PERFORMANCE ANALYSIS OF COOLING SYSTEM USED IN TRANSFORMER

N. R. Pathare, V. S. Shende, P. V. Jadhav, S. M. Awatade

***Abstract*— The life expectancy of the transformer largely depends on the temperature-rise in it. If the temperature-rise exceeds limits specified in the design standards, the aging of insulating materials is accelerated and also the capability of cooling medium is deteriorated. So, applicable limits of the temperature-rise are essential in designing transformer and coolers, demanding the estimation of the thermal behavior of transformer.**

In order to analyze the temperature Characteristics of the transformer, the numerical analysis by using ANSYS has been carried out, and temperature-rise test to verify computed results was made.

The results obtained in this study show that there is a good agreement between computed results and experimental one.

***Index Terms*— transformer, cooling system, performance analysis, temperature characteristics**

I. OBJECTIVES

- To check the heat transfer by using various materials used for manufacturing radiators.
- To study a data regarding the shape, material and the amount of heat transfer achieved.
- To suggest some new advance cooling techniques used in modern day transformers, which would certainly increase the efficiency of transformers.
- To compare the current heat transfer attained with present analysis values, and give comparative study, which will help for further development.

II. METHODOLOGY

In the study, 132/11 KV step down transformer of MSEB Ambazari Sub-Station is used to carry out the present work.

2.1 System Particulars

1. Nominal System Voltage: 132/11 kV
2. Frequency: 50 Hz with 3 % tolerance
3. Number of Phase: 3
4. Neutral earthling: Solidly earthed

2.2 SERVICE CONDITIONS

1. Max. Ambient air temperature: 50 Deg. C
2. Max. Wind pressure: 150 kg/sq. m.
3. Climatic Condition Moderately hot and humid tropical climate conducive to rust.
4. Reference Ambient Temperature for temperature rise: 50 deg C

The climatic conditions are prone to wide variations in ambient conditions and hence the equipment shall be of suitable design to work satisfactorily under these conditions.

2.3 FIN SPECIFICATIONS

- On each panel
- Material- low carbon steel CRCA MS sheet
- No. of fins = 25
- Length = 225cm
- Thickness of fin material = 1.5 mm
- Thickness of fin = 15 mm
- No. of panel = 12 to 15 on both sides

2.4 TRANSFORMER OIL

Transformer oil to be used in all the power transformers shall comply with the requirements of latest IS 335 or relevant. In addition the oil should conform to `Ageing Characteristics' specified below for New Oil and Oil in Transformers.

New oil - Ageing characteristics after accelerated ageing.

1. Specific Resistance (Resistivity)
   At 20 º C: - 2.5 x 10 12 Ohm-Cm (Min)
   At 90 º C: - 0.2 x 10 12 Ohm-Cm (Min)
2. Dielectric dissipation factor - 0.20 (Max. tem. delta) at 90 º C.
3. Total acidity mg/KOH/gm - 0.05 (Max)
4. Total sludge value (%) by weight - 0.05 (Max.)
5. Oil filled in Transformers:

An experiment is carried out on radiators.

- In present study C.A.T.I.A. software for modeling of the radiator is used
- Then model is analyzed by applying various boundary conditions using ANSYS software.

III. DESIGN AND CALCULATION ANALYSIS

3.1 ANALYSIS

The ANSYS program is a computer program for finite element analysis and design. One can use the program to find out how a given design works under operating conditions. One can also use the ANSYS program to calculate the proper design for given operating conditions.

The ANSYS program is a general-purpose program, meaning that one can use it for almost any type of finite element analysis in virtually any industry-automobiles, aerospace, railways, machinery, electronics, sporting goods, power generation, power transmission, and biomechanics, to mention just a few.

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General-purpose also refers to the fact that the program can be used in all disciplines of engineering-structural, mechanical, electrical, electromagnetic, electronic, thermal, fluid, and biomedical. The ANSYS program is also used as an educational tool in universities and other academic institutions.

