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User's Manual

Operation and Maintenance for Power Transformers



OPERATION AND
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MAINTENANCE FOR POWER
TRANSFORMERS



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1 Introduction

The transformer requires less care compared with other electrical equipment. The degree of maintenance and necessary inspection for its operation depends on its capacity, on the importance within electrical system, the place of installation within the system, on the weather conditions, and the general operating conditions.

In this part of the manual the operating instructions and maintenance is supplied. Our intention is to provide the necessary assistance to the maintenance personnel to facilitate a periodic inspection of the transformer and to indicate the steps that they should follow to effect a more detailed examination of the active part in case that is required.

ATTENTION:

If this is going to be used as a spare transformer (in Stand-by), it will have to be preserved always in the best conditions. Therefore, its maintenance must be equal to the transformer in service; special care must be taken in monitoring the condition of the oil. The templates are intended to harmonize the visual impression of ABB Documentation throughout the organization, Common Look & Feel. To provide help for editors to adopt Visual Identity guidelines related to documentation presented to our customers.

2 Maintenance and lines and bus bar inspection

The maintenance and the inspection are a dangerous work; from there, beforehand a detailed program must be developed, placing special attention on the safety of the workers and of the equipment.

When working with bus bar, lines, terminal, etc., the work can only begin after confirming that these parts are not receiving any power, verifying for this that the switches are in the open position, something which can be checked with a detector for circuits. The omission of these revisions, thinking erroneously that the circuits do not have voltage can cause serious accidents.

3 Preventive maintenance program

Write down the readings from the meters or gauges that are generally installed. These readings will be very useful. If the readings are very different from the ones obtained in normal conditions, it is necessary to perform a careful revision.

In addition, pay close attention to any abnormal signs such as noise, color change or smells.

- **Transformer's temperature**

The temperature of the transformer is directly related to the life span of the insulating materials; therefore, it is necessary to pay close attention.

In the case of transformers built according to procedures ANSI, the maximum temperature permitted for oil is of 90°C and the maximum temperature of the hottest point is 110°C.

- **Inspection of oil volume**

The volume of the oil has to be verified from the point of view of the insulation and from the refrigeration.

If the oil level fluctuates notoriously in relationship to the temperature, the cause must be determined for proper repair.

- **Noise**

In some instances some abnormal noise can be perceived, when you or the operators are being familiarized with the noise that the transformer produces during its normal operation, which can help to discover some defects. The following are the possible causes of abnormal noise:

- a) Resonance of the box and of the radiators due to abnormal changes in the frequency of the source of current,
- b) Defect in the adjustment mechanism of the cores,
- c) A defect in the central structure, (as loosening of the core) is possible that the tightening screws of the clamps have loosen up,
- d) Loosening of the grounding plates, and
- e) Abnormal noise by static discharge, due to lacking grounding plates or poor grounding.

These noises can be detected from outside the tank, even though they will not be very loud.

- **Loosening of the fixing pieces and the valves**

When grounding terminals are found to be loose, de-energize the transformer and tighten them immediately. The screws of the foundations that are subject to large loads must be tighten firmly to avoid the displacement of the transformer.

In some instances the valves are loosened due to vibrations, tight them again.

- **Oil leaks**

Oil leaks can be caused by the deterioration of some gaskets or they are in the wrong position; it takes some time to discover them, check carefully the valves and the gaskets. If there are any defects that could cause a leak, report it to ABB.

4 Periodicity of the inspections

The table 1 that appears below shows the frequency that the transformer must be checked.

No	Pieces to survey	Periodicity	Observations
1	Thermometers	once per year	
2	Accessory with alarm contacts and/or shut off	once per year	Verify the operation conditions of the contacts and measure the insulation resistance of the circuit
3	Cooling fans	once per year	If an anomaly is found
4	Conservator	once every five years	
5	Insulation resistance of the winding	once per year	When a sharp change after years of use is noted or when a change in comparison with data registered in previous tests.
6	Measurement of the tan Δ	Once in three years	just as the point 5.
7	Oil's breakdown value.	once per year	
8	Value of acidity of the oil.	once per year	
9	Test of the functioning of the oil.	Check if there is any abnormality noted in the tests of items 5 to the 8.	Take two liters of oil and check them according to ASTM D3487
10	Filtered insulating oil	Check if there is any abnormality noted in the tests of items 5 to the 8.	
11	Inside Components .	once every seven years	

Table 1. Periodicity of the inspections

5 Maintenance procedures for the insulating oil

To maintain the transformer in perfect operating conditions, keep in mind the previous items, also about the routine operation and not forgetting to give the proper treatment when some change in the service conditions is noted. It is necessary also to de-energize the transformer regularly and conduct a meticulous inspection.

