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Heat Transfer Analysis of UPS Transformer from FEA and Experimental Aspects: A Review

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Abstract - *This paper is focuses information regarding transformer heat dissipation rate and the factors to be considered while heat transfer calculations. It also gives different heat transfer modes in transformer and methods to increase the life of transformer. This paper also emphasised on different cooling methods incorporated in transformer cooling and also focuses modern trends in cooling of transformers. So as to increase the efficiency of transformer machine.*

Key Words: Heat dissipation, Modes of heat transfer-Conduction, convection, radiation.

1. INTRODUCTION :

The electric transformer experience heat generation while working with many components like primary and secondary windings due to joule effect in action. As the transformer not contain any moving elements and based on electromagnetic principle, it dissipates large amount of heat towards electromagnetic plates even in load or no load condition. For increasing durability and smooth operation of transformer it should be cooled to adequate temperature within time. If it not cooled within considerable time the heat dissipated from core can damage insulation and may affect the dielectric properties of it. A traditional method is used to cool transformer. If this method is failed it may give very detrimental effect on life of transformer considerably reduces life and may implies poor heat dissipation rate and thus reduces efficiency of transformers which is not desirable. Generally transformer develops two types of losses first is No load losses consisting hysteresis losses. Hysteresis loses are occurred due to type of material used, magnetic density and frequency. It can be reduced by optimising magnetic density and selecting economically suitable material. The second type of losses experienced by transformer is load loses. They are develops due to electric resistance in winding . The stray losses are experienced due to leakage in field windings. The stray losses create hot spots and thus reducing the overall rating of it. These losses dissipates heat due to the winding core .The transformer is subjected heat generation due to copper losses in core. Table 1 gives detail information about cooling systems.

Table -1: Types of cooling systems used in transformer.[6]

Sr. No.	Type of Cooling system	Nature of cooling
1.	Oil and air at atmospheric condition	Conventional flow of hot oil is used.
2.	Oil at atmospheric condition and air is in forced condition	Forced air used to radiate heat from surface.
3.	Oil and air is in forced condition	Oil is pumped with air on surface.
4.	Oil and water is in forced condition	Water is pumped with oil. It is most efficient method.
5.	Oil directed and air is in forced condition	Oil is directed towards plates and air is forced .
6.	Oil directed and water is in forced condition	Oil is directed on plates and water is pumped. This is more suitable than above.

1.1 Requirements of cooing system used in Transformer :

1. The normal transformers should have proper ventilation.
2. The blade should be check periodically of forced air transformer.
3. The acidity of water should be check regularly while working with water forced transformer cooling system so as to avoid chances of slurry formation.
4. The oil used for transformer cooling should be cooled [4]

The transformer working is affected by temperature and losses. These parameters are mainly depend on following factors.

1. Load on transformers.
2. Efficiency of cooling systems.
3. Ambient conditions.
4. Thermal distribution.

The lowering in temperature may impact on working of transformer. So wide research is in progress on transformer cooling systems so as to increase its life and considerably most important efficiency. The oil acts as a insulating material as well as cooling medium. For small rating transformer heat is removed with help of natural convection. And for high rating transformer forced convection method is utilised. As size and rating of transformer is increased it increases the chances of losses. The rate of power is calculated by expression,

$P = I^2 R$ .... (1)

Where, I-Amount of current flow, R-Resistance,
The rise of temperature can make the resistance (R) value of conductor increase by expression,
R = R20 [*1* +α (T -20)].. *(2)*
Where R20 is resistance of conductor in 20□ Temperature, α is temperature coefficient for resistance, and T is temperature of conductor.
As the detection of hot spot temperature in transformer help to improve design and life. The thermal analysis of transformer includes all three modes of heat transfer like conduction in transformer metals, convection with oil with plates and radiation with tank surfaces. The heat transfer analysis can be done with ANSYS software. The figure no 1 shows schematic of transformer and figure no. 2 gives the detailed working of transformer.

