack in order to place rollers under the tank or to remove the wheels.

The transformers shall be equipped with four (4) double-direction wheels, according to EN 50216-4. The wheels will be of W1 type, according to EN 50216-4. The distance between the fixing points of the wheels shall be 1070 mm.

The cover of the transformer tank shall be equipped with suitable lifting lugs, where it shall be possible to attach a steel wire rope in order to lift the whole transformer without any warping of the cover.

The lifting lugs shall be properly placed in order to ensure sufficient distance between the steel wire rope and bushings to avoid breaking of the insulators.

### **3. Earthing terminals of the tank**

The transformer tank shall be equipped with two earthing terminals of B1 type and M12 size, according to EN 50216-4. These shall be installed diagonally on the external surface of the tank wall, close to its bottom and they shall be suitable for copper conductors of 16 to 35 mm<sup>2</sup> cross-section.

### **4. Removable earthing link of the tank**

The transformer shall be equipped with a removable and flexible link made of tin plated copper sheets of at least 35 mm<sup>2</sup> total cross-section, which shall bridge the stud of the neutral bushing with the cover and the side wall of the tank. For this purpose, earthing terminals of B1 type and M12 size, according to EN 50216-4, shall be welded, one on the cover and one on the tank. The copper sheets shall be tightened with a screw made of stainless steel or brass, using two washers made of stainless steel or brass or copper.

### **5. Oil conservator tank**

The transformer must be equipped with a conservator tank to accommodate the changes in oil volume caused by the changes of the ambient temperature or the transformer load.

The conservator tank shall have suitable height so that the oil level at 20°C is at least 30 mm higher than the higher exhaust level of the MV bushing, and at 100°C no oil overflow from the expansion tank is observed. At -20°C the oil level shall be 35 mm higher from the bottom of the expansion tank.

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.

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 color.

## 6. **Bushings**

The design of bushings will be in accordance with IEC 60137 standard. The design will be also in accordance with EN 50180-1 standard for the MV bushings and with EN 50386 for the LV bushings.

The bushings of each transformer winding will be of outdoor, solid porcelain type with one end exposed in ambient air and the other end immersed in the transformer oil. The porcelain housing will comply in all relevant respects with IEC 62155.

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

|           |  | <b>MV</b>    | <b>LV, neutral</b> |
|-----------|--|--------------|--------------------|
| <b>1</b>  | Highest rated Voltage (phase to phase) ( $U_m$ ) (kV-rms)        | 52           | 1.1                |
| <b>2</b>  | Rated current ( $I_r$ )(A)                                       | 250          | 1250               |
| <b>3</b>  | Cantilever operating load (N)                                    | 1000         | 600                |
| <b>4</b>  | Creepage distance (mm)   | 1350         | 75                 |
| <b>5</b>  | Angle of mounting  | vertical     | vertical           |
| <b>6</b>  | Distance between terminals of same voltage (mm)                  | $\geq 480$   | $\geq 150$         |
| <b>7</b>  | Lightning impulse withstand voltage (kV)                         | 250          | 20                 |
| <b>8</b>  | Power frequency withstand voltage (kV)                           | 105          | 10                 |
| <b>9</b>  | Terminal material  | tinned brass | tinned copper      |
| <b>10</b> | Type according to EN 50180-1 for MV and EN 50386 for LV bushings | No.30        | No.4               |

### 6.1 **Additional characteristics of bushings**

- Bushings shall be designed for operation at ambient temperature from  $-25^{\circ}\text{C}$  to  $+45^{\circ}\text{C}$  and an altitude not exceeding 1000m.
- The maximum oil temperature under operating emergency conditions will be  $115^{\circ}\text{C}$ .
- In case of failure, it will be possible to interchange any MV or LV bushing with another, even from another manufacturer, having the same type and designation according to EN 50180-1 or EN 50386 respectively. The transformer manufacturer shall respect the exact bushing dimensions, following EN 50180-1 and EN 50386.

