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3d Modeling and Thermal Analysis of Electrical Transformer Cooling System.

M.Rambabu[1], Dr.P.Kumar Babu[2], M.Sunil Raj[3]

[1]*M.Tech CAD/CAM (Pursuing), Pragati Engineering Collage, Surampalem,* Rambabu3715@gmail.com

[2] *Professor and HOD, Department of Mechanical Engineering, Pragati Engineering Collage, Surampalem.* pkbbit@redefmail.com

[3]*Assistant Professor, Department of Mechanical Engineering, Pragati Engineering Collage, Surampalem* sunilraj46@gmail.com

ABSTRACT:-The electrical transformers are key components in the electricity distribution units. The efficient working of transformer plays a crucial role in residential, commercial and medical, also proper functioning of hospitals, Security, networking, banking and industrial sectors. The load on the transformer and ambient temperatures are two important factors that are influencing on the life of the insulating material. The age of the transformer is based on the life of insulating material.

This paper presents, the advanced naturel cooling system designed for Oil Natural Air Natural Transformer by using CATIA 3D Modeling for reducing the transformer hot spot temperature and increasing the life of insulating material. By this way, we get the increased life of the transformer and sudden failures can be avoided.

Keywords:- Age of The Transformer, Life of Insulating Material, Transformer Cooling System, Hot Spot Temperature, Thermal Analysis, CATIA 3D Modeling and ANSYS.

1. INTRODUCTION

The transformers are electrical static devices, which are used to alter the voltage and current levels from low to high or vice-versa with constant power output. Generally, the transformers are high efficient (around 95%) [3, 5]. The transformers are generally classified into two types. These are step-up transformer and step down transformer.

The life of the transformer purely based on the load and ambient temperatures because it affects the insulating material in the transformer (1, 2]. In the transformer the insulating material is used for obstruct the direct flow of electricity from on part to another part for avoiding the short circuit. Generally the transformers are having good life in mechanical arrangements because there are no moving parts or rotating parts. The transformer life is directly affected by high temperature causing increasing load on the transformer or high ambient temperatures [1, 2, 3].

In summer seasons the load on the temperature is too high and also the ambient temperatures are also high as compared with winter and rainy seasons. So that many of the transformers will fails to work in summer condition due to short circuit. This is because of in the transformer the insulation material will burn due to the overheat [4]. To overcome this issue some external assistance is provided to cool down the transformer to get increased life, but the efficiency is reduced due to utilization of energy within the network.

Based on the literature survey if the load and ambient temperature increase the age of the transformer is reduced. For this purpose innovative cooling system is required for Oil natural and air natural transformer to dissipate the more heat [7].

A. About Transformer Cooling System and Necessity:

As we know that the transformer is used for alter the voltage levels, during the alteration process the heat is generated in the transformer due to resistive losses occurring across the transformer parts.

The generated heat is harmful to the transformer age, because the insulating material used in the transformer fails due to heavy heat. Whenever the insulation failed, the transformer also fails [6].

The life of the insulating material is based on the transformer hot spot temperature. So we must dissipate the heat to the surroundings and reduce the temperature within safe limit.

B. **Types of Cooling Techniques**

I. Air Natural Cooling
II. Oil Natural Air Natural
III. Oil Natural Air Forced
IV. Oil Forced Water Forced

C. About Heat Transfer Through the Fin:

The rate of heat transfer from a wall at a temperature T_w to the surrounding medium at T_a is given by Newton's law of cooling

$$\mathbf{Q = h A_s (T_w - T_a)}$$

Where

Q	=	Heat Transfer (W)
h	=	convective heat transfer coefficient ($W/m^{2o}C$)
A_s	=	Surface Area (m^2)
T_w	=	Wall Temperature (^oC)
T_a	=	Ambient Temperature (^oC)

There are two ways to increase the rate of heat transfer [9].

