IOSR Journal of Electrical and Electronics Engineering
e-ISSN : 2278-1676, p-ISSN : 2320-3331
PP 13-19
www.iosrjournals.org

Computation of single phase distribution transformer faults by finite element method.

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ABSTRACT : *With the appearance of deregulation, distribution transformer predictive maintenance is becoming more important for utilities to prevent forced outages with the consequential costs to detect and diagnose a transformer internal fault requires a transformer model to simulate these faults. This project presents finite element analysis of internal winding faults in a distribution transformer. The transformer with a modeled using coupled electromagnetic and structural, thermal, electrical finite elements. The terminal behaviors of the transformer are studied by an indirect coupling of the finite element method and circuit simulation. The procedure was realized using commercially available software. The normal case and various faulty cases were simulated and the terminal behaviors of the transformer were studied and compared with field experimental results. The comparison results validate the finite element model to simulate faults in a distribution transformer.*

Keywords – *Transformer, finite element method, stress, strain, losses.*

I. INTRODUCTION

A transformer is a static piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency. In another circuit, it can raise or lower the voltage in a circuit but with a corresponding increase or decrease in current. The working is based on mutual induction between two circuits is linked by a common magnetic fluids.

In its simplest form it consists of two inductive coils which are electrically separated but magnetically linked through a path of low reluctance. If one coil is connected to source of alternating voltage an alternating flux is set up in the core. Most of which linked with the other coil in which produces mutually induced emf. According to faraday's law of electromagnetic induction. (e= md I/dt). If the secondary coil Circuit is closed, a current flow is it, electric energy is transferred from first coil to the second coil.

The transformer consists of following essential parts:

l) Coil: - The transformers consist of two coils having mutual inductance and a laminated steel core.

2) Core: - The two coils are insulated from each other and from steel core. The core is constructed of transformer sheet steel lamination continuous magnetic path with minimum air gap included. The steel used of high silicon contact sometime heat treated to produce a high permeability of a low hysteresis loss at the usual operating flux densities.

The eddy current loss is minimized by laminating the core the lamination being insulate from each other by light coat of core-plate varnish or by an oxide layer on the surface. The core laminations are binned. Transformer of generally two types Core type & Shell type

1.1 Sources of Heat Generation

The main source of heat generation in transformer comes from various losses inside transformer and the main losses are iron and copper loss.

1.1.1 Iron loss

Due to the alternating cement flowing through coils the alternating EMF induces in the core and they produce some losses in the low iron losses consists of

A.Hysteresis loss

B.Eddy current loss

A. Hysteresis loss

This loss due to the reversal of magnetization of core every pution of core undergoes one complete cycle of magnetic reversal after putting one cycle of alternating current through coils.

This reversal causes the hysteresis loss.

This loss depends on the volume and grade of iron maximum value of flues density and frequency of magnetic reversal.

B. Eddy current loss:

According to for a day's law when the coil is linked with core the EMF induced in the core. This EM F set up long current in the body of core due to its small resistance. This current is known as eddy current. The power loss due to the flow of this current is known as the eddy current loosed. This loss could be considerable if solid iron core were used. In order to reduce these losses and correspond heating of the core to small value the core is build up of thin laminations, which are started and then riveted at right angles to the path of eddy current their core are insulated from each other by thing coating of warmish.

1.1.2 Copper losses

All winding have some resistance (though small and hence there are copper losses associated with current flow in them). The copper losses can be sub divided into primary coil loss and secondary coil loss. These copper losses are proportional to the square of the current.

1.2 Dissipation of heat

The losses produced in the core and conductors of transformer are converted into heat, which raises the temperature of the several parts the presents of ambient air and ventilating system tends to drop the temperature of transformer in a dry type transformer. The tamp rise actually obtaining depends on the relation between the condition of cooling and the amount of heat produced. The final temperature is reached when the rate of heat production is equal to rate of heat dissipation.