### 6.2 **Tests**

The transformer manufacturer is obliged to present to the IPTO inspector bushings test reports while the inspector is at the manufacturer's premises for the transformer inspection and testing.

The test reports which are to be presented shall include the following type and routine tests.

The tests will follow IEC 60137 and IEC 62155:

**A. Type tests**

1. Power – frequency voltage withstand test, wet (IEC 60137)
2. Lightning impulse voltage withstand test (IEC 60137)
3. Temperature cycle test (IEC 62155)
4. Porosity test (IEC 62155)
5. Cantilever load withstand test (IEC 60137)
6. Verification of dimensions (IEC 60137)

**B. Routine test**

- Visual inspection and dimensional check

**7. Insulating oil and paper**

The transformer insulating fluid shall be unused mineral oil of the “inhibited transformer oil (I)” class, in accordance with standard IEC 60296. Also it shall not contain PCBs, PCTs and corrosive sulphur. The only allowed inhibitors are DBPC and DBP with content within 0.30% – 0.40% in weight. The lowest cold start energizing temperature (LCSET) of the oil shall not exceed -30°C.

The conductors of all windings, as well as all connecting conductors in the tank, will be insulated by Kraft paper, made by 100% sulphate wood pulp, manufactured and tested according to IEC 60641 series of standards.

**8. Instruments – Relays and transformer protection devices**

**8.1. Buchholz relay**

An earthquake proof Buchholz relay, double-float type, must be provided and be mounted in the pipe connecting the conservator to the transformer 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 transformer, (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 transformer (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.

### **8.2. Oil thermometer**

Each transformer will be provided with an oil thermometer of dial type, measuring the transformer oil temperature at its hottest part. The thermometer will have scale -20°C to 130°C. The thermometer shall be designed and tested following EN 50216-1 and EN 50216-11 standards. The test certificates shall be presented to IPTO inspector.

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 transformer and the ambient temperatures of par.V.

### **8.3. Oil level indicator.**

The transformer 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.

One (1) make contact will be provided for annunciating a low oil level alarm, suitable for 220 V DC (~ 0.5A) voltage.

## **9. Supplementary accessories**

- Oil drain plug with sampler, according to EN 50216-4.
- Oil filling plug, according to EN 50216-4. The filling plug shall be installed on the conservator tank.

## **10. Painting requirements for the transformer**

The transformer 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  $\geq 60\mu\text{m}$  and 3 – 4 epoxy or polyurethane paint coats of total thickness  $\geq 240\mu\text{m}$ , where the finishing coat will be of polyurethane paint. The transformer shall be painted internally with a white colored oil resistant primer coat.

## **X. TESTS**

The tests will be carried out in accordance with the IEC 60076-1, 2 & 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 for each winding, each phase and each tap position.

### **1.2 Check of voltage ratio and windings connection (Vector group)**

The voltage ratio will be measured on each OLTC tapping.

### **1.3 Measurement of short circuit impedance and load losses**

The short-circuit impedance and the load loss will be measured with the tap changer on the principal tapping No.4 and on the two extreme tappings No.1 and 10. The measured values of load loss will be corrected to the reference temperature of 75°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°C, will be represented as percentage (%), referring to 630 kVA power and to rated tapping voltage, according to the IEC 60076-1 standard. 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%.

### **1.4 Measurement of no-load losses and current**

The measurement will be performed at rated tapping voltage, with the tap changer on the principal tapping No.4 and on the two extreme tappings No.1 and 10. 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 Applied voltage test (AV)**

For the LV winding test, the applied voltage will be 10 kV. The MV terminals and the transformer tank will be short – circuited and earthed.

For the MV winding test, the applied voltage will be 95 kV. The LV terminals and the transformer tank will be short – circuited and earthed.

### **1.6 Induced voltage withstand test (IVW)**

During the test a three-phase voltage will be applied to the LV terminals and an induced voltage of 60 kV phase-to-phase value will be measured at the MV terminals. The LV neutral will be earthed and the tap changer will remain on principal tapping.

### **1.7 Auxiliary wiring insulation test (AuxW)**

All auxiliary wiring, including the wiring of the OLTC motor drive, will be tested with a 1min AC voltage of 2 kV to earth.