With this routine and with regular inspection, the degree of deterioration will be minimized. Since a transformer is made of many parts, such as the insulating oil, the cooling equipment, etc. must be checked permanently. Oil in addition to serving as insulating means serves to transfer the heat generated in the windings and the core

toward the walls of the tank and the radiators. Because of this, it is required that it complies with the following characteristics:

- High dielectric breakdown
- Low viscosity
- Well refined and free of materials that they may corrode the metallic parts
- Be free of moisture and polar ionic or colloidal contaminants
- To have a low pour point
- Low flash point.

The manufacturing techniques for transformers and their reliability have been improved to such degree that the internal inspection is almost unnecessary; currently the maintenance is limited almost exclusively to the maintenance of the oil to prevent its deterioration:

5.1 Deterioration of the insulating oil

The insulating oil deteriorates gradually with use. The causes are the absorption of the moisture from the air and foreign particles that get into the oil and start to cause oxidation. Oil is oxidized by the contact with the air and this process is accelerated by the increase in the temperature in the transformer and by the contact with metals such as copper, iron, etc.

In addition, the oil suffers a series of chemical reactions such as the decomposition and the polymerization that produces particles that are not dissolved in oil and that are collected in the coil and windings. These particles are called sediments. The sediments do not affect directly the dielectric breakdown, but the deposits that are formed on the winding hinder its normal refrigeration.

5.2 Preventing the deterioration of the oil

Due to the fact that the deterioration of the oil is caused generally by the oxidation, the method to prevent consists of reducing to a minimum possible its contact surface with the air. That is why a conservator tank is used. Moisture or humidity also accelerates the deterioration of the oil. To avoid this it must be used a dehydrating breather. The ideal method is the one that uses a nitrogen layer or a membrane on the surface of the oil to avoid that the oil be in direct contact with the air.

Dielectric oil is active under certain light conditions, heat and heavy metal ions, to produce free radicals that cause self-oxidation. To avoid this phenomenon, use additives that stop any oxidation.

5.3 Evaluation of the deterioration of dielectric oil

The methods to determine deterioration of dielectric oil are those that measure the degree of oxidation, the specific density, the superficial tension. In addition, it is common

practice to measure the dielectric breakdown, it is recommended to make an objective analysis of all these methods.

6 Maintenance and inspection of the bushings

6.1 Routine inspection

- Excessive local heating:

Pay attention to the clamping section of the terminals. It is convenient to paint this section with heat indicating paint.

- Pollution:

When there is much dust and salt, a clean up must be performed and to do so, the transformer must be place out of service and use water, ammonia or carbon tetrachloride. If they are very dirty, use concentrated hydrochloric acid diluted 40 or more times in water.

The solution should not be in contact with any metallic part; after the cleaning the porcelain parts, these must be neutralized with water that contains sodium bicarbonate in a proportion of 30 grams by liter. As long as it uses a chemical solution, make sure of washing it after with fresh water, so that no strange elements are left.

In systems in which will be difficult to stop the operation of the transformer for cleaning, or in zones where there are many damages by the dust or the salt, it is being using recently a washing method designated "of hot line". It is a method to wash the equipment without stopping its operation, and there are 2 or 3 forms of doing it. In any case, it must be verified the degree of dust and salt, the quality of the water to wash and the method of waterproofing when the cleaning is done.

- Mechanical damages:

Check if there are any damages or oil leaks in the bushings.