3.2 A TYPICAL ANSYS ANALYSIS

The ANSYS program has many finite element analysis capabilities ranging from a simple, linear static analysis to a complex, nonlinear transient dynamic analysis.

- Build the model
- Apply loads and obtain the solution
- Review the result

3.3 THERMAL ANALYSIS

Thermal analyses are used to calculate the temperature distribution and related thermal quantities in an object. The ANSYS program uses a heat balance equation obtained from the principle of conservation of energy as the basis for thermal analysis. All three primary modes of heat transfer-conduction, convection, and radiation are handled by the ANSYS program. In addition to the three modes of heat transfer, you can account for special effects such as change of phase and internal heat generation.

- Steady state thermal analysis
- Transient thermal analysis
- Radiation

3.4 MODEL GENERATION

The ultimate purpose of finite-element analysis is to recreate mathematically the behavior of an actual engineering system. The model generation will mean the process of defining the geometric configuration of your mode's nodes and elements. Typical steps involved in model generation:

- Planning your approach
- Erect coordinate systems
- Using picking and working plans
- Solid modeling
- Meshing your solid model
- Revising your model
- Adaptive meshing
- Direct generation
- Piping models
- Number control and element reordering
- Coupling and constrained equations

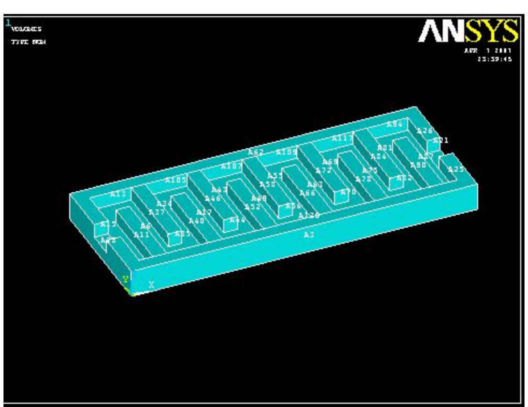

FIG 3.1 ANSYS MODEL OF TRANSFORMER RADIATOR FIN

3.5 MESHING

The surface mesh will always be generated prior to the volume mesh generation. However, it is often helpful to explicitly generate at least part of the surface mesh before volume meshing, to view it and ensure that the chosen length scales and controls will have the desired effect. Included in the surface mesh generation process is a mechanism called Section. Inflation for generating prism elements (and a small number of pyramids as required) near the walls. Inflation is used for resolving the mesh in the near wall regions to capture flow effects for viscous problems.

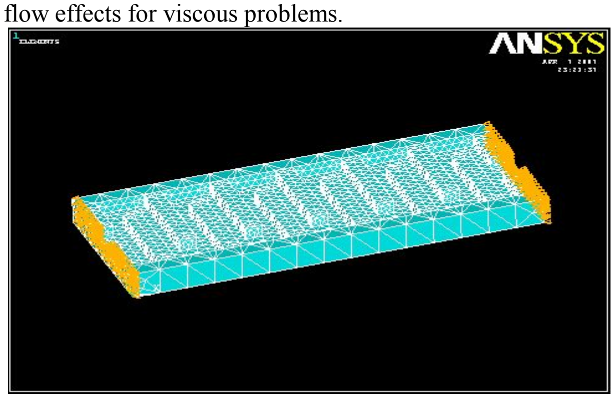

FIG 3.2 MESHING

3.6 LOADING AND SOLUTION

The primary objective is to examine the responses of a structure or component to certain loading conditions. Specifying the proper loading conditions is, therefore, a key step in the analysis. You can apply loads on the model in a variety of ways in the ANSYS program. Also with the help of load step options, one can control how the loads are actually used during solution.

