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A STUDY ON COOLING SYSTEM FOR TRANSFORMERS

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Abstract – *This paper presents the various cooling methods adopted to reduce the heat generated during the functioning of transformer. The efficient operation of transformer depends on reducing the heat generated to the specified level during operation. The different methods of colling the transformer is to be studied in detail. The various oils used for cooling are to be discussed.*

***Key Words*: Transformer, Coolant, AN, AF, ONAN, ONAF, OFAF, ONWF…**

1. INTRODUCTION

Power transformers are vital components for electricity supply system. The transformer converts one voltage level to another voltage level. During this process of energy transfer, losses occur in the winding of the transformer. These losses converted as heat that can burn the winding of the transformer. To overcome these problems cooling is necessary. Major failure of transformer occurs due to over-heating of the transformer during its working. The main source of heat generation in transformers are caused by copper loss in the windings and core (I^2R losses). Heat is also generated due to internal losses like hysteresis, eddy current, high ambient temperature and solar radiation. Removing and decreasing the heat of the transformer is useful for the efficient working, longer life and higher efficiency of the transformer. The various coolants that are used to reduce the temperature of the transformer are air, synthetic oils, mineral oils etc., If the heat generated in the transformer is not properly dissipated, there is a rise in temperature continuously which damage the insulation and hence the transformer. A transformer operating at just 10°C above its rating will reduce the life of the transformer by 50%.

2.HEAT TRANSFER METHOD

Heat transfer mechanism in transformers takes place by three modes namely conduction, convection and radiation. The heat from the core and winding, due to the presence of insulation, heat cannot transfer directly to the oil. The heat from the coil flows through several layers of insulation before reaching the coolant. The heat transfer from the transformer tank and radiators to the environment occurs through radiation and convection effects. More the surface area, more will be the heat transfer by radiation. The heat transfer by radiation depends on the surface emissivity factor. For tanks and radiators painted in grey, the surface emissivity is 0.95. In an oil-immersed transformer, heat from the core and the winding is transferred to oil by convection. As the oil temperature increases, the density of the oil drops. The hot oil moves to the top and is replaced by the colder oil from the bottom. This results in a continuous circulation of oil inside the oil tank naturally and transfers the heat to the external environment through the walls of the tank and radiators.

3.COOLANTS

The primary function of transformer oil or coolants are to insulate and cool the transformer. It should therefore have high dielectric strength, thermal conductivity and chemical stability and should keep these properties when held at high temperatures for extended periods. The heat dissipated by the core and the winding is removed using coolants. The choice of coolant depends on the method of transformer cooling, operational environment, voltages and several other factors. The most commonly used coolants for transformer cooling are

1. Mineral oil or transformer oil
2. Askarels
3. High temperature hydrocarbons
4. Silicones
5. Esters
6. Sulphur hexafluoride

3.1 MINERAL OIL OR TRANSFORMER OIL

Apart from enhancing the dielectric strength of coil insulations, transformer oil serves an important purpose of cooling the transformer core and coil. Transformer oil is made from paraffin, naphthalene, aromatics and olefins. Transformer oil is commonly known as hydrocarbon mineral oil. It picks up the heat from the coil and windings and passes it to the tank surface and thus to the environment.

3.2 ASKARELS

Askarels are used in transformers operating in places where flammability is a major concern. Askarels are originally a compound known as polychlorinated biphenyls. Although the compound is inflammable, it can be decomposed by electric arc or fire and may result in formation of toxic materials like furans and dioxins. These compounds are harmful to the environment.

3.3 HIGH TEMPRATURE HYDROCRBONS

High temperature hydrocarbons are also known as high molecular weight mineral oil. It is a less inflammable compound and is used as an alternative to askarels in distribution transformers. The biggest disadvantage is its high cost and its diminished heat extracting capability when compared to mineral oil or askarels.

3.4 SILICONES

Silicones are also used as coolant in transformers as they are less flammable. The most commonly used silicone compound is polydimethylsiloxane.