6.2 Regular inspection (Once every two years).

- Evaluation of the deterioration of the insulation:

The methods to detect the deterioration of the insulation are the measurement of the insulation resistance and $\tan \Delta$

The measurement of the insulation resistance in the bushings is not simple, since the bushing and the winding of the transformer should be independent; nevertheless, the measurement must be made the best way possible.

The measurement of the $\tan \Delta$ is also difficult, since the bushings should be separated from the transformer in most cases.

The evaluation of the result of the measurement should not depend solely on the absolute values obtained, but on the values obtained each year and from the variation among them. If there are large discrepancies in the values, special attention is necessary.

When the insulation resistance is superior to 1000 MΩ at normal temperatures, it can be considered as good condition, but the value of the tan also must be taken into consideration for the evaluation.

6.3 Inspection due to excessive partial heatings

The excessive heating of the terminals in most cases is due to loosening. If this condition is observed, eliminate the dust or dirt from the parts from contact and tighten firmly.

6.4 Local damages inspection (fissures) on the bushings

The cleaning of the bushings must be done according to what was mentioned. If the damages are very serious it must be replaced with new ones.

6.5 Inspection for oil leaks

Check the various pieces of the bushings to see if there is any oil leaks. If oil is leaking through the gasket, tighten it or replace it. If there are bushings of immersed in oil type and the oil leak is through other part of the bushing, report it to the manufacturer.

6.6 Storage

Keep the bushings in a vertical position and in a dry place. It is recommended to keep them in their original packaging.

7 Maintenance and inspection of the cooling equipment

The cooling equipment is the most important part in the normal daily operation of a transformer. It is necessary a special care for its maintenance and inspection, since any abnormality can reduce the useful life of the transformer or cause serious defects.

7.1 Self – cooling type radiator

Check oil leaks from the upper-ends of the radiator and the welded parts of the panel or from the pipe. If there are any sediments accumulated in the radiators' elements or in the pipe, the flow of oil is hindered and the temperature drops. For this reason, check by hand if these parts have the adequate temperature. If the radiators are detachable, check that the valves are open correctly.

8 Maintenance and inspection of the thermometers

It is important to check the temperature of the transformer in service, since this indicates the conditions of operation. The internal conditions and the normality of the interior, therefore, the indicators that measure the temperature should be checked and be maintained in good conditions, so that they indicate correctly the temperature.

8.1 Dial type thermometer

This is a form of pressure measuring device with a bulb that contains a special liquid or sealed gas. It is connected with a very fine pipe to move the needle by expansion and contraction of the fluid; it must be verified comparing it with a normal thermometer once per year or more often.

Also, it must be checked carefully that it is free of rust in the inside, that water won't get in, that the needle moves adequately and that the alarm contacts operate correctly.

If the crystal is blurred by moisture that gets inside, remove the lid from the crystal and change the seal.

After many years of use, the pipe of Bourdon wears out, the same as the sprocket and the support, leading to wrong readings; also the movable indicating parts may fall because of blows or vibrations. The guiding pipeline generally is double and the connection with the measuring device is separated or is broken easily. Therefore, it is necessary a careful handling of the dial type thermometer, if it is to be removed during the inspection of the transformer.

Check that the alarm contacts have been made adequately.

9 Maintenance and inspection of oil level gauge

The gauge is placed outside the conservator and it is of simple construction; it shows the level of the oil directly, being able to see it from the outside. Pay attention to any oil leak that may be visible.

When the crystal is dirty, you can wipe it off with a rag.

The oil meter is resistant to damages and to inaccurate readings, compared with older models of oil level type L and type U.

9.1 Oil level gauge dial type

In this gauge, the revolving axle has on one end a floatation device that supports an arm connected to the gauge and on the other extreme a magnet to make to the rotor turn and to allow an upward and downward movement of the floatation device. When the level of the oil changes, this triggers the support arm that makes the magnet turn in the other extreme, and at the same time it triggers the rotor through the division wall that it is outside the gauge. The needle indicates the oil level.

The gauge needs the same maintenance that any ordinary instrument; furthermore, as it comes with a metallic floating device. It requires close attention when there is an

inaccurate reading due to any leakage of oil into the flotation device, or by vibrations, and above all, when it has been in used for a long time.