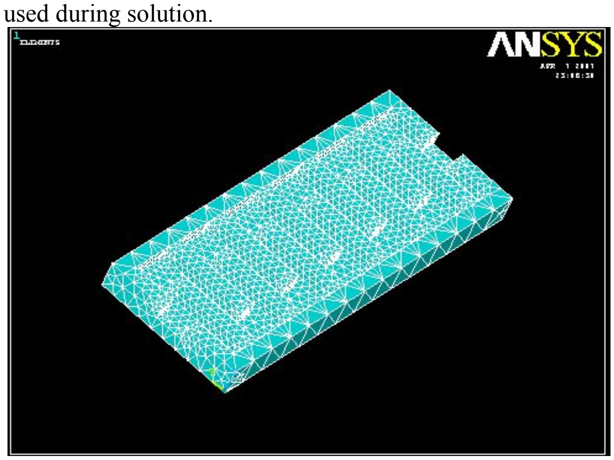

FIG 3.3 Loading Condition Temp T1=65°C ON LEFT SIDE AND T2=85°C ON RIGHT SIDE

3.7 POST PROCESSING

Post processing is that phase of an analysis in which you review the results. It is probably the most important step in the analysis. Two post processors are available to review your results: POST1, the general post processor, and POST26, the time-history processor.POST1 allows you to review the results over the entire model at specific load steps and sub steps. POST26 allows you to review the variation of a particular result item at specific points in the model with respect to frequency, or with respect to some other result points.

3.8 SELECTING AND COMPONENTS

Select logic is the ability to select subsets of nodes, elements, Key points, lines, etc. so that you work with a handful of entries. The ANSYS program uses a database to store all the data that you define during an analysis. This database design allows you to select only a portion of the data without destroying the rest of the data.

You can select a subset of entities by using a combination of seven basic select functions: select, reselect, also select, unselect, select all, select none, and invert.

3.9 DESIGN OPTIMIZATION

Design optimization is a technique that seeks to determine an optimum design. To calculate an optimum design, the ANSYS program performs a series of analysis and the usual procedure for design optimization consists of six main steps:

- Initialize the design variable parameters
- Build the model parametrically
- Obtain the solution
- Retrieve the results data parametrically and initialize the state variable and objective function parameters
- Declare optimization variables and begin optimization (OPT)
- Review and verify optimum results

IV. ANALYZING THERMAL PHENOMENON

A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are:

- The temperature distributions
- The amount of heat lost or gained
- Thermal gradients and fluxes

Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate *thermal stresses* (that is, stresses caused by thermal expansions or contractions).

4.1.1 How ANSYS Treats Thermal Modeling

The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The finite element solution performed via ANSYS calculates nodal temperatures, and then uses the nodal temperatures to obtain other thermal quantities.

The ANSYS program handles all three primary modes of heat transfer: conduction, convection, and radiation. Convection

An ANSYS user specifies convection as a surface load on conducting solid elements or shell elements. You specify the convection film coefficient and the bulk fluid temperature at a surface; ANSYS then calculates the appropriate heat transfer across that surface. If the film coefficient depends upon temperature, you specify a table of temperatures along with the corresponding values of film coefficient at each temperature.

Temperature plot

Temperature plot shows the distribution of temperature over the entire length of radiator fin with different temperature represented by different color.

The right side is the entry side of the hot oil whereas the left hand is the exit of oil from radiator fin.

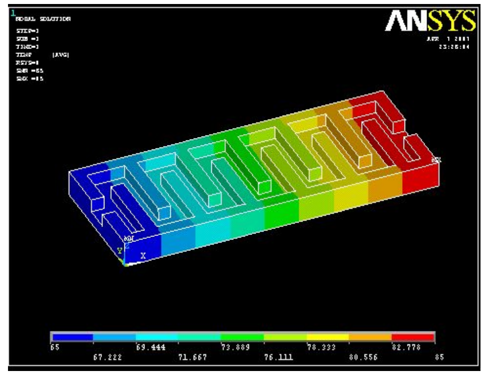

FIG. 3.4

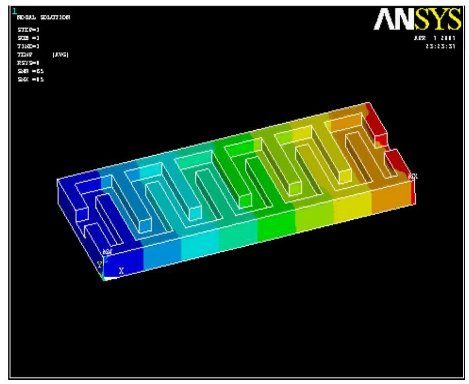

FIG 3.5

K1=55W/m K(CR MS)

