INSTRUCTION MANUAL AND TECHNICAL DOCUMENTATION

for oil-immersed distribution transformers

with off-load voltage regulation

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ABB

1 Introduction

This documentation refers to three-phase, oil-immersed, two-winding, step-down hermetic and free breathing (conservator-type) transformers.

Transformers may only be installed in well-ventilated closed rooms or places where proper cooling conditions are ensured.

Transformers may NOT operate at altitudes exceeding 1000 m above sea level unless technical specification delivered with the transformer states otherwise.

Industrial frequency 50 Hz.

This transformer meets requirements of the following standards:

IEC 60076: Power transformers

Polish Standard PN-IEC 76-1: 1988 Transformers. General Requirements.

IEC 600296: Transformer oil.

Polish Standard PN-90/C-96058: Electro-insulating oil for transformers and switchgear.

IEC 60076-7. Loading guide for oil-immersed power transformers.

Others agreed and confirmed in technical specification.

2 Technical Data

2.1 Technical Parameters of Transformers

Technical parameters of transformers are stated on the rating plate and in the factory routine test report.

2.2 Power rating

We guarantee continuous operation of transformer at full load stated on the rating plate at ambient temperature not exceeding value given in the technical specification.

2.3 High Voltage

This transformer may operate continuously at voltage exceeded by no more than 5% of rated High Voltage of tap changer position. In such a case the transformer power remains unchanged.

2.4 Frequency

Rated frequency is 50Hz or other if agreed and confirmed in technical specification.

2.5 Voltage regulation in commutable transformers

Voltage regulation is realized by means of turning the drive of the tap changer whose dial is placed on the transformer cover. Commutable transformers are equipped with two dials, one of which regulates the voltage while the other functions as an HV selector switch (for instance 10kV/20kV). Transformer must be de-energized while using any of the tap changers! Tap changer positions indicate different parts of transformer winding in operation. Position one (1) always corresponds to maximum number of winding coils in operation.

2.6 Environmental Conditions and Temperature Rise

Transformers are designed for normal operation in the following environmental conditions:

- air ambient temperature may NOT exceed value given in technical specification,
- guaranteed temperature rise (maximum temperature rise of oil and average winding temperature rise) above the ambient temperature will not exceed values stated in technical specification.

In the event that ambient temperature exceeds value defined in the technical specification, allowable temperature rise of oil and windings needs to be reduced to the same degree by means of reducing the transformer power.

2.7 Hermetically Sealed Transformers

Hermetically sealed transformers are air-tight. No conservator or air cushion guarantees that transformer oil will not come into contact with atmosphere, which brings about its accelerated deterioration. Transformers are filled with oil at the temperature of about 20°C and very low,

near-vacuum pressure. This ensures that oil will pervade transformer windings completely and no air remains in small crevices between coils. After sealing, pressure inside the transformer is equal to normal atmospheric pressure. Changes of oil temperature and volume during normal transformer operation cause either increase or decrease of internal pressure, which is absorbed by flexible corrugated walls of transformer tank.

The fins will not deform permanently if transformer is loaded in accordance with guidelines set out in IEC 60076-7.

The manufacturer guarantees correct operation of transformer, if during production process, (apart from other requirements of this technical documentation) tightness conditions will be kept as follows:

Screw torques of bars connections					
Screw size	M 8	M 10	M 12	M 14	M 16
Torque [Nm]	15	30	60	90	140

Torques for Insulators bolts							
Insulator	HV 250 A	LV 250 A	LV 630 A	LV 1000 A	LV 2000 A	LV 3150 A	LV 4500 A
Torque [Nm]	15	15	30	75	95	110200 (Pb80)	200
Rubber gasket (Spanish standard)				65	85	100	

Torques for welded bolts made from stainless steel					
Screw size	M 6	M 8	M 10	M 12	M 16
Torque [Nm]	7	15	20	30	30
Transformers ACEA – Italy (orginal gasket with insulator)		12	15		

Screws Torques for other mechanical connections (covers)		
		Torque [Nm]
Cover:	Gasket: Silicon	80
	Gasket: Nebar	90
	Gasket: Pb 80	90
Drain valve:	Type: Nw 22	100
	Type: Nw 44	150
	Type: Nw 31	130

If required transformers are equipped with an oil level indicator. Transformer may NOT be operated if oil level falls below the MIN (minimum) mark on the scale of oil level indicator. If this is the case, oil level is below the mark required for safe transformer operation. The transformer must be immediately switched off, any leaks found, sealed and more transformer oil added. Transformer oil must be poured at the ambient temperature of 20°C± 4°C through the filling orifice located on the cover.

