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THEORETICAL ANALYSIS OF ELECTROMAGNETIC MODEL OF A TRANSFORMER FOR DETECTION OF FAULTS BY USING FREQUENCY RESPONSE ANALYSIS

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ABSTRACT

Power transformers prove to be a vital element or tool in electrical power supply and transmission system. They are capital intensive units and need to be monitored for faults. Faults in transformers leading to their failure are unacceptable. Thus, there is a need to detect such faults at an initial level. This project is to detect the short circuit faults in any turn by theoretical and experimental methods, using frequency response analysis. Theoretical calculations are done by using the EMTP (electromagnetic transient program) software. With the help of EMTP voltage, current and frequency at each node can be seen. And further, by comparing these graphs with the faulty transformer, the fault can be identified at each node. Experimentally an electromagnetic model of the transformer is made by using enamel copper wire winding on a cylindrical hollow pipe. And by applying impulse voltage the respective current and voltage graph can be obtained, which can be further compared with the fault condition of a transformer.

I INTRODUCTION

Power transformers are an important part of the power systems. The transformer must work properly for the reliability of the connected system. This will provide uninterrupted quality power to the utility. Neutral current comparison at full and reduced voltage is used to detect a fault in transformer during Standard lighting Impulse voltage Test. However, there are disadvantages in terms of the proper determination of fault, particularly if minor fault i.e. only one turn fault is involved. Several diagnostic methods have been used by testing agencies to determine different types of fault in transformers.

Thus, Frequency Response Analysis (FRA) is a useful tool to determine fault in a transformer. It is also used for determining twist, bulge and other deformation in power transformers.

The most important method used to determine fault in a power transformer is Sweep Frequency Response [SFR] technique. In this method, a low voltage of 10 volts is applied between terminals of transformer at selected frequencies between 10 Hz and 2 MHz[1-4]. A plot of the ratio at the above frequencies is obtained. This work as the initial signature of the transformer. Any fault caused in transformer due to operation in system reflects a difference in frequency plot. This difference in the plot is used to obtain the type of failure of the transformer.

The other method is by applying impulse voltage to the winding and subjecting neutral current to FFT analysis[5-8]

II. FREQUENCY RESPONSE ANALYSIS TECHNIQUE

It has been observed that in a large transformer it is difficult to locate the position of a fault in the winding. Due to which if any faults occurs in transformer the whole winding need to be replaced. This takes time and leads to an interruption in power supply.

This paper deals with the detection of turn faults in the winding of a transformer. First, the electromagnetic model of a transformer is constructed by comparing the inductance and capacitance of a standard transformer. The consideration given is that the frequency response of the main transformer must remain same for building an electromagnetic model. Voltage and current characteristic are estimated by using Electro-Magnetic Transient Program(EMTP). Finally, the Frequency response [FR] is obtained by using FFT program.

By comparing both the FR of healthy model and model with simulation, the fault is detected.

III. CONSTRUCTION OF AN ELECTROMAGNETIC MODEL OF A TRANSFORMER.

In order to construct a model of the transformer winding, the high voltage winding of an 11.5 kV/230kV, 61MVA is considered. The HV winding is divided into 6-section. The resonant frequencies were calculated.

The electromagnetic model was constructed based on the above resonant frequencies and availability of suitable non-inductive capacitors. The Electro Magnetic model is designed with an insulating pipe of radius 11 cm with wall thickness of 3mm. It is wrapped with an enamel-insulated wire of diameter 1 mm. It consists of 500 turns divided into 6-section. Each section is connected in parallel with 8500 pF capacitors to simulate the capacitors of section of main transformer. Similarly section to ground capacitance of 200 pF is connected to take into account the core to winding capacitance.

