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Effective Conversion of Transformer Losses into Dissipated Heat

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Abstract—This paper highlights the effective methods of cooling the transformer. There are many losses that occur during the functioning of a transformer which in turn causes heat generation. This heat, if not dissipated properly causes a lot of metallurgical problems in the transformer. It explains the effect of the transformer oil and winding temperatures on the achievement of the expected transformer lifetime. The paper also explains the electrical parameter which if controlled during operation will in turn reduces the heat produced and helps to increase the transformer life.

Index Terms— **Metallurgical, Electrical.**

I. INTRODUCTION

In power industry transformer is a frequently heard name and most of us are well aware by the functioning principle of transformer electrically. Transformer is a device having no moving element, step-up or down the voltage by electromagnetic principle. The no-load and load-losses created by the transformer core and windings will generate high temperatures that, if not controlled in a timely manner, can damage the dielectric properties of the insulation. During normal operating conditions, the thermal process is controlled by the cooling system that keeps the transformer in a thermal equilibrium [1]. If these methods are not effective according to the heat produced, then a very detrimental effect on the lifetime of it, is seen. These problems would be partially alleviated by the development of cooling techniques. Even though transformers are very efficient devices, converting from 95-99% of their input power, some of its energy is lost during the voltage transformation [2]. The losses in a power transformer can be classified as no-load losses and load losses.

No-Load Losses: Eddy current and hysteresis losses are belongs to this category. For reducing eddy losses, higher resistively core material and thinner lamination of core are employed. This loss decreases very slightly with increase in temperature. Eddy losses contribute to about 50% of the core losses [3].hysteresis losses depends upon material, frequency and maximum magnetic density. It can be decreased by optimizing the max. Magnetic density and selecting economically best material considering this loss into mind.

Load losses: The load losses in a power transformer are due to the electric resistance of windings and stray losses. The Resistive action of the winding conductor to the current flow will be lost in the form of heat and will be dissipated in the Surrounding area inside the transformer. The magnitude of that loss increases by the square of the current. Stray losses occur due to the leakage field of winding and due to high currents seen in internal structural parts such as bus bars. Stray losses can affect the overall rating of the transformer because they can create hot spots when the current leads become excessive, affecting the overall life of the transformer[4]. Losses in the transformer are of the order of 1% of its full load kW rating. These losses get converted in the heat thereby the temperature of the windings, core, oil and the tank rises. Thus a load serving transformer not only experiences an electrical process but also goes through a thermal process that is driven by heat. The heat generated by the no-load and load losses is the main source of temperature rise in the transformer. However, the losses of the windings and stray losses seen from the structural parts are the main factors of heat generation within the transformer. The thermal energy produced by the windings is transferred to the winding insulation and consequently to the oil and transformer walls. This process will continue until an equilibrium state is reached when the heat generated by the windings equals the heat taken away by some form of coolant or cooling system (5).the dielectric properties of the insulation deteriorate very quickly if the temperature exceed beyond a certain limit. Life of insulation is the life of the transformer [6]. The primary cause of heat generation in a transformer is its copper losses. If the heat is not dissipated properly, the rising temperature may cause damages in the paper insulation of the transformer. Following are some methods of transformer cooling:

- Oil natural air natural - In this type, convectional flow of hot oil is used for cooling.
- Oil natural air forced - The heat dissipation can be increased by increasing the dissipation surface. This method uses forced air flow which takes away the heat from the surface radiator.
- Oil forced air forced - Its functioning is vis a vis , oil natural air forced except that oil is forced through circulation pipes by means of oil pumps.
- Oil forced water forced - Since the ambient temperature of water is much less than air, water acts as a better heat exchanger. This method is more effective than oil forced air forced.
- Oil directed air forced - It is the tweaked version of oil forced air forced. The path of oil flow is predetermined in this case.
- Oil directed water forced - The method is same as oil directed air forced except that the hot oil is cooled in cooler with help forced water instead of air. [6]

The load that a transformer carries without heat damage can be substantially increased by using an adequate cooling system. This is due to fact that a transformer's loading capacity is partly determined by its dissipate heat. Hence maintenance of these cooling systems is of undeniably of utmost importance

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● For normal dry transformers proper ventilation should be provided.

● For forced air type transformers, which use cooling fans for forcing air , the blades of these fans should be properly checked periodically.

● For water type transformers, leaks should be properly checked upon. Formation of sludge should be prevented by regularly keeping in check the acidity of water.

● The oil coolants used, should be tested to be free of acids and alkalis at the same time. They should have low viscosity in order to facilitate flow[7].