### **1.8 Operation test on On – Load Tap Changer**

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

- a. With the transformer 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 transformer un-energized and with auxiliary voltage reduced to 85% of its rated value, one (1) complete cycle of operation.
- c. With the transformer energized at rated voltage and frequency at no load, one (1) complete cycle of operation.
- d. With the LV terminals short-circuited and rated current through the MV terminals, ten (10) cycles of tap-changer operations across the range of two steps on each side from principal tap position No.4. During this test, the tap changer will pass 20 times through the principal tap position.

### **1.9 Tightness test for the transformer tank**

Gas pressure of at least 30 kPa over the normal oil pressure will be applied for 8h in the conservator, with the transformer in assembled state. No leaks shall be observed. The pressure shall be recorded during the test with a calibrated manometer.

### **1.10 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.

## **2. Type tests**

### **2.1. Temperature rise test**

The test will be carried out in accordance with the IEC 60076-2 Standard. The purpose of the test is following:

- a. To measure the top oil temperature rise in steady – state condition, with dissipation of maximum total losses (load-losses and no-load losses). It shall not exceed 60 K.
- b. To measure the average winding temperature rise 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.

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

1. Application of a three-phase test voltage to the MV terminals, while the LV terminals are short-circuited. The tap-changer will be positioned at the maximum current tapping No.10. The measured active power will be equal to the total losses (load and no-load loss) of the transformer on tapping No.10, under rated power. The load and no-load losses will be taken from the corresponding loss measurements in par.X.1.3 and X.1.4, for tapping No.10. The test current will be above rated tapping current to the extent necessary to cover the total loss. The top oil temperature rise will be reported for rated transformer loading at tapping No.10.
2. When the top oil temperature rise has been established, the test will immediately continue with the test current reduced to rated tapping current at MV terminals. The average winding temperature rise of LV and MV windings will be reported for rated transformer loading at tapping No.10, as in previous step.

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

## **2.2. Measurement of no-load losses and current**

The measurement will be performed at the principal tapping No.4 and at 90%, 100% and 110% of rated voltage. 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%.

## **2.3. Lightning impulse test on LV terminals (LI)**

The test will be carried out using full wave lightning impulse of 20 kV. The MV terminals and the LV neutral terminal, shall be earthed directly. During the test, the oscillograms of the applied voltage shape and current flowing through the tested terminal will be recorded.

## **2.4. Determination of acoustic sound level**

The test will confirm that the transformer sound power level under rated voltage, no-load operation and at principal tap position does not exceed 54 dB(A), with zero positive tolerance.

## **3. Special tests**

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

### **3.1 Measurement of capacitance and dissipation factor**

The measurement shall be carried out for the following connections:

- a. MV - (LV+tank) earthed



- b. LV - (MV+tank) earthed
- c. (MV+LV) - tank earthed
- d. MV - LV with tank only earthed

The test voltage shall be 10kV.  
 $\tan\delta \leq 0.5\%$

### **3.2 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. MV-(LV+tank)
- b. LV-(MV+tank)
- c. (MV+LV)-tank
- d. MV-LV

The test voltage shall be 2.5kV.

### **3.3 Measurement of zero-sequence impedance**

The test will be performed at the rated frequency and between the LV line terminals and the neutral terminal, with the MV terminals open-circuited. The zero-sequence impedance will be measured with the tap changer on the principal tapping No.4 and on the two extreme tappings No.1 and 10. The measured values of zero-sequence impedance will be corrected to the reference temperature of 75°C and will be represented as percentage (%), referring to rated transformer power and to rated tapping voltage, according to the IEC 60076-1 standard.

### **3.4 Chopped wave lightning impulse test on MV terminals (LIC)**

The test will be carried out using full wave lightning impulse of 250 kV and chopped wave lightning impulse of 275 kV.

The LV terminals, including neutral terminal, shall be earthed directly.