Formula use

a)Self inductance

L=$\frac{\mu_0 \mu_r a n^2}{l}$=$\frac{4\pi\times10^{-9}\times1\times93.31\times83.5^2}{10}$

=0.81754 mH

Capacitance in parallel

c_s=8500 pF (Obtained from transformer parameter calculation)

Capacitance to ground

c_g=$\frac{\varepsilon_0 \varepsilon_r a}{d}$=$\frac{8.854\times10^{-4}\times2.5\times1648.50}{0.3}$=

1216.31 pF

a=$\pi D \times l = \pi \times 10.5 \times 50 = 1648.5 cm^2$

Frequency

$$f_{r=}\frac{1}{2\pi\sqrt{lc}}=\frac{1}{2\pi\sqrt{0.8175\times10^{-3}\times8500\times10^{-12}}}=60.376kHz$$

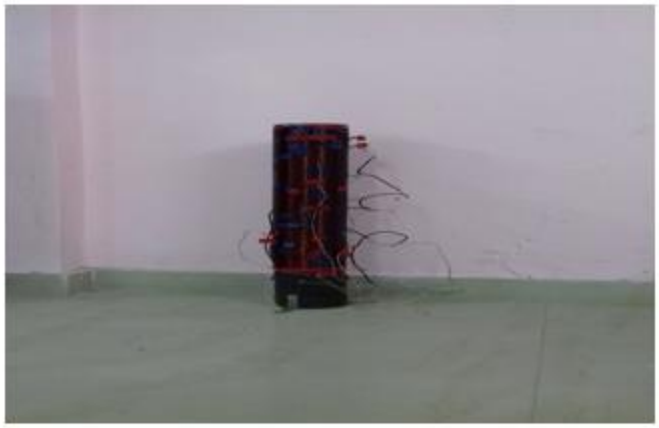

Figure1:- Electromagnetic model of HV winding of 60 MVA, 11 kV/230kV transformer.

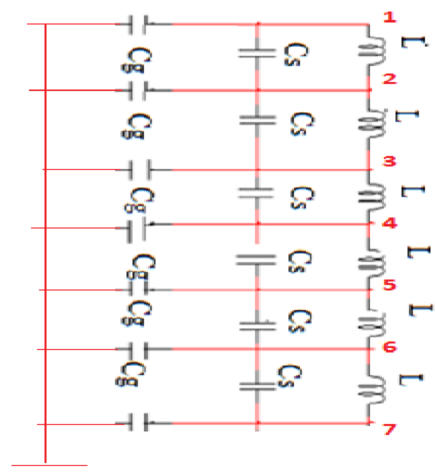

Figure 2.Equivalent network of electromagnetic model.

IV. RESULT AND ANALYSIS

Voltage and current graphs are obtained by using EMTP software. The data for software is given in the form of inductance in mH and capacitance in μF. The Impulse source by using the code specified in rule book of EMTP [9] .

Without fault

b) Voltage graph at node 1,node 2,node 3

node 1 node 2 node 3

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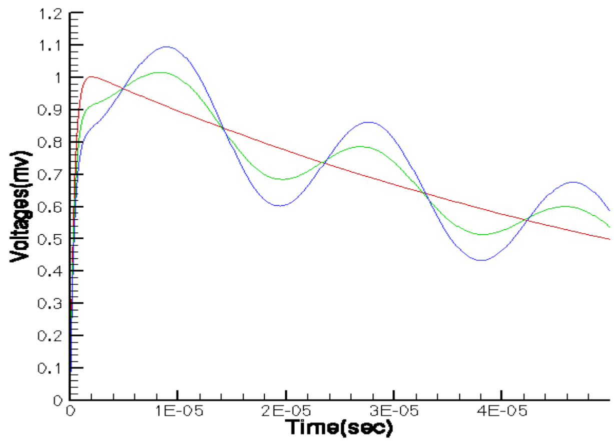
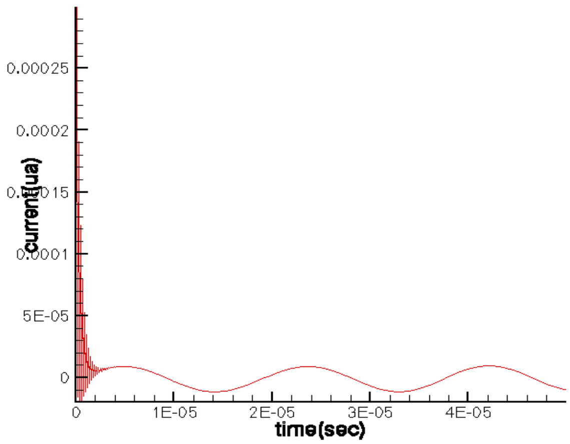


Figure 3. Voltage output of transformer at various nodes without fault

In Figure 3 node 1 is the impulse voltage. Voltage at node 2 and 3 seems to be greater then applied impulse voltage . This happens because of LC oscillations.