A hot body dissipates heat by radiation, conduction and convection. Most of heat is removed from dry type transformer by combination of convection and conduction assisted somewhat by radiation by surfaces.

In core of dry type of transformer the most heat is conducted dissipated by face convection in this process when a surface is maintained in still fluid at a temperature higher than that of fluid. A layer of fluid add to the surface gets heated. A density difference is created between this layer and still fluid surrounding it the density difference introduce buoyant force causing flow. Of fluid near to the surface and the heat is arrived away.

The heat carried away by convection is given by "Q=hA(ts-tq)"

Q = Heat transform W

h = Convection coefficient W/m^2 °c

A = Area m^2 and

Tq = temperature of fluid at distances well removed from the surfaces temp rise of insulation

It may be said that the insulation of the transformer constitutes their weakest member insulating materials are essentially non metallic, and have great variety of constitute. An ideal insulating material should have.

1.High dielectric strength
2.Good heat conductivity
3.Permanence/ particularly at high temp.
4.Good mechanical proportion
5.Resistance to failure by abrasion or bending.
6.No alteration for moisture.

II. GENERAL DESCRIPTION OF FINITE ELEMENT METHOD

In the finite element method, the actual continuum or body of matter like solid, liquid or gas is represented as an assemblage of sub-divisions called finite elements. These elements are considered to be interconnected at specified joints, which are called nodes or nodal points. The nodes usually lie on the element boundaries where adjacent elements are considered to be connected. Since the actual variation of the field variable (like displacement, stress, temperature, pressure and velocity) inside the continuum is not known. We assume that the variation of the field variable inside finite element can be approximated by simple function. These approximating functions (also called interpolation models) are defined in terms of the values at the nodes. When field equations (like equilibrium equations) for the whole continuum are written, the new unknown will be the nodal values of the field variable will be known. Once these are known the approximating function defines the field variable throughout the assemblage of elements.

The solution of a great continuum by the finite element method always follows: an orderly step-by-step process. The step-by-step procedure for static structural problem can be stated as follows.

Step 1: Discretization of the continuum structure (domain):
The first step in the finite element method is to divide the structure or solution region into subdivisions or elements. The number, size and arrangement of the elements have to be decided.

Step 2: Selection of a proper interpolation model
Since the displacement (field variable) solution of a complex structure under any specified load condition can't be predicted exactly, we assume some suitable solution within an element to approximate the unknown solution. The assumed solution must be simple from computation point of view, but it should satisfy certain convergence requirements.

Step 3: Derivation of element stiffness (characteristics) matrices and load vectors:
From the assumed displacement' model, the characteristic (stiffness) matrix [k (e)] and the load vector [P(e)] of element 'e' are to be described by using either equilibrium conditions or a suitable variation principle.

Step 4: Assembling of element equations to obtain the equilibrium conditions:
Since the structure is composed of several finite elements, the Individual element stiffness matrices and load vectors are to be assembled in a suitable manner and the overall equilibrium equations to be formulated as
[k] ¢= p
Where [k] is called the assembled stiffness matrix, < I > is the vector of nodal displacements and P is the vector of nodal forces for the complete structure.

III. ENGINEERING APPLICATION OF FINITE ELEMENT METHOD

The finite element method was developed originally for the analysis of aircraft structures. However, the general nature of its theory makes it applicable to a wide variety of boundary value of boundary value problems in engineering/a boundary value problem is one in which a solution is sought in the domain (or region) of a body subject to the satisfaction of prescribed boundary (or edge) conditions on the development variable or their derivative Applications of the finite element method divided into three major categories of boundary value problems viz.

a. Equilibrium or steady state or time independent problems.
b. Eigen value problems.
c. Propagation or transient problems.