10 Maintenance and inspection of the buchholz relay

This relay is made to protect the oil immersed transformer against internal defects. It is attached to the connection pipe between the tank of the transformer and the conservator.

The operation of the relay is divided into a first phase (minor defects) and a second phase (for severe defects); the first is used for the alarm, and the second for the shut down of the transformer.

Its structure presents two flotation devices, one in the upper part and other in the lower part of a steel box (oil chamber) and they are fixed in such a way that each floatation device can turn, being their rotation center the support beam or axle.

Each floatation device has a switch and the contacts are closed when the floatation device turns. If the organic structural materials of the transformer are burnt or produce a gas caused by a small flash over, this will remain in the internal upper part of the box. When the volume of the gas surpasses the fixed volume (approximately 150 to 250 cc) the floatation device of the first low phase and the contacts are closed, triggering off the alarm system.

The lower floatation device that is for the second phase closes the contacts and sets off the alarm system, or turns off the circuit switch when an arch is originated in the interior of the transformer and gas and oil vapors are produced quickly, forcing the movement of the oil. Also, if the oil level drops below the permissible minimum level of the conservator, the alarm system goes off.

On one side of the box of the Buchholz relay, there is an inspection window that allows to observe the volume and the color of the gas produced, and to extract samples to evaluate the cause and the degree of the failure.

The modern Buchholz relay comes with micro-interrupter magnetic contacts. Also, today there is a whole array of relays with mercury contacts.

The mercury contacts should be handled with extreme care, since they can be broken when there are vibrations. As a routine, examine for oil leaks and the gas production from the relay. If gas is found, take a sample and have it analyzed; also, verify the oil level in the conservator.

Clean the crystal from the inspection window, check the interior and verify if the floatation device is moving freely, with the support arm as its rotation center to regular intervals.

The relay can operate incorrectly when the float is submerged in oil, when the support shaft of the floatation device is left out from the joint or there is an oil leak.

11 Maintenance and inspection of the overpressure valves

The overpressure relief valve with contact alarm triggers the alarm when the needle of the switch moves. It is placed by making contact with the expansion plate; the adjustment spring and the contacts of the micro-switch are in relation with the elevator that is related at the same time with the interrupter's needle.

When there is an accident, the internal pressure increases and pushes the valve out, making the needle of the switch move, and then it pushes and bends the expansion plate. When the pressure reaches a certain limit, the expansion plate is broken and the pressure is released, closing (shutting off) the contacts of the micro-switch, that are in the step up that is related to the needle of the switch, and the alarm sounds.

Verify there is no oil leak or air coming out from the device.

12 Maintenance and inspection of the silica gel breathers

These devices are made to eliminate any moisture and dust that enters the transformers, with the air flow resulting from the fluctuation in temperature of the oil from the transformer; it is placed between the air duct of the transformer and the atmosphere.

It is formed by a deposit of a dehydrating agent and oil, as well as the attaching metal parts for its fixture. The gasket must be checked to see if it is secured, so it will not allow air from entering the transformer by any other space other than the vent hole. Also, check the oil level of the deposit is not below the pre-established level.

If the dehydrating agent becomes impregnated with oil, it is because there is too much oil in the deposit, or because there is an internal failure which cause must be detected. Silicon gelatin is used as the dehydrating agent.

Generally, it is dyed blue with cobalt chloride, and when the moisture absorption reaches a 30 or 40 %, the color changes from blue to pink. In this case, the silicon gelatin must be replaced or dried before reusing it. To regenerate the silicon gelatin, place the silicon gelatin in a bucket or in a clean pot and shake it while it is heated up at a temperature of 100 to 140 °C. Continue heating it until the color changes from rose to blue, or spread the wet silicon gelatin in a container, such as a filter box for 4 or 5 hours, maintaining the temperature between 100 and 140 °C.

13 Maintenance and inspection of gaskets

13.1 Installation of gaskets

When using a gasket follow the instructions supplied by the manufacturer, but in case that are not supplied, the following instructions can be followed for general cases. For the gaskets on the curbed surface of the common transformer, cork or nitrile is used, even though the cork no longer is employed. For some unions, special lead or asbestos gaskets or O rings are used; if the type of gasket is indicated, it must be used following the instructions.