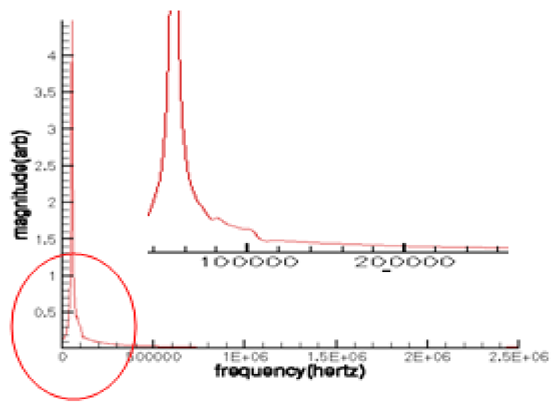


Figure 4. current in the neutral circuit **Figure 5: Frequency of transformer without fault**

Figure 3 and Figure 4 shows the voltage and current graphs respectively. Three voltage curves at node 1,2 and 3 can be observed in Figure 3. Figure 4 shows the current at node 7 which is the neutral current of transformer. FFT program makes use of 2048 (2^{11}) values for deconvolution into frequency domain.

Figure 4 represents the frequency of the transformer without fault. The frequency can be observed as 55 kHz.

Analysis with fault is described below .

The faults are created in model by shorting nodes one by one to simulate the failure of winding. For every fault the current in the neutral is calculated.

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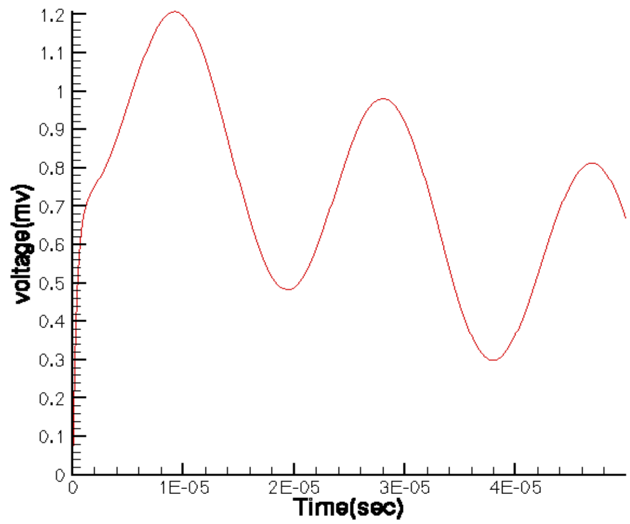

Figure 6: Voltage at node 6 after shorting node 5 and node 6.

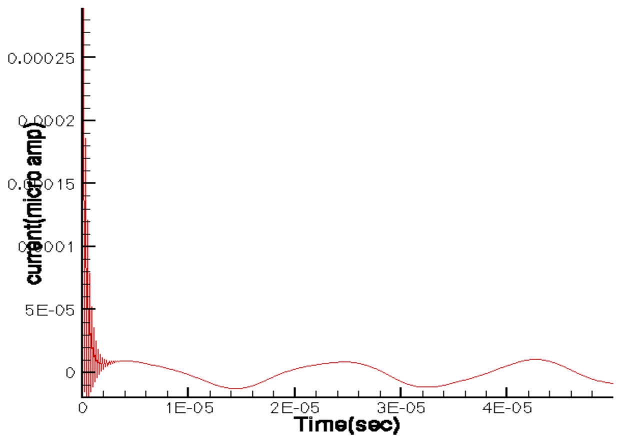

Figure 7: current between node 7 and ground between node 5 and node 6.