3.5 ESTERS

Synthetic esters are commonly used as transformer coolants in many European countries. They have a high-temperature capability and are biodegradable. But they are expensive than hydrocarbon mineral oil.

3.6 SULPHUR HEXAFLUORIDE

In places where transformer oil or any other compounds cannot be used for environmental reasons, pressurized sulfur hexafluoride can be used. It is relatively inert gas and has higher dielectric strength than air. It is used in high voltage transformers where oil cannot be used.

4. COOLING METHODS FOR TRANSFORMER

Oil and air are the primary cooling materials used in a transformer. Oil serves the dual purpose as an insulator as well as a coolant. In oil immersed transformers, hot oil is circulated through radiators or other heat exchangers which transfers the heat to surrounding air or water which serves as the cooling medium. In small distribution transformers, fins or corrugations are made over the tank surface to increase the surface area to provide enough cooling surface. The following are the possible ways to transfer heat from inside of transformers to the environment.

1. By natural air circulation.
2. By forced air circulation using fans.
3. By natural oil circulation due to buoyancy
4. Forced oil circulation using pumps.
5. Heat exchangers with forced water circulation.

5.TRANSFORMER COOLING ARRANGEMENTS

Transformers are broadly divided into two types

1. Dry type transformer
2. Oil immersed type transformer

Based on cooling method the dry type transformers are further sub-divided as

1. Air natural (AN)
2. Air blast or forced (AF)

Based on the cooling methods oil immersed type transformer are further subdivided as

1. Oil Natural Air Natural (ONAN) or OA cooling
2. Oil Natural Air Forced (ONAF) or FA cooling
3. Oil Forced Air Forced (OFAF) or FOA cooling
4. Oil Forced Water Forced (OFWF) cooling
5. Oil Directed Air Forced (ODAF)/ Oil Directed Water Forced (ODWF)

5.1AIR NATURALS (AN)

In air natural method, if the temperature of the transformer rises higher compared to the temperature of the surrounding air, the heated air is cooled by the circulation of natural air. This method is called as self-cooled method and is used for cooling the smaller output transformer rating up to 1.5 MVA.

5.2 AIR BLAST OR AIR FORCED (AF)

In this method, the temperature of the transformer decreased by the forced air circulation. The high velocity of air is forced on the core and the windings of the transformer by fans and blowers. The fans and blowers are switched ON automatically if the alarm of the standard safe level of the transformer is activated. This method is used for transformers rating up to 15MVA.

5.3 OIL NATURAL AIR NATURAL (ONAN)

In lower capacity oil-immersed transformers, the heat generated is directly transferred to the environment without any additional cooling arrangements. It needs a larger heat transfer surface in the form of radiators or tubes mounted directly on the tank. The radiator is mounted separately in the form of radiator banks supported from the ground. In Oil Natural and Air Natural transformers, oil circulates itself due to gravitational buoyancy. The heat generated in the coil and the core is passed to the oil by convection heat transfer. The oil heats up and its specific gravity drops. This causes the hot oil to flow to the surface and cooler oil with higher specific gravity flows downwards. The heat from the oil is then transferred to the transformer surface and then transfers it to the surrounding air. The cooling efficiency can be improved by installing additional cooling tubes and radiators. Since the heat transfer from the active part to the oil and from oil to the atmospheric air is by natural means. This transformer cooling method is known as Oil Natural Air Natural cooling. The transformer in which this method of cooling is implemented is called as ONAN Transformer