13.2 Methods of joining or connecting gaskets

It is better to use the gasket without a joint, but this can not be avoided when the gasket is too large. There are round gaskets, square, rectangular and oval-shaped, but in any case try to join the gaskets by using a flat portion of the gasket. The part that overlaps must measure more than 50 mm and must apply an adhesive to the union.

When using an element or a component to seal, make sure of selecting the material adapted for the gasket; apply a thin layer and let it dry with air and then place the gasket.

13.3 Work instructions

To remove corrosion, nitrile, oil or the grease, use a wire brush, thinner and alcohol.

Apply the adhesive only to the side of the gasket and use only the necessary amount to attach it to its place.

If the gas or oil leak is not stopped after correct adjustment, the gasket will have to be replaced with a new one.

A gasket with low elasticity such as lead type must always be changed with a new. Do not use the old one again.

14 How to detect a leak?

When the leak is below the oil level, wash first with thinner or alcohol the affected part, and once the dust or the cement has been eliminated, the place where the leak is located, it will appear clearly as a black stain.

When the leak is above the oil level, load the nitrogen gas to an appropriate pressure (approximately 0.3 to 0.4 Kg/cm₂), place a soapy solution on the suspected part of the gasket. If there is a leak, bubbles will be formed. Be careful not to permit the operation of the pressure exhaust pipe during this operation.

- Treatment of tank leaks.

If the leak is on the tank that contains oil, must be repaired by welding, make sure that the heat from the welding is not going to produce an explosive gas mixture. (There is no need to take any cautionary steps in the case of nonflammable oil).

If the leak is some 70-mm or more above the oil level and if the thickness of the wall of the tank is greater than 6 mm, there will not be danger of combustion, since the oil will cool the heat of the welding.

If the part of the leak is above the oil level, place nitrogen gas in the interior of the tank to prevent a fire.

If the thickness of the wall of the tank is less than 4.5 mm, place a metal piece on top of the part of the leak and weld it. It is better if there is no oil in the place of the repair.

The simplest way of repairing a small leak orifice is to caulk it carefully with a chisel.

Do not cover the small orifice of the leak with caulk or with painting, since it will not last for long.

Do not repair a leak orifice on the steel tank by welding or caulking it. The part of the steel box will have to be replaced. When it is not possible to puncture a hole in the place of the leak, tap and introduce a stopper impregnated in shellac or other component.

If a leak is found on an important piece of the equipment, consult with the manufacturer the adequate steps to take.

15 Failures and countermeasures

15.1 Causes of the failure

To track the cause of the failure is the first step to formulate its solution. The origin of the defects is not simple. Generally, it is the combination of many factors that can be classified in the following way:

- **Imperfection on the specifications**

- Mistake in the selection of the type of insulation.
- Not appropriate capacity.
- Lack of attention to the conditions in the place of installation (dampness, temperature, dangerous gases, etc)

- **Imperfection on the facilities**

- Wrong installation.
- Wrong capacity and protection range of lightning rods
- Switch and relay for protection is wrong.

- **Imperfections on the operation and maintenance of the equipment**

- External conducting parts loose and heating up of the same.
- Deterioration of the insulating oil
- Excessive load or mistakes in the connection of the cables.
- Mistake in the operation, and carelessness in the arrangement of the protection circuits.

- Insufficient inspection of the gaskets and valves.
- Poor maintenance of the accessories.
- Abnormal voltage
- Normal wear and tear
- Natural disasters

15.2 Types of failures

The failures produced by the causes mentioned above, create secondary failures and of a third type, hindering their tracking. However, the operating conditions in the moment of the failure, the inspection records of the relays of protection of the various parts, as well as the maintenance and the regular inspection, will help to detect the cause in many occasions.