1. By Increasing the convection coefficient (h)
2. Increase the surface area $A_{s.}$

For increasing "h" may require some external assistance, or replacing the existing one with a larger one, but this approach may or may not be practical. The alternative method is to increase the surface area by attaching to the extended surfaces called fins.

Finned surfaces are used for enhance heat transfer from a surface by exposing a larger surface area to convection and radiation. There are a so many variety of fin designs are available in the market. A circular profiled fins are high efficient than rectangular fins. [8]

In the analysis we consider, the steady state operation with no heat generation in the fin, and we assume the material thermal conductivity "K" is remains constant. We also assume the convective heat transfer coefficient "h" to be constant and uniform over the entire surface of the fin.

2. DESIGN OF TRANSFORMER TANK

Designing of 500 kVA, 50 Hz, 6600/400 V, Oil Immersed, Natural Cooled Power Transformer [10].

A. Losses:

I. Copper Losses:

Total I^2R or heat losses = 1562+ 1951 = 3513 W.

The loss increased by about 10% to account for stray load losses.

Therefore, Total I^2R or heat losses including additional loss = 1.1 x 3513 = 3865 W.

II. Core Losses:

In this we use 0.33 mm thick 56 grade laminations.

Length of mean flux path l_i	=	2(437.5+475+270) x 10^{-3}	= 2.37 M.
Weigh of core iron	=	2.37 x 0.0537 x 7.65 x 10^3	= 94 kg.
The specific loss of core iron	=	1.25 W/kg.	
Coreloss	=	1.25 x 94	= 1217.4 W.
This is increased by about 20% to account			
For joints	=	1.2 x 1217.4	
Total core loss	=	1460 W	

III. Total Heat Loss of Transformer:

Total heat loss = copper losses+ core losses = 3865 + 1460 = 5325 W.

B. Tank dimensions:

I. Height of the frame = 977.5 mm
II. Height of the tank = 1600mm or 1.6 M.
III. Length of tank L_t = 1193mm or 1.2 M.
IV. Width of the tank W_t = 618 mm say 650 mm

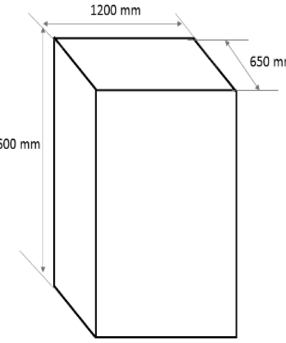
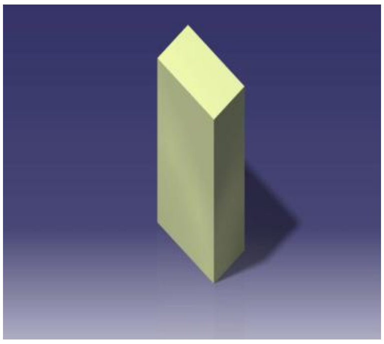
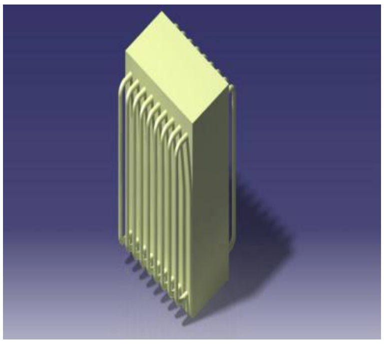