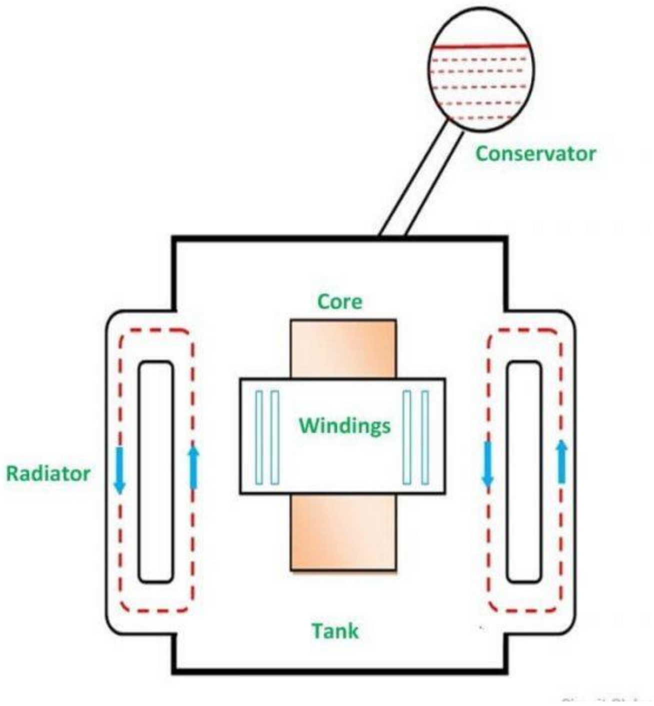

Fig.1 ONAN

5.4 OIL NATURAL AIR FORCED (ONAF)

As the capacity of transformer increases, the heat generated in the transformer also increases. To enhance the heat transfer between the radiators and the surrounding air, fans are used to blow air in to the radiators. The heat transfer coefficient is significantly increased. In ONAF transformers, the circulation of oil inside the transformer tank occurs in the same way as in the ONAN transformers. But the only difference is that additional fans are used to force air over the cooling surface to increase the cooling effect. The cooling fans are installed either at the bottom or at the top of the radiators. The temperature of the oil at the top of the radiator will be higher than that at the bottom. While mounting fans on the radiator, their operation should not produce appreciable vibrations on the transformer.

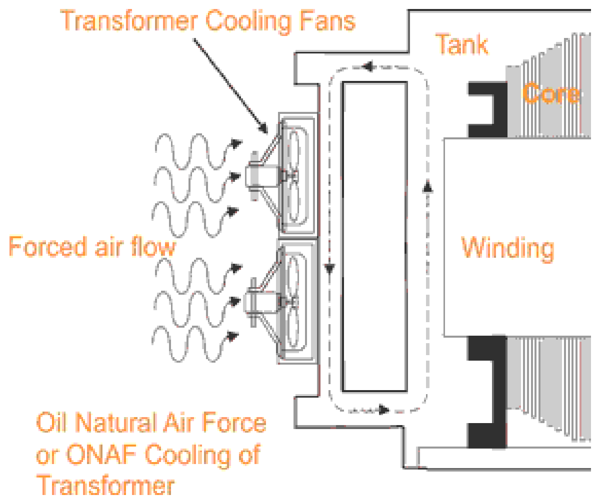

Fig.2 ONAF

5.5 OIL FORCED AIR FORCED (OFAF)

In ONAN and ONAF transformers, the oil flow inside the transformer is governed by natural factors. To improve the circulation and heat transfer rate, an external pump is used in high-capacity transformers. The pump continuously circulates the oil between the radiators and the tank. Fans are fitted to the radiator to ensure improved airflow and enhance cooling.

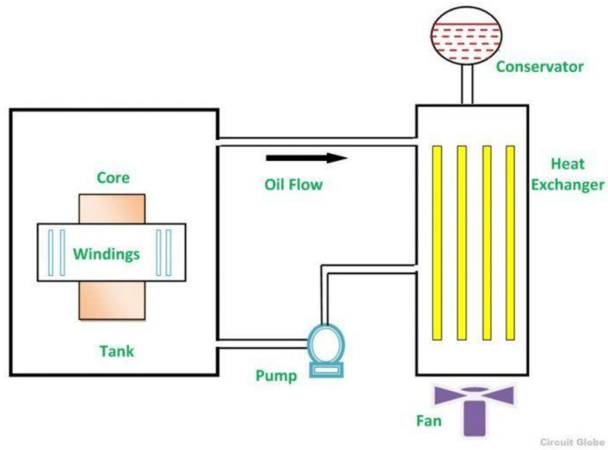

Fig.3 OFAF

5.6 OIL FORCED WATER FORCED (OFWF)

In this method of cooling, oil-water heat exchangers are used in OFWF transformers to transfer the heat from the oil to water. The specific heat capacity of water is four times greater than air. Hence water is used to cool the oil circulated through the heat exchangers. This type of transformer cooling method is used in hydropower generation stations where sufficient amount of water is available.