A red pointer inside the transparent cylinder, directly connected with the float, is the only oil level indicator. Presence or lack of oil in the transparent cylinder is not decisive information on the oil level in tank (depending on conditions encountered during filling of transformer, some quantity of oil can be, but does not have to be, drawn into the cylinder).

2.8 Transformers with Conservator

In this type of transformer, a conservator (an additional dedicated tank mounted on the transformer cover) compensates for any volume changes in transformer oil, relieving radiator fins from this task. The conservator is connected with transformer tank. This connection enables flow of oil between both vessels when its volume changes. Transformer oil does not come into direct contact with the atmosphere thanks to silica-gel dehydrating breather that absorbs all moisture from air and prevents it for entering the transformer tank. A change of silica gel color from orange to light-yellow indicates its moistening. In such a case and if oiling

up occurs, silica gel should be replaced with new or regenerated silica gel. Conservator is equipped with a magnetic oil level indicator located on the side of the conservator tank. Transformer may NOT be operated if oil level falls below the MIN (minimum) mark on the scale of oil level indicator. Having identified and removed the cause of oil leakage, some oil needs to added until its level is above the MIN (minimum) mark. The transformer must be immediately switched off, any leaks found, sealed and more transformer oil added.

Oil may be poured (added) through a filling orifice on top of the conservator. Alternatively, oil may be added through the pipe connecting silica-gel dehydrator and conservator. This pipe needs to be undone prior to refilling.

2.9 Mechanical Strength of Tank

Oil-immersed transformer tanks are guaranteed to withstand without any permanent deformation internal pressure of about ±300 hPa.

2.10 Loading of Transformers

Transformers should be loaded in accordance with standards they have been designed to meet.

In particular, it is recommended to observe regulations included in the following documents:

- IEC 60076-7. Loading guide for oil immersed transformers.

2.11 Short-circuit withstand capacity

Transformers are designed and guaranteed to withstand without any damage all mechanical and thermal effects of short-circuit according to IEC60076 or Polish Standard PN-IEC60076-1.

2.12 Withstand Voltage

Transformers are designed and guaranteed to withstand without any damage all test voltages within the range specified in IEC60076 or Polish Standard PN-IEC 60076-1.

2.13 Transformer efficiency (η)

$$\eta = 1 - \frac{P_o + n^2 \cdot P_{zw}}{n \cdot S \cdot \cos\varphi + P_o + n^2 \cdot P_{zw}}$$

where :

P_o - no-load losses in kW

P_{zw} - load losses in kW

S - nominal power in kVA

n - load factor, 1 for nominal load

$\cos\varphi$ - power factor

3 Transformer Construction and Design

3.1 Core

Transformer's core is made of grain oriented, low loss magnetic cold-rolled silicon steel. Both sides of steel sheets are laminated with ceramic insulation. The core construction is optimized for cold-rolled steel properties so that best parameters for magnetic circuit are obtained, i.e. minimum no-load losses and small magnetizing power.

The core is of column-type.

3.2 Windings

Transformer's windings are made of electrolytic copper or aluminium. High voltage windings are multi-layer type. Interlayer insulation is made from cable insulating paper, prespan and transformer oil. Low voltage windings are wound with profile wire or foil insulated with diamond

dotted paper and prespan. Windings may be wound directly on the core legs or on mandrels and pressed by means of top and bottom yoke clamps.

3.3 Tap Changer

Transformer is equipped with a three-phase off-load tap changer enabling voltage regulation when the transformer is de-energized. The tap changer's drive operates synchronously on all three phases and its handle/dial is located on the transformer's top cover. Voltage regulation is realized by means of turning the tap changer's dial to a required position. Tap changer may NOT be used when the transformer is energized.