Figure – 1. Transformer Tank

C. Transformer CATIA 3D Models:

i. Model-1 Model-2 Model-3





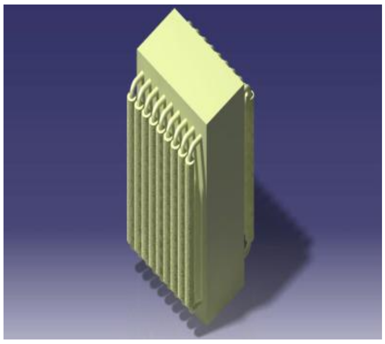
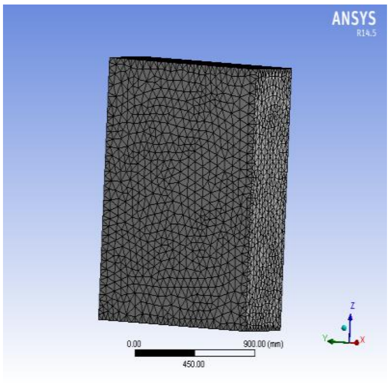
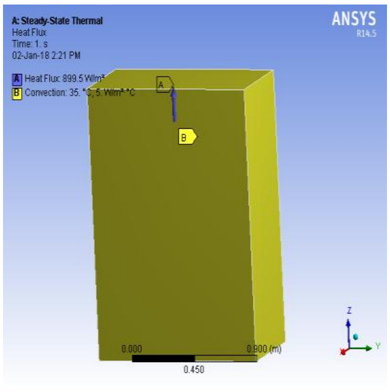


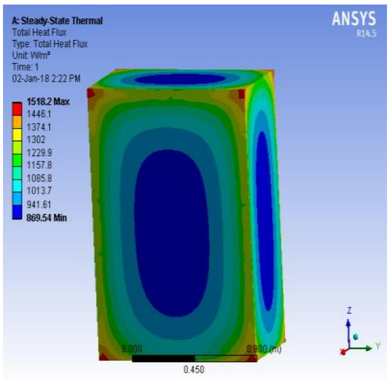
Figure-2. Plane Transformer, Figure-3.Transformer with Tubes Figure-4. Transformer with Finned Tubes

4. SIMULATION ANALYSIS

A. Model-1

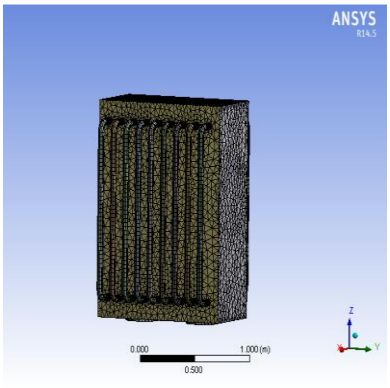




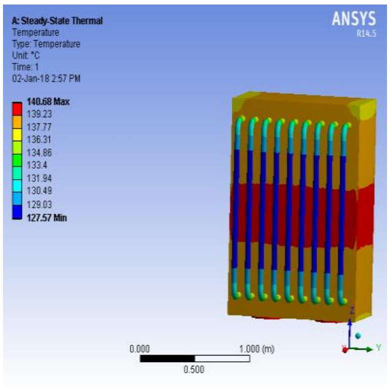


i. Meshing *ii. Boundary conditions* iii. Temperature result

B. Model-2

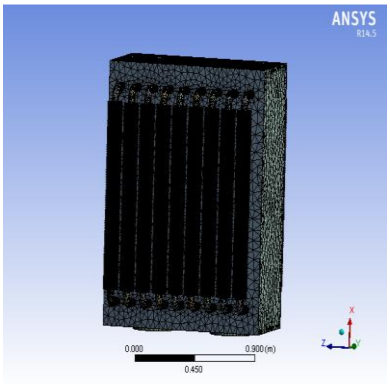


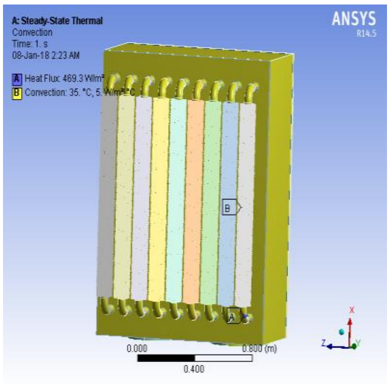
i.