IV. PERFORMING 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.
A typical ANSYS analysis has three distinct steps:

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

4.1 Element Type:

The ANSYS library contains different element types. Each element type has a unique number and a 'prefix that identifies the element category. The following element categories are available:

Table 4.1 Types of elements

BEAM	**PIPE**	**COMBINATION**
PLANE	CONTACT	SHELL
HYPERELASTIC	FLUID	SOLID
SOURCE	INFINITE	SURFACE
LINK	USER	MASS
INTERFACE	MATRIX	VISCOELASTIC

The element type determines, among other things:
•The degree -of -freedom (DOF) set
•Whether the element lies in 2-D or 3 -D.

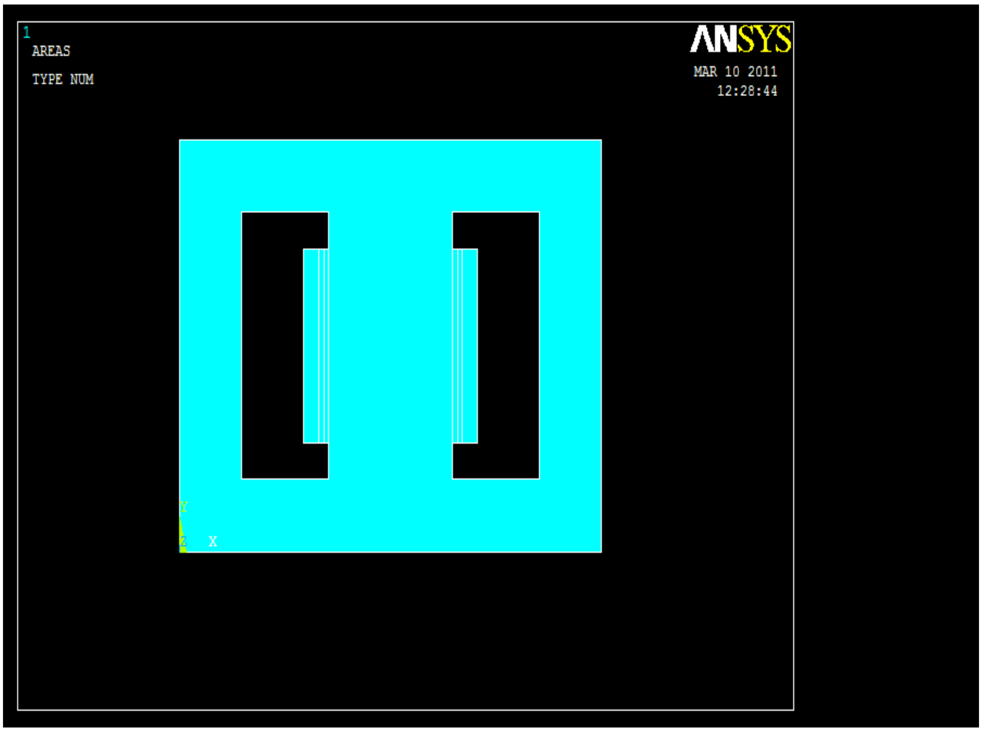

Fig.1 Transformer 2-D Model

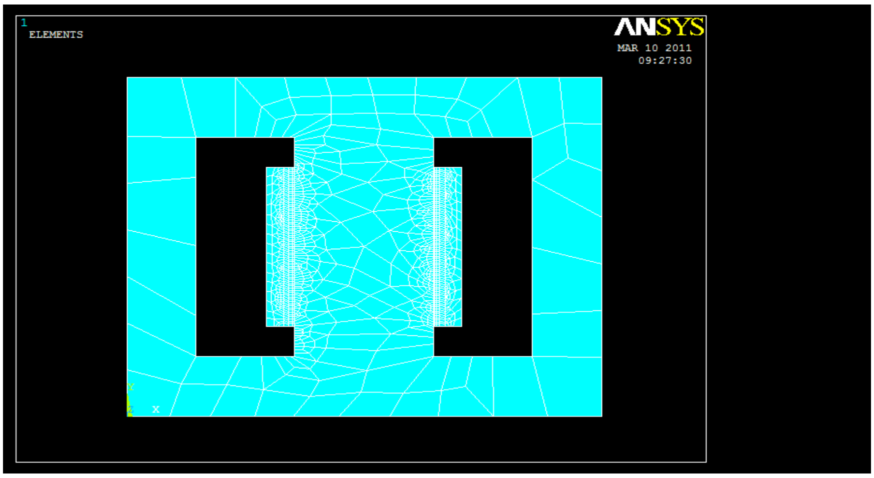

Fig 2. Meshing of 2D model

V. ANALYZING THERMAL PHENOMENA

A Thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities are:
•The temperature distributions
•The amount of heat lost or gained
•Thermal gradients
•Thermal fluxes

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a. Types of Thermal Analysis:

ANSYS supports two types of thermal analysis:

i. A steady-state thermal analysis determines the temperature distribution and other thermal quantities under steady-state loading conditions.

ii. A Transient thermal analysis determines the temperature distribution and other thermal quantities under conditions vary over a period of time.