Tap changer's dial incorporates perforated ring and locking pins that ensure correct positioning (setting) of the dial after voltage regulation.

In commutable transformers there are two tap changer dials on the cover. One of them is used for selecting one or two possible high voltage (HV) settings while the other allows small-step voltage regulation.

3.4 Tank

Hermetically sealed transformers incorporate a tank with corrugated walls designed to act as radiator fins.

Free breathing transformers (conservator type) have also corrugated type tank.

Transformer tank has a sturdy design that allows for normal transportation of an oil-filled transformer without any damage resulting from vibration.

Tank's undercarriage has facilities for securing the transformer firmly in place during transportation by means of synthetic belts or ropes of high mechanical strength.

The following facilities can be found in the lower part of the tank:

- drain/sampling valve.
- sampling valve (optionally)
- undercarriage frame with bi-directional (90°) wheels (optionally) and earthing terminals.

The undercarriage frame has holes designed for pulling transformer by short distances on a smooth surface.

Pulling transformer by the bars reinforcing corrugated walls of the tank may result in damage to the tank or oil leakage.

The anticorrosion coating of transformer should be adapted to environmental conditions in which the unit will operate. Standard painting ensures protection in a non-aggressive environment. For industrial, maritime etc. environments reinforced, galvanized or other paint coatings should be ordered, determined individually.

3.5 Cover

The following facilities can be found on transformer cover:

- 2 lifting lugs for lifting the transformer or its active part
- oil level indicator pocket (in hermetically sealed transformers)
- filling orifice for filling the tank with oil (in hermetically sealed transformers)
- thermometer pocket (optional)
- DGPT-2 pocket (optional)
- connecting socket for conservator (in conservator-type transformers)
- high and low voltage bushings
- earthing terminal(s) (optional)

3.6 Conservator

The cylindrical vessel called conservator is located horizontally over the cover. In some versions, the pipe connecting conservator and the cover may be equipped with a gas-flow relay.

Located at the side of the conservator vessel is a magnetic oil level indicator showing current oil level in the transformer.

Oil filling inlet can be found at the top of conservator vessel.

It may be either tightly sealed with a cap or have a short pipe leading to a silica gel breather providing means of balancing internal and external pressure.

Conservator versions with a sealing cap only have the silica gel breather built-in and the breather's air inlet is located underneath the conservator vessel.

Optionally, conservator vessel may be equipped with a drain valve for removal of sediment or excess water.

3.7 Transformer Oil

Transformers are filled with mineral oil without PCB. Before filling oil is cleaned and dried in order to attain required electric strength. The value of breakdown voltage in a sample of treated new transformer oil should not be lower than 45kV/2.5mm in a system defined by applicable norms (for a transformer in operation, electric strength should be not lower than 35kV). If measured value of breakdown voltage is lower oil needs to be regenerated by filtering or equivalent method.

On request transformer may be filled with other types of oil agreed and confirmed in technical specification.

4 Transformer accessories and equipment

Please refer to transformer's technical specification and dimension drawing for a complete list of installed accessories and additional equipment.

4.1 Thermometer pocket

On request, transformer may be equipped with thermometer pocket allowing screwing in of contact thermometer sensor. The thermometer pocket has no connection with the tank, hence there is no oil leakage hazard after its opening. To take a measurement thermometer pocket must half-filled with transformer oil. Unused pocket must be sealed to prevent water or air from entering the transformer. If not sealed, in temperatures below 0°C expanding ice may damage the pocket.

4.2 Double contact thermometer

Thermometer is equipped with two change-over electrical contacts that may be connected to trip and alarm circuits. The change-over contacts are designed for 250V DC or AC. The respective alarm or trip circuit is closed when the pointer (hand) crosses the pre-set (user adjustable) value on the thermometer's face.

Thermometer's range is: 0°C—120°C. Thermometer probe has length of 140mm, thread $R^3/_4$ or R1 and is immersed in oil. Connection reactor of three-phase electric cable of external insulation diameter of 16 mm. Connection clamps of 6x1 - 2,5 mm^2 electric cable.