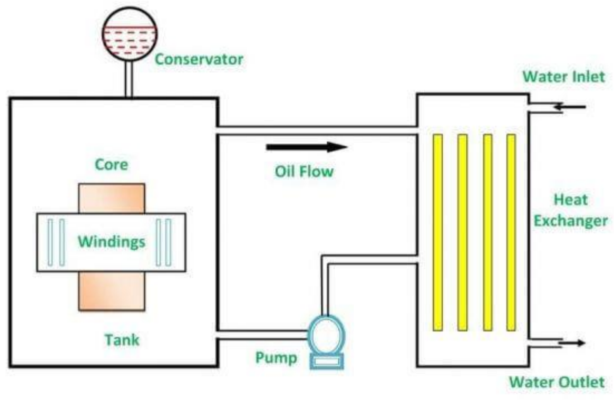

Fig.4 OFWF

5.7 OIL DIRECTED AIR FORCE (ODAF)/OIL DIRECTED WATER FORCE (ODWF)

To increase the heat transfer rate, additional arrangements are made in the transformer which directs the circulated oil through predetermined paths. It is used with a forced oil system. The oil entering the tank from the heat exchanger is passed through the windings in a predetermined manner to enhance the heat transfer. The oil pressure in heat exchangers is always greater than the water pressure so that no water leakage into the oil.

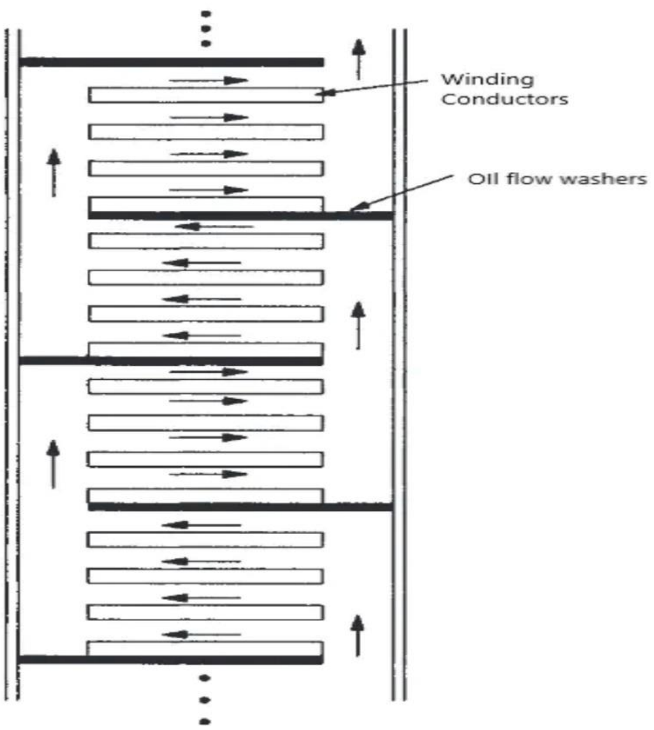

Fig.5 ODWF

6. CONCLUSIONS

This paper concluded with

- The proper functioning and life of a transformer mainly depends upon proper cooling of the transformer.
- The selection of coolant depends upon the type of the transformer.
- Due to the heat generated in the transformer, the temperature raises and it should be kept in the pre-determined level to safeguard the transformer.
- Research areas were identified by incorporating nano additives to the coolant oil which may increase the life of the transformer.

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BIOGRAPHIES

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