VI. SIMULATION OF THERMAL AND ELECTRICAL DISTRIBUTION IN A TRANSFORMER

6.1Initial and boundary condition :

For analysis of the following are taken as initial and boundary condition -The heat produced by losses is given in table. The heat transfer coefficient at the surfaces given in the respective analysis.

1. The temperature of air is assumed to be 35°C.
2. The air temperature in small gaps is assumed to be 40°C.

The properties of materials are,

Table 6.1 the properties of different material

Table Material Properties / Sr. No.	Material	Thermal Conductivity *KW/moc*	Density Kg/m"	Specific heat KJ/Kgk
1	Copper	0.829	8940	0.385
2	steel(core)	0.0265	7650	0.452
3	PVC insulation	0.0002	1300	0.97

6.2 Problem definition

The Electrical analysis was carried out for a 1KVA 15/230 1 Phase shell type transformer.

The geometry the transformer and its· Electrical properties are known we have calculated current and voltage distribution volume at various portions. The natural air connection is being happened for transformer cooling. The problem is to find out the Electrical distribution in the following cases.

1. Transformer with normal load condition.
2. Transformer with faults condition.

6.3 For analysis we have mode following assumptions.

1. Steady static condition
2. The Electrical properties of material do not vary with temperature.
3. The current and voltages transfer coefficient of core is more than coil surface.