Thermometer settings:

- 95*C - alarm - after achieving this temperature the client has to analyze transformer operation conditions, reduce the load or cause additional ventilation.
- 105*C - disconnection- after achieving this temperature the transformer should be switched off immediately and overheating causes analyzed.

4.3 Safety Valve

Safety valve's rated overpressure is 0.030—0.035 MPa (0.3—0.35 at).

4.4 Buchholz Relay (in free breathing, conservator-type transformers)

Buchholz relay incorporates two floats and two contacts for alarm and trip. It is mounted on the pipe connecting transformer and the conservator.

An arrow on the relay cover must point at the conservator.

Signalling:

- gas accumulation — alarm
- internal short circuit — trip

Connector characteristics:

- voltage rating 24 – 240V AC or DC
- rated current 0.5A
- breaking capacity 2A AC or DC

4.5 Multifunction protection device.

R.I.S. is a universal multi-function protection device. Its functions include the following:

- PRESSURE:
  - Pressure switch closes/opens a circuit on pressure ranging (from 100 up to 500 mbar).
- TEMPERATURE:
  - Thermometer - visual indication of oil temperature and max. temperature reached.
  - "T2" thermostat switch (alarm) - closes/opens a circuit at a predetermined temperature level (from 30°C up to 120°C).
  - "T1" thermostat switch (stop) - closes/opens a circuit at a predetermined temperature level (from 30°C up to 120°C).
- OIL LEVEL:
  - Indicator - visual indicator of slight oil level variation.
  - Detector - visual detector of significant oil level variation through closing/opening of an electric circuit.
- GASSING:
  - Detector - closes/opens a circuit when the max. gas volume is reached (max. 170 cm^3).

It is forbidden to unscrew the upper, sealed valve without distinct cause. It poses a danger of transformer depressurization and drawing in of air to tank interior.

4.6 Auxiliary terminal box

Inside the auxiliary terminal box there is connection diagram clearly depicting how external control devices should be connected.

4.7 Pressure monitor AKM 47500 with two contacts

Recommended values of overpressure: 0.030—0.035 MPa (0.3—0.35 at).

Diameter of AKM pocket: R 3/8''.

5 Transport

Transformers are delivered to the customer fully assembled and ready for operation.

Transformers may be transported by railway, lorry or other means of transport ensuring reasonable standards.

During transport, transformers must be securely placed in vertical position and firmly fastened to prevent any displacement. Transformer's undercarriage has small pulling eyes designed for ropes or fastening belts.

6 Commissioning and start-up

6.1 Transformer survey

Upon delivery of transformer it is mandatory to perform the following:

- Visual inspection to determine any possible transport damage (cracked bushing, dented tank wall, etc.).
- Check level of transformer oil; if required, add oil through filling orifice on the cover or conservator. Added oil must be of the same type as oil already in the transformer.

- Clean all metal elements by removing anticorrosive lubricant, especially from bushing bolts and earthing terminals.
- In the event of small leakages, eliminate them by tightening appropriate screws and bolts.

6.2 Positioning the transformer for normal operation

The transformer should be mounted as follows:

- Transformer weight must be distributed evenly across all supporting points.
- All indicators should be visible or easily accessible.
- Free breathing transformers (conservator type) should be positioned in a way that the side with conservator is elevated slightly to obtain an angle of 1°÷2° between transformer base and the flooring.

6.3 Connecting the transformer and preparing for start-up

Once the transformer has been positioned in place it is necessary to:

- Secure the transformer to prevent any displacement.
- Connect earthing cables.
- Check transformer ratio in all tap changer positions. In order to do that, apply voltage 3x380V on HV side and take a series of measurements on LV side for different tap changer positions (recommended).
- Measure effective HV and LV resistances on each tap. These values should be equal (with ±5% tolerance) for all three phases (recommended).
- Put tap changer dial in the position required for normal transformer operation.
- Connect HV cables to HV bushings.
- Connect LV cables to LV bushings, perform cable connections to LV insulators, contact surfaces should be clean and smooth to ensure small connection resistance, bushing nuts should be tightened with a torque spanner with a moment:
    - M12 – 25Nm
    - M20 – 40Nm.
- Busbars and cables connected to insulators should not exert a load on insulators greater than 0,3kN.
- Supports of busbars or cables to LV insulators should ensure that a bending force over 2 kN is not exceeded during flow of shorting current,
- Check the earth electrode resistance.
- Connect leads to signaling and protection devices.
- Inspect the whole transformer with equipment.
- Perform control measurement of transformer insulation with cables at disconnected star points.
- Check correctness of choice and connection of transformer protection devices from overvoltage and short-circuit.