Few variation can be seen in the above Figure as compared with the previous Figures.
Frequency Response of Figure 7 is shown in Figure 8.

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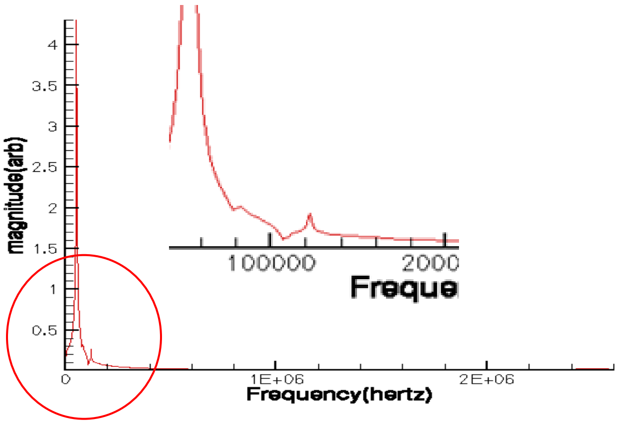


Figure 8: frequency of transformer with fault

Difference between Figure 5 and Figure 8 can be seen, with regard to occurrence of frequencies. In Figure 5, it can be observed that only one peak at 55 kHz is seen clearly where as other peaks are obscure. In Figure 8 there are existence of two frequencies viz 55 kHz and 120 kHz. Figure 6 is the representation of the voltage at the shorted node and figure 7 is the current of the transformer.

Short circuit is selected between section 2 and 3 while short circuit exist between 5 and 6 and voltage is recorded between 2 and ground as shown in Figure 9. The current in this configuration is shown in Figure 11.

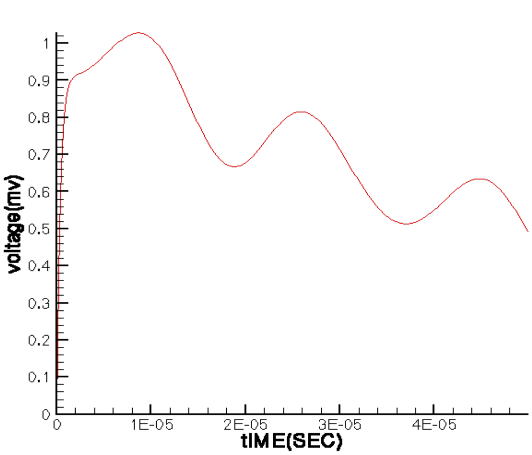


Figure 9: voltage at node 2 after shorting node 2 and node3.

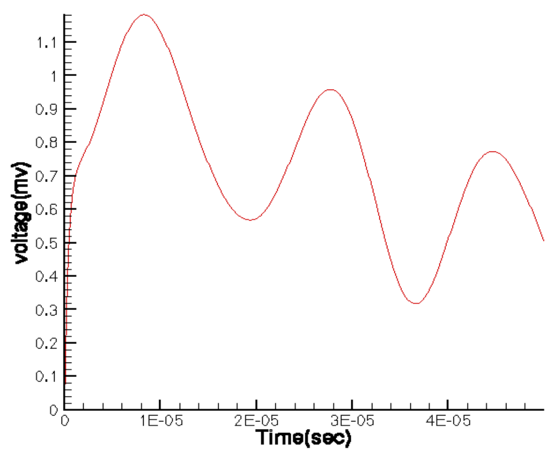
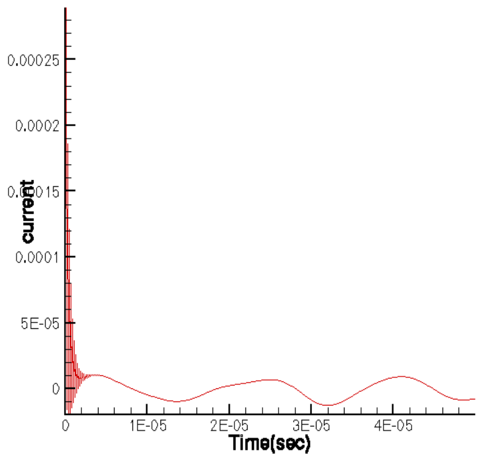


Figure 10: voltage at node 5 after shorting node 4 and node 5.