During the test on one phase the tap changer will be on position No.1, for another phase on principal position No.4 and for the third phase on position No.10. During the test, the oscillograms of the applied voltage shape and current flowing through the tested terminal will be recorded.

### **3.5 Dissolved gas analysis (DGA)**

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

### **3.6 Insulating oil tests**

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

1. Breakdown voltage (BDV) following IEC 60156, with value  $\geq 70$  kV
2. Dielectric dissipation factor (DDF) following IEC 60247 or IEC 61620, with value  $\leq 0.005$
3. Water content following IEC 60814, with value  $\leq 40$  mg/kg
4. Inhibitor content of DBPC or DBP type following IEC 60666, with value within 0.30% – 0.40%
5. PCBs existence following IEC 61619, with negative result (not detectable,  $< 2$  mg/kg)
6. Acidity following IEC 62021-1 or -2, with value  $\leq 0.10$  mgKOH/g

## **XI. SPARE PARTS**

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

| <b><u>Item No</u></b> | <b><u>Description</u></b>   |
|-----------------------|---|
| 1                     | One MV bushing complete   |
| 2                     | One LV bushing complete   |
| 3                     | Complete set of gaskets for all bushings, covers, radiator flanges for one transformer.   |
| 4                     | Set of replacement parts for each type of part likely to be damaged upon operation of the relays, contactors, instruments, safety devices, etc. |
| 5                     | Two sets of replacement parts of the O.L.T.C. likely to be damaged during operation (complete set of contacts).                                 |

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.

## **XII. 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 transformers, which will help the technical evaluation process.
4. Technical data for the OLTC and the transformer accessories and systems.
5. Drawings showing the outline dimensions of the transformers offered and any other information deemed necessary, including terminal markings.
6. Any type test reports for the type and special tests specified in this hereby specification.

### **XIII. DATA TO BE SUPPLIED BY THE SUCCESSFUL BIDDER**

The Bidder shall furnish (3) three copies for approval and of the following:

- a) Assembled transformer outline drawing
- b) Transformers operation schematics and wiring diagrams
- c) Bushings outline drawings, including type and designation according EN 50180-1 and EN 50386.
- d) Nameplate drawing
- e) Terminal designations
- f) OLTC control system operation diagram and wiring diagram.
- g) Calculations for the thermal and dynamic ability of the transformers under short circuit, according to par.VII.7.
- h) Instruction manual covering installation operation and maintenance
- i) 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.
- j) Detailed quality control plan (QCP), incorporating quality assurance (QA) and inspection and test plan (ITP).

### **XIV. RATING PLATE**

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

- 1. Relevant Standard IEC 60076
- 2. The manufacturer's name
- 3. Serial number
- 4. Year of manufacture
- 5. Number of phases
- 6. Rated power (kVA)
- 7. Rated frequency (Hz)
- 8. Rated voltages (V or kV) at all line terminals and for all tap positions.
- 9. Rated currents (A) at all line terminals and for all tap positions.
- 10. Symbol of the windings connection
- 11. Measured short-circuit impedance in (%) at rated power, for the principal and for the two extreme tap positions (No.1, 4, 10)
- 12. Measured no-load loss at principal tapping and rated voltage
- 13. No-load loss class, according to EN 50588-1
- 14. Measured load loss at principal tapping and rated current, corrected to reference temperature 75°C.
- 15. Load loss class, according to EN 50588-1
- 16. Type of cooling.
- 17. Insulation levels of all windings
- 18. OLTC plate
- 19. Guaranteed temperature rise of top-oil at rated loading.
- 20. Guaranteed average temperature rise of windings at rated current.
- 21. Diagram of the windings configuration
- 22. Transformer total mass

- 23. Type of electrical conductor (copper)
- 24. Transformer conductor mass
- 25. Type of magnetic core material (silicon steel)
- 26. Transformer core mass
- 27. Type of transformer insulation oil (inhibited transformer oil)
- 28. Transformer oil mass

#### **XV. ECONOMIC COMPARISON OF THE OFFERS**

The economic comparison of the offers shall be based on the transformer 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 total ownership cost of the transformer 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.