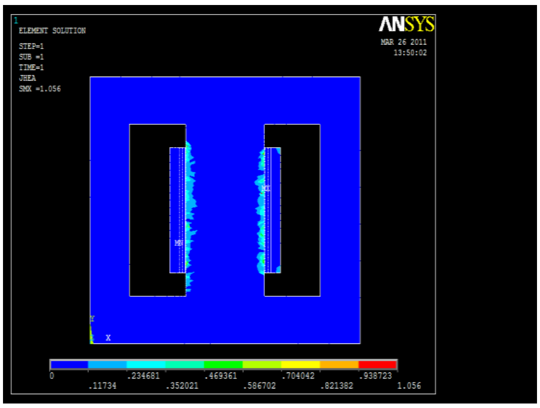

Fig. 3. Heat generation in the transformer winding

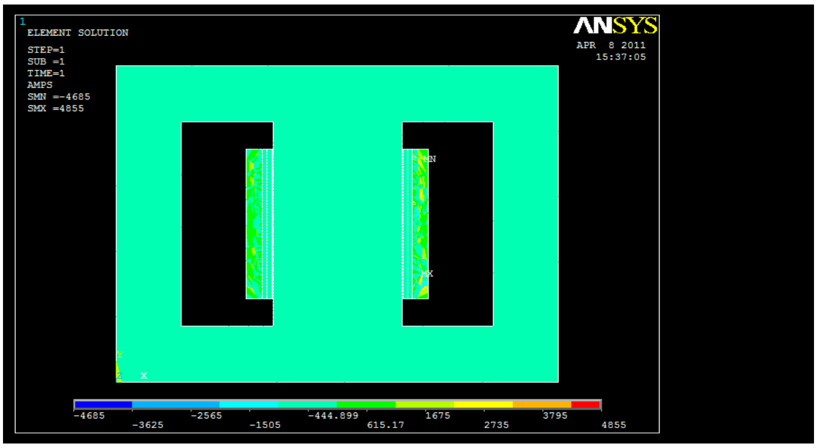

Fig 4. Current distribution in transformer

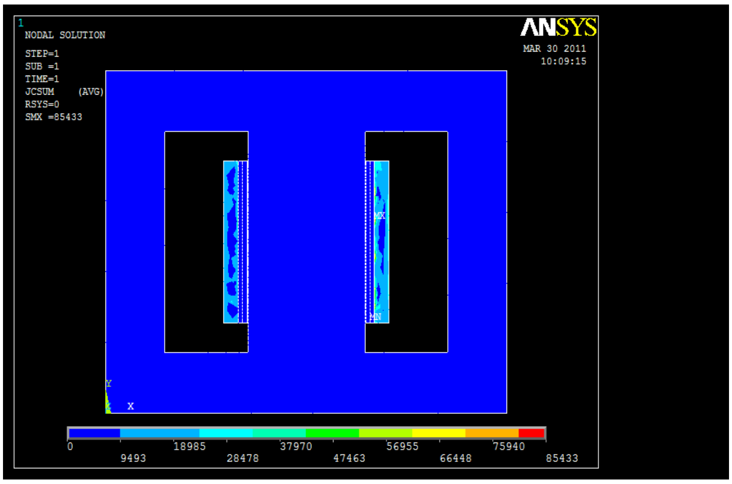

Fig. 5. Charge distribution in transformer winding

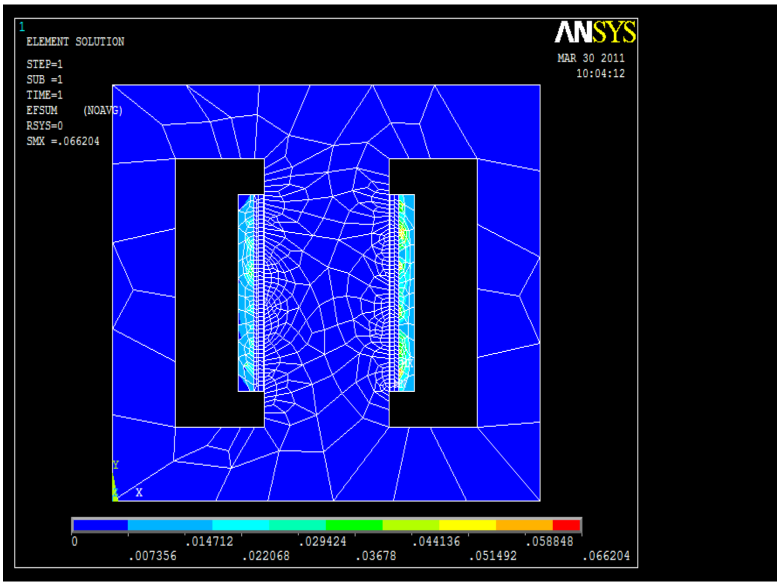

Fig 7.4 electric field vector sum

VII. CONCLUSION

In this paper, when an internal fault occurs, the leakage flux of the transformer enlarges. If the fault is on the primary winding, the secondary voltage and current will not change. Primary current increases and the current flowing in the shorted turns are very large if the fault is on the secondary winding, the secondary voltage and current decreases and the primary current increases. The terminal values in the simulations and the experimental results were compared. The comparison results validated the finite element model for simulation of internal faults in distribution transformers. From simulation and experimental results we see that the FEA transformer model can provide an accurate estimation of the terminal values of an internal winding fault for a distribution transformer.

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