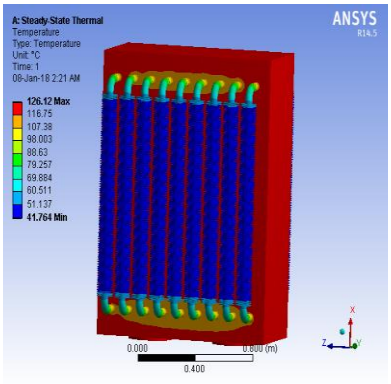


Meshing ii. Boundary condition iii. Temperature result

C. Model-3







i. Meshing ii. Boundary condition iii. Temperature result

5. RESULTS

I. Mathematical Results Based on Heat Transfer Analysis:

TABLE-1 : Comparison of temperature results

	Total Heat	Convective Coefficient	Surface Area	Temperature Rise	
				T_w	T_a
	WATTS	$W/M^{2O}C$	M^2	^OC	^OC
Model-1	5325	5	5.92	214.89	35
Model-2	5325	5	10.08	140.65	35
Model-3	5325	5	35.26	66.46	35

TABLE-2 : Comparison of life of insulation results

Model No	Temperature	Life of Insulation (In Years)
Mode-1	214.89	0.000286877
Mode-2	140.65	0.228891503
Mode-3	66.46	181.7764968

II. Mathematical Results Based on Transformer Design Analysis

TABLE-3: Comparison of temperature results

	Total Loss	Combined Heat Transfer Coefficient	Surface Area	Temperature Rise	
				T_w	T_a
	WATTS	$W/M^{2O}C$	M^2	^OC	^OC
Model-1	5325	12.5	5.92	106.96	35
Model-2	5325	12.5	10.08	77.26	35
Model-3	5325	12.5	35.26	47.08	35

TABLE-4: Comparison of life of insulation results

Model No	Temperature	Life of Insulation (In Years)
Mode-1	106.96	4.74964
Mode-2	77.26	68.77566
Mode-3	47.08	1040.09807

III. Simulation Results

TABLE-5: Comparison of temperature results

Model No	Temperature		Total Heat Flux		Directional Heat Flux	
	Max	Min	Max	Min	Max	Min
Mode-1	212.56	203.29	1518.2	869.54	1191.8	-1202.8
Mode-2	140.68	127.57	4323.9	8.9341	3006.6	-4312.7
Mode-3	126.12	41.764	25111	1.3684	24807	-24648

TABLE-6: Comparison of life of insulation results

Model No	Temperature		Life of Insulation (In Years)	
	Max	Min	Max	Min
Mode-1	212.56	203.29	0.00035	0.00081
Mode-2	140.68	127.57	0.22837	0.74313
Mode-3	126.12	41.764	0.8467	1678.509