#### **XVI. PACKING**

The transformer accessories must be packed inside robust, entirely closed wooden boxes of at least 20mm thickness (seaworthy packing). The above requirement does not include the bushings of the transformer.

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

**630 kVA, 30 / 0.4 kV THREE-PHASE TRANSFORMERS**  
**WITH ON-LOAD TAP CHANGER**

**ATTACHMENT "A"**

**INFORMATION BY SELLER**

1. Type of transformer (short description):  
Nominal voltage, number of phases, connections symbolism, rated power  
.....  
.....  
.....  
.....
2. Core type :.....
  - a. Flux density at rated voltage (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 630 kVA :.....
6. Transformer connection. :.....
7. Temperature rise limits : .....K for windings  
: .....K for oil
8. Losses data  
(The guaranteed losses shall be as indicated in paragraph VII.12):
  - 8.1. No load loss and exciting current at principal tap:

| <u>Voltage level</u><br>(kV) | <u>No load loss</u><br>(kW) | <u>Exciting current</u><br>(% of rated current) |
|------------------------------|-----------------------------|---|
| 27                           | .....                       | .....   |
| 30                           | .....                       | .....   |
| 33                           | .....                       | .....   |

8.2. Load loss and impedances at principal tap and reference temperature 75°C:

| <u>Load</u><br>(kVA) | <u>Load loss</u><br>(kW) | <u>Positive sequence</u><br><u>Impedance</u><br>(%) | <u>Zero sequence</u><br><u>Impedance</u><br>(%) |
|----------------------|--------------------------|---|---|
| 630                  | .....                    | .....   | .....   |

9. Sound power level (at rated power and voltage) :.....dB(A)

10. Harmonics of no-load current for principal tap:

- a. Third harmonic :.....% of no-load current
- b. Fifth harmonic :.....% of no-load current
- c. Seventh harmonic :.....% of no-load current

11. On - load tap changer (OLTC)

- a. Manufacturer and type of the OLTC : .....
- b. List of all parts of the OLTC : .....  
.....  
.....  
.....
- c. Type of the OLTC (oil or vacuum) : .....  
.....  
.....
- d. Does the OLTC includes transition resistors or reactors? : .....  
.....
- e. Number of tapping positions : .....  
.....
- f. Oil operating temperature  
Minimum : .....  
Maximum : .....
- g. Is the tap selector and resistors or reactors in their own

|     |  |         |
|-----|--|---------|
|     | oil – tight compartment?   | : ..... |
|     |  | .....   |
|     |  | .....   |
|     | h. Is the OLTC equipped with its own conservator ?                                     | : ..... |
|     | i. Is the conservator equipped with oil level indicator and breather?                  | : ..... |
|     |  | .....   |
|     | j. Does the OLTC consist of a three-phase unit, suitable for delta-connected winding ? | : ..... |
|     | k. Is the OLTC equipped with its own oil-flow relay?                                   | : ..... |
|     | - Describe where it is installed   | : ..... |
|     | - Type and manufacturer  | : ..... |
| 12. | Tapping arrangement  | : ..... |
| 13. | Position of tapping  | : ..... |
| 14. | Maximum rated through current of OLTC  | : ..... |
| 15. | Maximum rated step voltage of OLTC   | : ..... |
| 16. | Rated frequency of OLTC  | : ..... |
| 17. | Rated Voltage of OLTC  | : ..... |
| 18. | Supply voltage for the control circuits of the motor drive unit                        | : ..... |
| 19. | Power frequency withstand voltage  | : ..... |
| 20. | Lightning impulse withstand voltage  | : ..... |
| 21. | Describe the oil-flow controlled relay and where it is installed                       | : ..... |
|     |  | .....   |
|     | -Type manufacturer   | : ..... |
|     |  | .....   |
| 22. | Number of make output contacts of the oil-flow controlled relay                        | : ..... |

23. Pressure withstand value for the selector compartment : .....
24. Is the motor drive unit suitable for Local/Remote operation? : .....  
: .....
25. Is the motor drive unit equipped with emergency stop? : .....
26. Indicate installation position of the motor drive unit : .....  
: .....  
: .....
27. Supply voltage and frequency of the motor drive unit motor : .....
28. IP class protection of the motor drive unit panel acc. IEC 60529 : .....
29. 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 : .....
30. Can the motor drive unit be controlled remotely? : .....
31. Can tap position, number of operations and any alarms be displayed at a remote distance? : .....
32. Power frequency withstand voltage of the auxiliary circuits of the motor drive unit : .....
33. Warranty terms of OLTC : .....  
: .....  
: .....  
: .....