K2=235W/mK (Aluminium

(All the temperatures are in degree Celsius.)

Fig. 3.4 shows the temperature plot of Cold rolled Mild Steel whereas

Fig 3.5 shows the plot for aluminium. From the two plots it is quite evident that the heat transfer achieved in aluminium is more.

The temperature change can be seen by the change in colour on the radiator model.

Thermal gradient plot

Thermal gradient plot shows the change in temperature with respect to length.

The temperature plot shows the change of (dT/dx) over the radiator length.

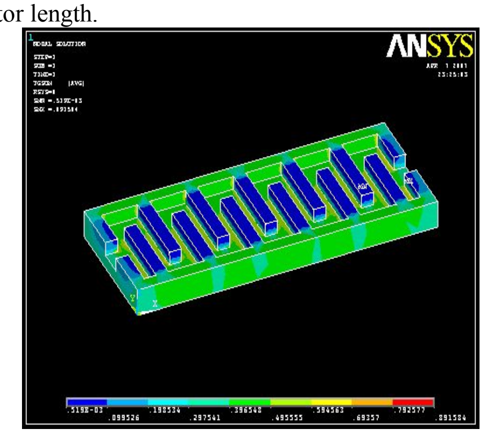

FIG 3.6 Thermal gradient plot

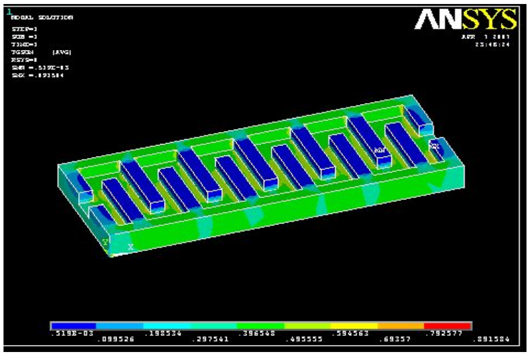

FIG 3.7 Thermal gradient plot

K1=55W/mK (CRMS)
K2=235W/mK (Aluminium)

Above figure shows thermal gradient of radiator model where cold rolled mild steel material is used.
The above figure shows thermal gradient plot of radiator fin made of aluminium.
From the figure we can see that the temperature decreases considerably greater along the length as compared to cold rolled mild steel.

Thermal flux

The rate of flow of fluid, particles, or energy through a given surface is called flux. Thermal flux is defined as the number of lines through the given surface. The flow of heat from, or to the surface through which heat flows creates a small temperature difference between the upper and lower surfaces of the metallic fin.
The above figure shows the thermal flux at various region of the cold rolled mild steel radiator fin.

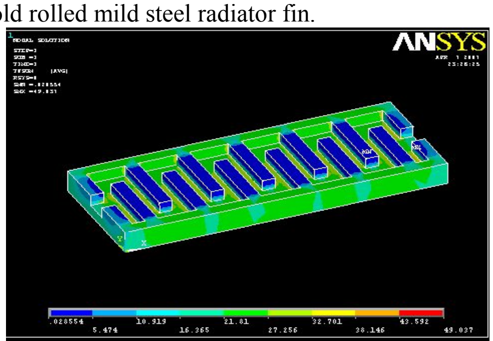

FIG 3.8)