6. GRAPHICAL REPRESENTATION

I. Mathematical Results Based on Heat Transfer Analysis:

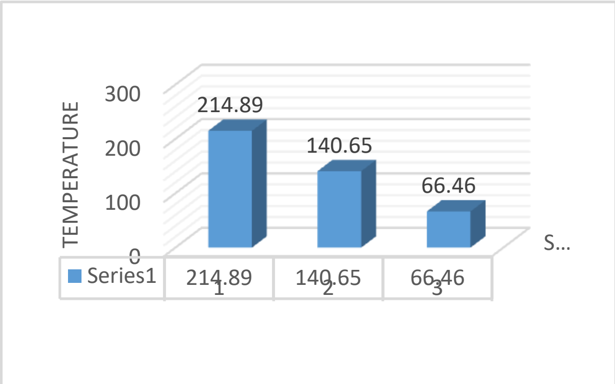


CHART-1: Comparison of temperature results

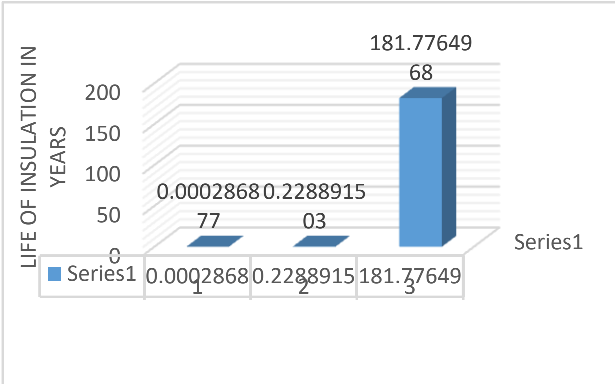


CHART-2: Comparison of life of insulation results

II. Mathematical Results Based on Transformer Design Analysis.

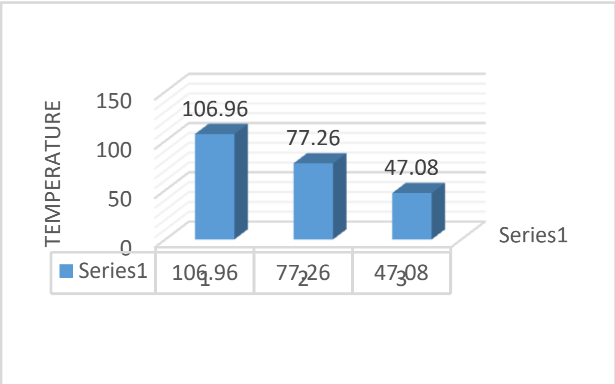


CHART-3: Comparison of temperature results

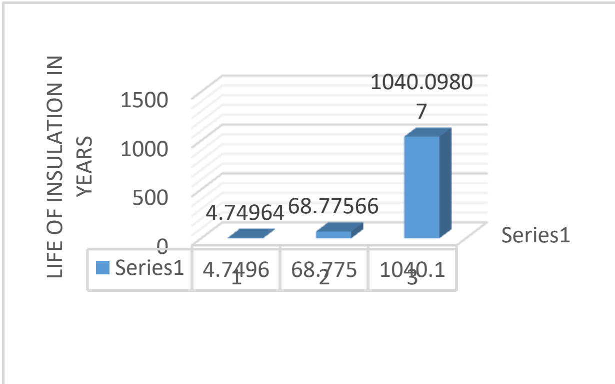


CHART-4: Comparison of life of insulation results

III. Simulation Results

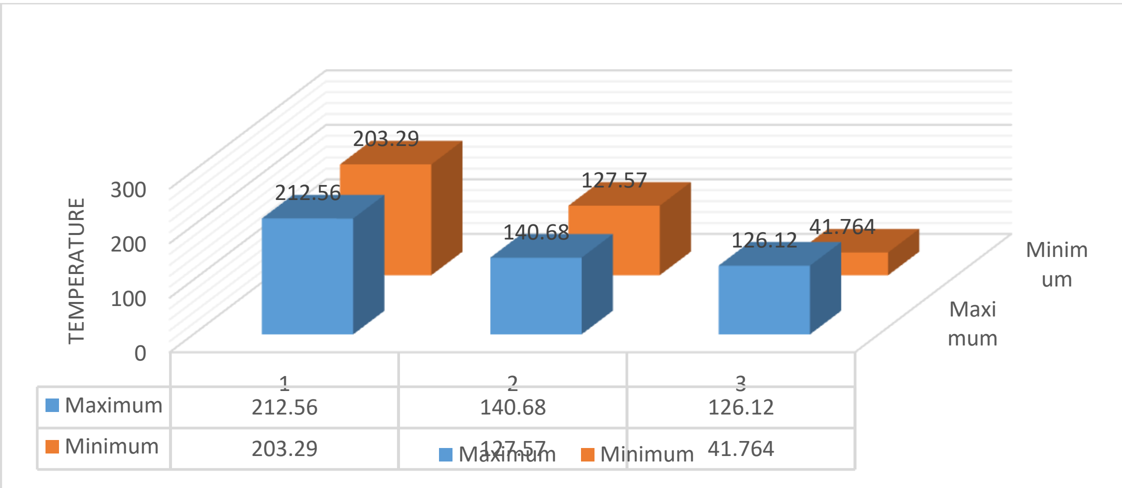


CHART-5: Comparison of temperature results

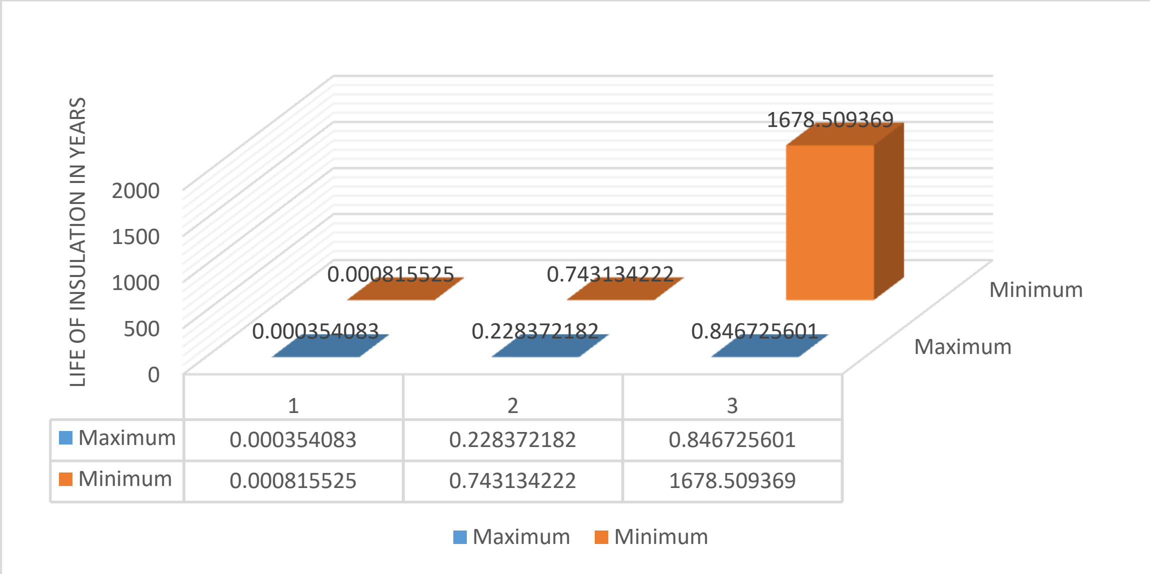


CHART-6: Comparison of life of insulation results

7. CONCLUSION

In this project I designed three different transformer cooling system models for 50 MVA, 6600/400 V Oil Natural Air Natural cooling transformer units at constant load. In the three models first two models are existing transformers and third one is new innovative model. The three models are designed using CATIA modelling and analyzed by mathematical tools (heat transfer, transformer design analysis) and simulation analysis (ANSYS study state thermal analysis).

As per the results obtained from mathematical analysis and the thermal analysis, our innovative design gives the best results over the existing transformers with same load and losses. The details are given below table-7.

I conclude that based on above tabulated results the model-3 i.e. Finned Tube Transformer is having increased life and less temperature compare to other existing transformers. Hence if you provide the fins on the transformer tubes the life of the transformer and capabilities of cooling system is increased.

TABLE-7: Conclusion in all aspects

Method of Analysis		**Mathematical Analysis**		**Simulation Analysis**	
		Heat Transfer Analysis	**Transformer Design Analysis**	**Maximum**	**Minimum**
Model-1	Temperature	214.89	106.96	212.56	203.29
Model-2		140.65	77.26	140.68	127.57
Model-3		**66.46**	**47.08**	**126.12**	**41.764**
Model-1	Life of Insulating Material	0.0002	4.74964	0.00035	0.00081
Model-2		0.2288	68.7756	0.22837	0.74313
Model-3		**181.77**	**1040.09**	**0.84672**	**1678.50**

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