6.4 Transformer start-up

Before energizing the transformer, verify the following:

- whether an inspection of all devices associated with transformer operation has been done,
- whether all transformer parameters conform to local energy grid.
- apply rated voltage to the transformer HV terminals and leave the unit in an idle state (no-load) for 60 minutes. Only then transformer may be loaded up to maximum value stated on the rating plate.

- measure LV voltage (between phases and to neutral point) before and after loading. Differences between values on different phases should not be bigger then 1%.

Note! If trip function is activated in any of the protecting devices, the transformer must not be turned on again before the cause of trip activation is determined.

7 Transformer Operation and Maintenance

7.1 Operating the transformer

7.1.1. Frequency of inspections

It is imposed by power engineering regulations of the country in which the transformer operates, but the manufacturer recommends at least every 12 months.

7.1.2. Scope of a routine transformer inspection

During an inspection it is strongly recommended to pay special attention to the following points:

- indications of all meters and measuring devices,
- current oil level shown by oil level indicators,
- temperature of transformer oil indicated by the thermometer installed on the transformer cover,
- transformer loading (value of current)
- condition of auxiliary devices,
- condition of bushings,
- condition of all connections leading to protection devices as well as the condition of protection devices themselves,
- environmental conditions with special emphasis on ambient temperature,

It is also necessary to take note of:

- condition of bushing terminals,
- any abnormalities in the sound generated by the transformer
- traces of oil underneath the transformer

Note! During the inspection all applicable safety regulations must be observed.

In the case of transformers equipped with casings, the state of elements closed inside also should be checked.

Lack of tightness causing small leakage (under the condition that the indicated oil level is maintained above minimum) does not cause deterioration of parameters of oil in tank. After repairing cause of leakage there is no need for performing oil control tests.

7.1.3. Abnormal transformer operation

In the event of any damage or disturbances preventing normal transformer operation the transformer must be switched off and an emergency inspection carried out. Typical causes calling for such action are listed below:

- leakage/loss of oil,
- any clearly visible damage to the bushings,
- any easily perceptible changes in the intensity of noise generated by the transformer,
- excessive heating of connecting cables,
- increase of temperature indicated by thermometer on the cover over the allowable value of about 105°C.

7.1.4. Noise

If the noise level of a working transformer is a significant parameter in operation (e.g., transformer installed near apartments, offices, etc.), the contracting entity should determine the upper noise limit emitted by the device.

A subjective impression of high noise during transformer operation cannot be the basis of a claim. Similar units can differ in noise level, hence comparison also can be insufficient. The only reliable measurement is a measurement performed in a professional sound-proof chamber.

7.1.5. Gassing

It is a dangerous phenomenon, although occasionally occurring in transformers. It is based on slow flammable gas evolution, mainly hydrogen, as the result of partial discharge in oil or in other insulation material. A gas cushion formed in the upper part of tank causes decrease of oil level and pressure increase in tank. A systematic decrease of oil level with no occurrence of distinct leakage is characteristic. Prompt notification of such case is recommended to transformer manufacturer or specialist service.

7.2 Voltage regulation using off-load tap changer

It is necessary to make sure that in no event voltage connected to the transformer exceeds allowable value, i.e. 105% of values listed on the rating plate, for any given position of the tap changer. In order to change high voltage, the following actions should be taken, observing the sequence below:

- disconnect all cables leading to HV & LV bushings,
- earth both HV and LV windings,
- put the tap changer in required position by turning the tap changer dial on the transformer cover,
- re-start the transformer.

7.3 Untanking the transformer (removing active part from the tank)

During the warranty period the customer may not, without prior consent of the manufacturer, modify, replace or remove any of transformer parts or elements.