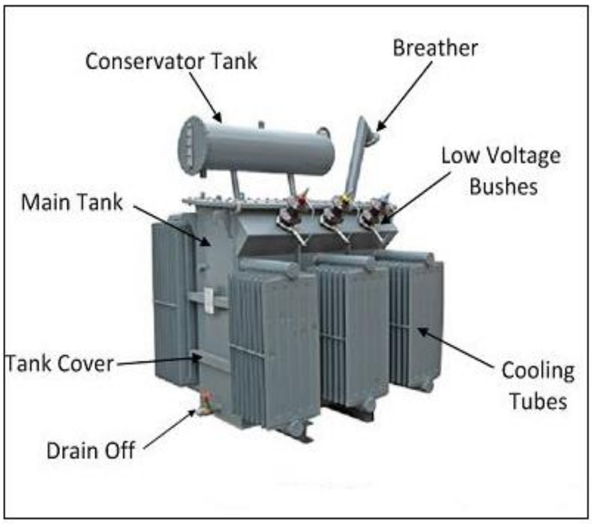

Figure 1- Transformer construction

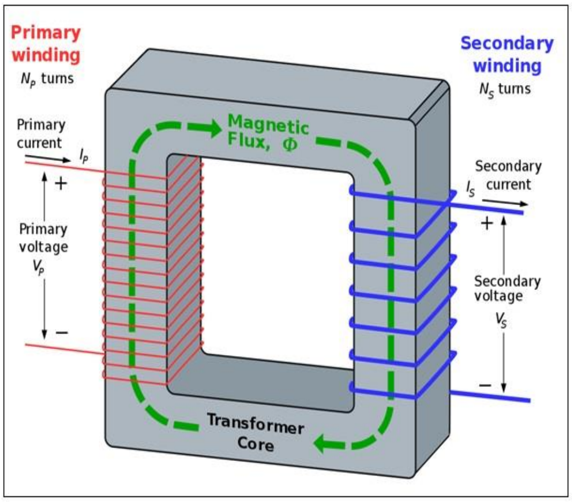

Figure 2-Transformer working

The transformer is working on electromagnetic principle explain by figure no . 2

2. Mathematical Model and Finite element analysis-[6]

It is well known that losses in electromagnetic core, windings are subjected to heat dissipation. An electromagnetic finite element method is used to calculate such dissipation rate effectively. We know that heat is transfer to surrounding air with several stages due to temperature differences. The steady state heat generation can be given as from expression no.3

$$\frac{d}{dx}\left(k\frac{dt}{dx}\right)+\frac{d}{dy}\left(k\frac{dt}{dy}\right)+q^{0}\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

where T is temperature in (˚C), x and y are spatial variables in (m), K is the thermal conductivity in (W/m˚C) and qois the heat transfer rate in (W/m3).
The heat transfer by convection is given by expression no. 4 ,

$$-k\frac{dt}{dx}-k\frac{dt}{dy}=\square(T-Tb)\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where, Tb is the adjacent bulk temperature while h is the convective heat transfer coefficient in (W/m2□) which could be determined by classical Nusselt number Nu correlations as by expression no. 5

$$nu=\frac{\square l}{k}\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where, L = height in (m); while for horizontal plates the characteristic dimension L = length in (m)
The heat transfer by radiation can be expressed by equation no .6

$$-k\frac{dt}{dx}-k\frac{dt}{dy}=\square(T^{4}-Tb^{4})\ldots\ldots\ldots\ldots\ldots(6)$$

Where, σ is Stefan-Boltzmann constant, 5.67 10 × e^{-8} w/m^{2}□ ^{4}. Note that ε is the infrared emissivity = 0.95

Literature Survey :

1. 1.Joe perez et al. concluded the basic fundamental principles useful to study transformer thermal loading and protections.
2. Kulkarni S.V.et al .included various constructional features of transformer and design aspect. They also focuses on different cooling techniques. Also they concluded recent trends for cooling and optimising transformer life.
3. 3.Devki engineers manual gives detailed design and operating parameters which should be taken in account while designing of transformers.
4. 4.Hunt et al. concluded study of transformer cooling with radiator and fluid with forced convection and noticed heat transfer enhancement.
5. Prashant Gour et al. included the heat dissipation in transformer and imperial relations for calculation of heat transfer rate.
6. 6.IEEE guide focused details about constructional features in transformer.
7. Tim Gradnik et al. developed Thermo-hydraulic model of an OFAF transformer and tested on many thermo physical parameters like cooling and temperature distribution and observed increase in life of transformer.

8. Lien hard et al. textbook on heat transfer gives detailed imperial relation used to calculate heat dissipation in transformer.
9. 9.Davies et al. concluded the different mathematical modeling used to calculate the heat transfer by radiation. They also included different methods used in radiation heat transfer.
10. 10.Chen et al. concluded the detailed information about load carrying cable for transformers and load and no load conditions it also included the impact of load and no load conditions on transformer life.

3. CONCLUSION

The transformer consist core and windings which are subjected to heat dissipations in load and even no load condition due to hysteresis losses. Thus the normal transformer is worked with natural cooling which is considerably not suitable for peak load orlarge rating transformers due to its low rate of cooling. The heat dissipation can be reduced with transformer oil with pumped air which is quite suitable for large rating transformer but, it may increases the cost of unit and if pump system may fail it reduces the efficiency of transformer and also reduces the life of it.

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