K1=55W/mK(CRMS

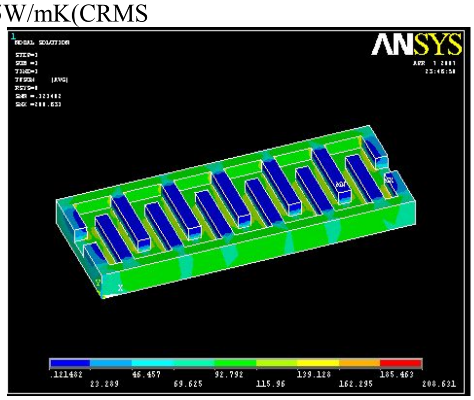

FIG 3.9)

K2=235W/mK (Aluminium

The above figure shows the thermal flux at various region of radiator made of Aluminium.

V. RESULTS / DISCUSSIONS

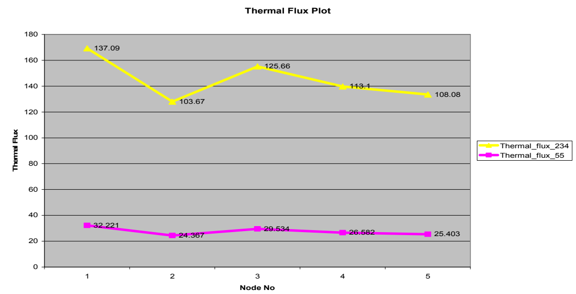

FIG 4.1 COMPARATIVE GRAPH

From the above graph we can infer that as the node number increases the thermal flux fluctuates between a specific range. We can also infer that the thermal flux for Aluminium is greater than that of mild steel.
Summarizing from the information above, the various factor that affect the thermal performance of the radiator are as listed below:

1. Width of plate

Affect heat transfer area for the same center to centre distance between header but the plan footprint changes and must remain acceptable.
Changes intake of ambient air but follows the law of diminishing return.

2. Length / Height of radiator or center-to-center distance between headers:

Performance improves with increasing Length / Height, again governed by the law of diminishing returns.

3. Number of plates :-

Performance improves with increasing number of plates, again governed by the law of diminishing returns.

Intake of ambient air increases with number of plates
The heat transfer area increases linearly with number of plates.

4. Header size :-

Performance improves with increasing header size. Reduces pressure drop for fluid flow.
For the same top oil temperature a lager pressure drop available across the radiator ensuring higher flow velocity and hest transfer coefficient.

5. Oil flow capacity :-

Performance improves with increasing oil flow capacity, Increases LMTD due to reduced temperature drop in Radiator fluid.
A good indicator is the oil holding capacity of the radiator plates, a larger capacity means a larger hydraulic diameter and so reduced friction for flow this reduces the drop in oil temperature ensuring a higher.

6. Heat transfer area:-

Performance improves with increasing heat transfer area, enhanced surface due to ripple increases heat transfer area, however ripple could reduce the flow rate due to torture oil flow path and increase pressure drop.

7. Distance between plates:-

Performance improves with increasing distance between plates.

It reduces the interference between the boundary layer for air.

VI. FUTURE SCOPE OF WORK

The heat transfer rate can also be increased by increasing the design and shape of the radiator.

A deep and complex analysis can be done by using "Computational Fluid Dynamic (CFD) Analysis"

By the use of Non-Rusting materials like Aluminium alloys, much advanced water sprinklers can be used to reduce high temperature.

The use extruded aluminum finned tubes to provide a highly efficient heat transfer surface. The integral fins can be fabricated as one piece through a rotary extrusion process, eliminating the problem of galvanic corrosion associated with other fin types.

CONCLUSION

The thermal analysis of 132/11 kV step-down transformer is done by using ANSYS software. Various figures showing the thermal gradient, thermal flux were obtained.

The high temperature can have detrimental effects on the performance and life of radiators and other important components inside the transformer. The analysis shows it is possible to bring down the temperature. We have reached to a conclusion that our analysis is about 60% correct considering various factors that affected the heat transfer. By using different material we have shown graphically that the temperature can be reduced.

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