If any irregularities are discovered during the preliminary inspection or testing, it may become necessary to untank the transformer to determine the cause. It may only be done with manufacturer's consent.

If there is any suspicion that gasses accumulated in the transformer tank (underneath the cover) no electrical measurements may be taken. This may result in a spark and cause an explosion of accumulated gases. Measurements may be taken when the active transformer part is removed from the tank.

When untanking the transformer, the following sequence must be observed:

- disconnect all cable leading to HV&LV bushings,
- drain about ¼ of total quantity oil in the tank through the drain valve (in free breathing transformers drain all oil from conservator vessel),
- disassemble and remove cable boxes and the conservator,
- disconnect all cables leading to additional accessories, equipment and protection devices,
- undo fastening nuts and bolts on the cover,
- lift transformer active part from the tank by lugs on the cover,
- allow some time for excess oil to drain from active part and place it in a dry and clean place.

Drained oil should be stored in a clean and tightly closed container. Transformer active part must be re-immersed in oil within 8 hours. If this time is exceeded the transformer must be dried. Drying sequence lasts approximately 70 hours in temperature 80—90°C. When dried, active-part should be impregnated with oil.

7.4 Collecting Oil Samples for Test

When should oil samples be collected?

- before start-up; for free breathing transformers (conservator type),
- for periodical testing during operation (for transformers with conservator),
- in any circumstances indicating possibility of damage to the transformer and especially when any protection devices are triggered.

Hermetically sealed transformers do not require sampling in normal operation conditions. In certain circumstances, e.g. low oil temperature, sampling may cause depressurisation of tank, causing drawing inside of air containing moisture. Such an air cushion can be the cause of partial discharge and as the result - gassing.

Oil samples are to be taken only if internal damage is suspected of active part.

To collect a sample use a sampling valve at the bottom of transformer tank.

When sample is being collected it is imperative that all tools and vessels used are clean. Transformer oil is a hygroscopic substance and must be protected against contact with moisture. It is strongly recommended that oil sample is kept in a hermetically sealed container at all times.

7.5 Maintenance of unused transformers

Please note the following:

- not operated transformers should be maintained in the same way as transformers in operation,
- transformer should never be disassembled,
- check oil level at least every six months,
- carry out a visual inspection at least once a year,
- measurements of insulation level and oil tests as for transformer in operation,
- provide protection for fragile parts and elements,
- protect all metal terminals with anticorrosive lubricant,
- restrict access of unauthorized persons to the transformer.

7.6 Fire emergency

In the event of transformer fire or fire in its immediate vicinity the unit must be de-energized and appropriate emergency services notified as outlined by the law in your country. In addition to official instructions everyone is obliged to:

- join fire-fighting action using accessible equipment,
- inform emergency services about general situation at the fire site,
- try to clear all access ways leading to fire site of any obstacles that may prevent arrival of emergency services,
- upon arrival of emergency services offer your help to the commanding officer.

Apart from permanent extinguishing agents also the following manual means are used for fire protection of transformers:

- portable fire-extinguishers or carbon-dioxide extinguishing units,
- carbon-dioxide units on undercarriages,
- dry-powder extinguishers,
- sand in wooden crates or concrete circles,
- asbestos blankets.

The type and quantity of portable fire-extinguishing means is determined by the fire protection service.

7.7 Operation at 60 Hz

If a transformer of nominal 50Hz frequency is connected to a 60Hz frequency grid, then losses or shorting voltage will change in the following way:

Rated power 100%

No-load losses at 80-85%

Load losses at 100%

Impedance at 115-120%

7.8 Parallel operation of transformers

Conditions for parallel operation of transformers:

- identical vector group,
- primary and secondary no-load voltages are the same,
- comparable power ratings (power ratio not greater than 3:1),
- comparable values of short circuit voltage (difference between their average value not greater then +10%).

8 Documents delivered with the transformer

- technical parameters specified on the rating plate,
- factory tests report,
- instruction manual and technical documentation,
- dimension drawing (for non-standard transformers),
- manuals for all accessories and protection devices (if provided by respective manufacturers),
- connection diagrams for the transformer and its all elements (including auxiliary termination box, if installed).

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