34. Transformer tank
- a. Type : .....
  - b. Material of the tank : .....
  - c. Is the transformer tank in accordance with the requirements of par.IX.1? : .....
35. Transformer 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 par. IX.5? : .....
36. Oil of the transformer
- 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? : .....
37. Bushings
- |   | MV    | LV and 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 withstand current (kA)                                     | ..... | .....          |
| g. Rated dynamic withstand current (kA)                                     | ..... | .....          |
| h. Cantilever withstand load (N)  | ..... | .....          |
| i. Creepage distance (mm)   | ..... | .....          |
| j. Power frequency withstand voltage (kV)                                   | ..... | .....          |
| k. Lightning impulse withstand voltage (kV)                                 | ..... | .....          |
| l. Indicate as to whether the bushings meet the requirements of par. IX.6.1 | ..... | .....          |
38. Type of material of the winding conductors : .....
39. Type and manufacturer of BUCHHOLZ : .....
- Location : .....
  - Characteristics of contacts : .....
40. Type and manufacturer of oil thermometer : .....
- Characteristics of contacts : .....
41. Type and manufacturer of oil level indicator : .....

- Characteristics of contacts : .....
42. Net weights and dimensions
- Core (steel) : ..... kg
  - Coils (copper) : ..... kg
  - Tank and fittings : ..... kg
  - Oil : ..... kg
  - Total weight : ..... kg
  - Overall height (including bushings): .....m
  - Projected floor dimensions:
    - Length : .....m
    - Width : .....m
  - Description of the movement system : .....  
.....
43. Tests (acceptance of the specified tests)  
(Yes or No) : .....
44. Color of the transformer : .....
45. Corrosivity category and durability category of the  
transformer's painting, according ISO 12944 : .....
46. Does the transformer accessories  
packing follow par.XVI? : .....

**630 kVA, 30 / 0.4 kV THREE-PHASE TRANSFORMERS  
WITH ON-LOAD TAP CHANGER**

**ATTACHMENT "B"**

**INFORMATION BY SELLER**

For the capitalization of losses, the following method will be used.

**1. Transformer initial cost and losses:**

a. Transformer initial cost

(The 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 630 kVA, at principal tapping and at reference temperature 75°C, (guaranteed value)

:  $P_k$  = ..... kW

**2. Transformer total ownership cost**

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

$$CL = 6805 \cdot P_0 + 907 \cdot P_k$$

Capitalized losses (CL) = ..... €

$$TCO = IC + CL$$

**Total ownership cost (TCO) = ..... €**

**3. Penalty for losses excess**

With regard to load and no-load losses, a transformer is considered as successfully inspected if the losses measured during inspection (relevant routine tests, par.X.1.3, X.1.4) do not exceed the losses guaranteed by Seller (par.VII.12), by more than the maximum accepted tolerance of 15% for no-load and load losses, as well as 10% for the total losses (sum of no-load and load losses), according to IEC 60076-1. Also the measured no-load loss shall not exceed the maximum  $AA_0$  limit for 36kV transformers (par.VII.12) with no tolerance, which is 675 W, according to EN 50588-1. Additionally the measured

load loss shall not exceed the maximum  $A_k$  limit for 36kV transformers (par.VII.12) with no tolerance, which is 5060 W, according to EN 50588-1. Otherwise the transformer is rejected. The measurement uncertainty is not taken into account, according to IEC 60076-19.

On each successfully inspected transformer, 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.