The voltage recorded between 5 and 6 is shown in Figure 10. Frequency Response of Figure 9 is shown in Figure 12.



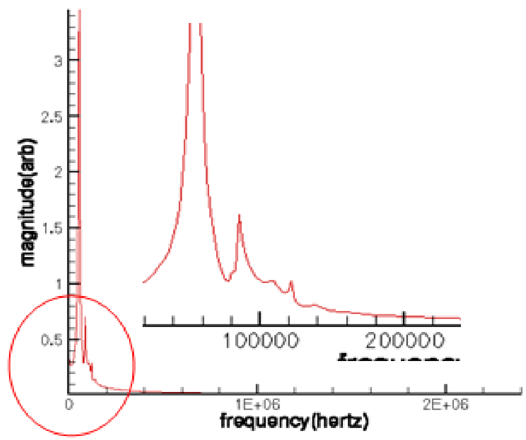
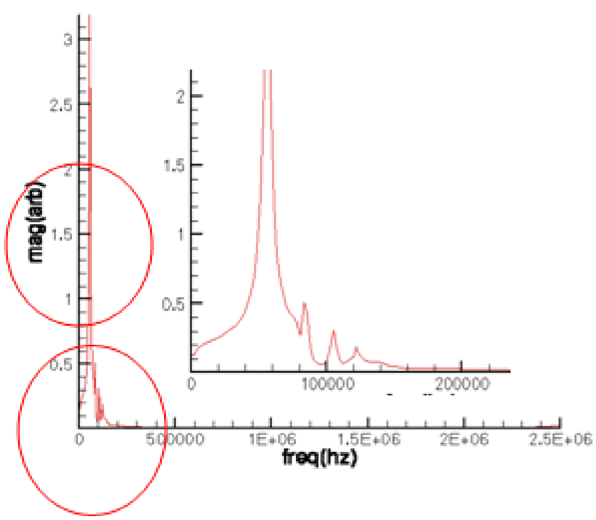


Figure 11: current between node 7 and ground . **Figure 12: frequency for faults at two nodes**

Fault at three nodes

Figure 13 shows the frequency response for the case of three short circuit s node 2-3,4-5 and 5-6.



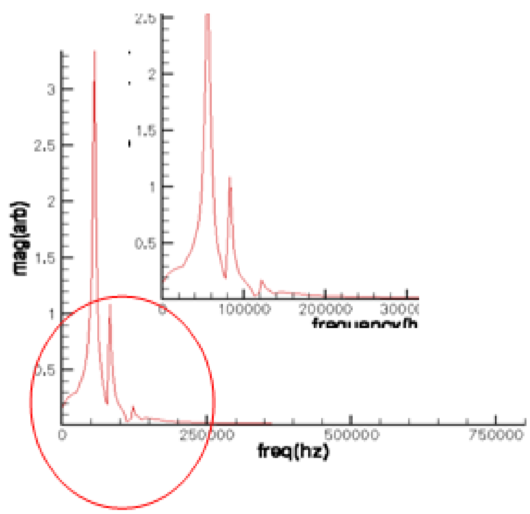


Figure 13: frequency for faults at three nodes **Figure 14: frequency for faults at three nodes.**

Figure 14 shows fault in the same sections, however the number of turns shorted is made equal in two sections and in third section number of turns shorted is different.

It is observed that depending on the number of turns shorted and location of section the number of frequencies and the magnitudes vary.

V. CONCLUSION

The comparison of result show that the number and magnitude of frequency in a winding depends on the number of turns shorted and location of short circuit. Further by comparing the voltage and current at each node there is a likelihood of locating the region of fault.

VI. ACKNOWLEDGEMENT

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