The main two parameters of cooling optimization of a transformer are the temperature and losses of the cooling system of a transformer.
These parameters, which are in contradiction, depend on several factors:
• Load of a transformer;
• Efficiency of the cooling system;
• Temperature settings of the thermal image;
• Ambient temperature.
Lowering of temperature slows down ageing of a transformer and at the same time increases losses of the cooling system [7]. Thus in practice, the problem of optimizing cooling is frequently translated into the question: How high can the temperature or how weak can the cooling be, in order for a transformer not to age too fast? To prevent the transformer from adverse effects following types of cooling should be adopted:
1) Natural convection cooling by air or oil.
2) Forced convection cooling by air and oil.
Oil acts as both insulating material and also cooling medium in the transformer. For small rating transformers heat is removed from the Transformer by natural thermal convection. For large rating transformers this type of cooling is not sufficient, for such applications forced cooling is used. As size and rating of the transformer increases, the losses increase at a faster rate. So oil is circulated in the transformer by means of oil pumps. Within the tank the oil is made to flow through the space between the coils of the windings. Several different combination of natural, forced, air, oil transformer cooling methods are available. The choice of picking the right type of transformer cooling method for particular application depends on the factors such as rating, size, and location. Thermodynamics analysis: for a system using incompressible medium the heat transfer (Q) is given by the increase in the internal energy
(ΔU) [8]:
$Q = \Delta U$
$= C\,\Delta T$
$= m.c.\,\Delta T$
For where C is the heat capacity of the medium and c and m are the specific heat and mass flow rate of the medium respectively.

Heat generate from coil is the shape of energy came from the electricity. The current flow into a conductor can produce heat if there is a number of a resistance. The heat is direct effect of Joulean Power Loss; with the number of heat produce (P) is [9]:
$P = I\ 2R$
Where I amount of current flow and R is resistance inside the conductor. The heat produce can raise the temperature of conductor.
The rise of temperature can make the resistance (R) value of conductor increase by [10]:
$R = R20\ [1 + \alpha\ (T - 20)]$ (11)
Where R20 is resistance of conductor in 20°C Temperature, α is temperature coefficient for resistance, and T is temperature of conductor. There is three way to transfer the heat, conduction, radiation, and convection. In conduction, thermal energy transferred by interaction among atoms or molecules themselves. The heats transferred by collusion between molecules and, in metals, this process accelerate by the free electron flows inside. Fourier Law can calculate the number of heat transferred by equation [8]:
$q = -K.Dt/Dx$
Where q is the heat flux,k is the thermal conductivity of the material used and Dt/Dx is the temperature gradient. Different from conduction, in radiation, thermal energy is emitted and absorbed by the bodies in form of electromagnetic radiation according to Stefans Boltzman equation. also the heat transfer by convection is also taken into consideration which is governed as per by Newton law of cooling. Total heat transfer so mainly depends upon the thermal conductivity of material used, surface area exposed, surrounding temperature, heat transfer coefficient etc. In case of transformer it is found by the past research that Transformer Oil is one of liquid isolator used in electrical machinery. One of criteria good transformer oil is the capability of absorbs heat. This paper mainly discuss about the heat capability of transformer oil. By experiment, the heat specification of oil can be measure. The experiment running using three variables of current injection, and two kind of coil as heater to produce heat into oil. The comparison has been made between coil inside the transformer oil and coil in free air. From the experiment can measure the energy absorb into the oil, by calculating the heat capacity of transformer oil itself. The results of the experiment shown that inside the oil transformer the heat is more produce from coil which is have a larger contact area with oil. The larger energy generate from heater coil is change shape to influence the time to reach the equilibrium point not again in shape of temperature. From the analysis, the transformer oil has more than 15 times heat capacity higher than coil itself. Its mean that to raise the temperature of transformer oil needs 15 times more energy than coil in free air[12].

II. CONCLUSION

Transformer oil has a good thermal conductivity to absorb heat generated from a coil and release it into the free air. With this condition, the performance of electrical machinery using coil can have a greater capability to receive more power. Beside that with the

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good thermal conductivity, the coil inside the oil have lower heat losses because heat generated into rising the temperature is lower than free air coil. Transformer oil also has a good heat capacity, so the temperature of coil inside the oil is maintained at a low temperature because of the low temperature of oil itself. By keeping in low temperature, the coil has capability to receive more power to get a good performance. In application, by knowing the heat capacity of oil, the heat generate of some kind of electrical machinery can be measured without an experiment. By comparing the results, the ageing of electrical machinery can be predicted.

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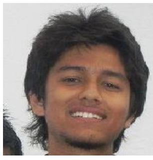

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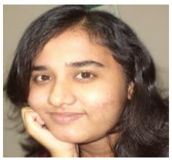

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