The defects of a transformer can be classified in the following way:

- **Internal failures of the transformer: in core and coil**
 - Dielectric interruption
 - Rupture and twist of the winding
 - Mistake on the grounding
 - Open connection of tap changer
 - Insulating oil
- **External defects of the transformer: In the tank**
 - Due to oil leaks in the gasket, valve, or weld cord
 - Due to the bushings of the breathers, over pressure valve, thermometers, oil level gauge, etc.
 - Defects on the forced cooling fans, Buchholz Relay, exit of the current transformers of the bushings, etc.

15.3 Discovery of the failures

It is unnecessary to say that the sooner a failure is detected, the better for the transformer, and it requires a careful and detailed maintenance and inspection; there are procedures made for the regular inspection and of routine. By means of this inspection a failure can be detected before it becomes serious, and reduce any damage in whatever possible. Some defects are caused by reasons beyond human control. Such as:

- **Sudden failures**

Most of the dielectric interruptions occur suddenly, especially due to lightning or to an abnormal tension, causing a direct failure.

Excessive current by an external short circuit or by a mechanical hit also happen suddenly. Disturbances by earthquakes and fires can accidentally damage the transformer.

- **Defects that develop slowly**

Sudden defects are related generally to totally external or foreign factors to the transformer of such form that it is outside of our scope the power to foresee them and to prepare us to face these.

The objective of our maintenance and inspection is to discover the defects that occur and that may develop slowly. These defects are the following:

-Deformation of the insulation materials and of the windings, due to mechanical blows caused by an external short circuit. The transformer generally is designed and is manufactured to resist the heat and the mechanical blows. However, if it is exposed to frequent and intensive mechanical blows, even a small deformation can be converted into a serious internal defect.

- Insulation of the core. There can be poor insulation between the sheets of the core, between the tightening screw of the core and the insulation pipe, etc. The poor insulation cause a short circuit in the magnetic flow, producing a constant short circuit current flow in this place and generating excessive heating up which can lead to serious defects.

- Poor insulation due to a harsh operational condition such as excessive load. According to what was mentioned in the instruction manual, the insulation of the transformer deteriorates by the increase in the temperature and this deterioration over the years worsens and is converted into a serious failure when the transformer suffers an excessive load.

-Deterioration of the insulation materials such as oil, bushings, etc. due to moisture absorption, to oxidation and to formation of a partial discharge, etc.

-Deterioration of the external insulation of the transformer due to wind, snow, salt and dust. This can be prevented with the correct inspection and maintenance.

-Defects in the accessories, oil leak, gas leak, etc.

15.4 Internal defects of the transformer

a) Defects in the winding

-Short circuits

There are short circuits between the turns, between the phases and between the windings. Most short circuits failures are caused by abnormal tensions on the surge arresters and others because of the deterioration of the insulation oil and to the penetration of rain. Also, some short circuits are caused by the deterioration because of heat, caused by an electromagnetic mechanical force or by an abnormal excessive load. Generally, as secondary effect, internal short circuits cause serious deformations to the windings.

-Breakage of the terminals of the winding

The terminals of the spooled suffer damages by an excess of current (external short circuit, etc) or by a lighting strike. Also, the short circuit accidents of the system that accumulate, cause damages on the supports of the windings, by their repetitive mechanical destructive force, that finally break the terminals.

- Short circuit to ground.

The impulse voltage or the deterioration of the insulation can cause a short circuit to the grounding of the winding or of its terminal to the core or to the tank.

The mentioned defects can be detected easily through an external diagnosis or an electrical monitoring.

b) Defects in the core

There are defects due to poor insulation of the tightening screws of the core, or an oil-cooling duct obstructed, that cause excessive heating of the core. The defects on the core develop slowly. The insulation and the poor grounding contact already mentioned, cause a partial short circuit current, a deterioration of the oil of the insulation materials in their surroundings, which gradually are converted into serious failures.

A poor or loose tightening between the core and the clamps of the windings can cause damaging vibrations.

15.5 How to detect internal failures?

Use the different relays that the transformer has to detect and be protected of failures.

Next you can find which parts are used to protect the transformer from internal failures:

- Those devices that are attached directly to the transformer, and detect failures mechanically: Buchholz Relay, pressure rise relay, pressure relief device.
- Those devices that are indirectly joined to the control cabinet which detect failures electrically: Differential Relay, overcurrent relay, ground current relay.



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