Simulative Experiment of Major and Minor Inter-Turn Short Circuit Faults in Power Transformer Windings

O.Sobhana, V.Ganesh, M.Surya kalavathi

Abstract: Frequency Response Analysis is offline technique to detect the winding deformations. This paper intends to analyze the power transformer under major and minor inter-turn short circuit faults in the winding of transformer using simulative study. An EMTP-RV based lumped circuit model was given based on the number of sections and turns of winding to simulate the faults at different levels by short circuiting windings of adjacent turns with modified circuit parameter for each fault level and simulated results have represented as neutral current in time-domain and corresponding frequency responses with and without fault levels were plotted for major and minor inter-turn faults.

Index Terms: EMTP-RV simulation, lightning impulse, lumped circuit, FRA.

I. INTRODUCTION

The main cause of inter-turn fault is due to decoration of turns of adjacent windings leads to occurrence of short circuit current may cause considerable damage to the insulation integrity between turns and windings. Many detection and identification methods were presented in past years [1-3] to overcome the offline method several researches discussed new online techniques to identify the faults based on current locus diagrams [4] when the transformer is in working situation. New methods were proposed based on digital image processing to find the fault [5].but because of the sensitivity of minor i.e., single, two three turn fault analysis in the early stage is still challenging for the reliability of transformer.

In accordance with test procedures standardized for power transformer lightning impulse test is performed to assess the winding integrity. In the power transformer number of turns in the winding is huge which is not possible with human intervention. An impulse test is conducted by applying standard impulse voltage of full magnitude to locate the turn fault in the windings by measuring the neutral current at one end of the winding. Several methods are in exist such as sweep frequency response analysis and transfer function method, though Frequency Response Analysis is one of the offline method used to find the fault in a transformer [2-4] have proposed.

FRA is most popular method to assess the mechanical deformations caused by the short circuit faults. The short circuit leads high current flow across the windings, creates electromagnetic forces which damage the winding. Due to interaction of flu density vector and current these short circuit forces were produced across the winding the fundamental basis of Frequency response analysis is change in frequency plot with change in inductance, capacitance of the winding under fault. Whenever there is a turn fault which changes the flux associated with that part according the frequency dependent parameters will effect which leads frequency responses of faulted section. Winding faults significantly changes the magnitude and shape of the neutral current and node voltages.

II. TRANSFORMER WINDING MODEL

To design the 160 MVA, 220/66KV power transformer only High voltage winding is considered. The HV side winding has two sections with each 631 turns because of symmetry only upper half of the winding is considered. The HV winding with interleaved section has divided into 8-sections with number of turns in each section are different. The number of turns in each section is different as per the given specification of transformer data sheet represented in Table. I.

Design parameter	value	Rating
Rating	160	MVA
Phase voltage HV/LV	220/66	KV
Frequency	50	Hz
No.of Winding turns	631	Turns
No.of discs	8	
HV Winding coil resistance	0.30189/75^{o}c	Ohms
Height of winding(HV)	1135	mm
Inner radius	484	mm
Outer radius	715	mm

Table.I Transformer design specifications

The EM model is designed by considering each section self-inductance and inductance with respect to every other section also capacitance across series discs, capacitance with respect to ground and core Grover's method [6] of equations are used to calculate self, mutual inductances also series and shunt capacitances are represented in the form of matrix form. as represented in Fig.1

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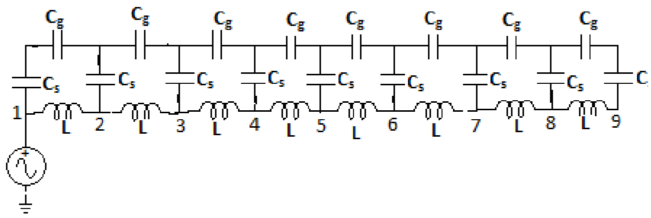

Fig1.EM Circuit model of transformer winding

Fault level	Short circuited turns
1%	7 turns in section-1
3%	18 turns in section-3
5%	32 turns in section-4

Table II. Major Fault level with shorted turns

The standard impulse wave shapes are chopped, lightning and steep fronted surges former two surges are caused due to lightning.

The marx impulse generator can be used with single stage and two stage to generate the wave shape as per standard time. A standard impulse of wave shape has front time 1.2µsec and tail time of 50µ seconds is acceptable. The generated impulse wave is applied at one end of transformer to measure the neutral current The Major faults were represented as percentage of fault level (FL) with total number of turns of the winding but minor faults were simulated with single turn, two turn and three turn fault were represented below in Table II.

$$\text{FAULT LEVEL} = \frac{\text{No.of S.C Turns}}{\text{Total No.of Turns}} * 100$$

Total Number of Turns = 631

The faults were analysed based on the fault level to show the effect on the neutral current and respective frequency response study to summarise the severity of fault level.

III SIMULATION RESULTS FOR MAJOR INTERTURN FAULTS

The Electromagnetic Circuit model is simulated by applying full impulse voltage on HV winding of 160 MVA Power Transformer and neutral current was measured at other end of same winding with a unit magnitude of resistance connected at the ground. For each fault level the simulations are carried out using the model designed in EMTP-RV. The faults were simulated as Major turn faults and Minor turn faults. the measured neutral current with different fault levels were simulated and also frequency responses were measured at different fault levels as major turn faults in the windings are considered with respect to fault levels.

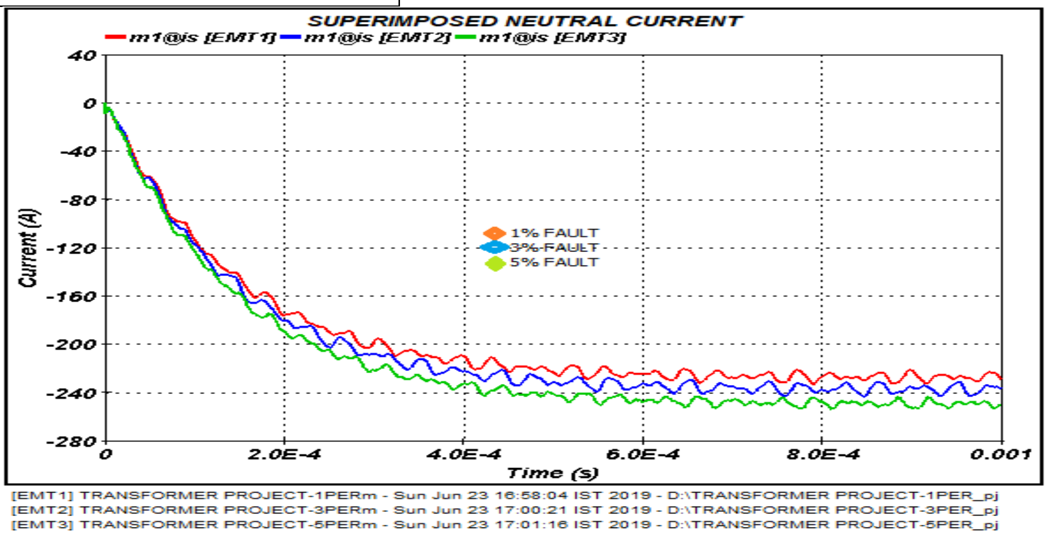

Fig.2 Neutral current measured with 1%,3%,5% turn fault

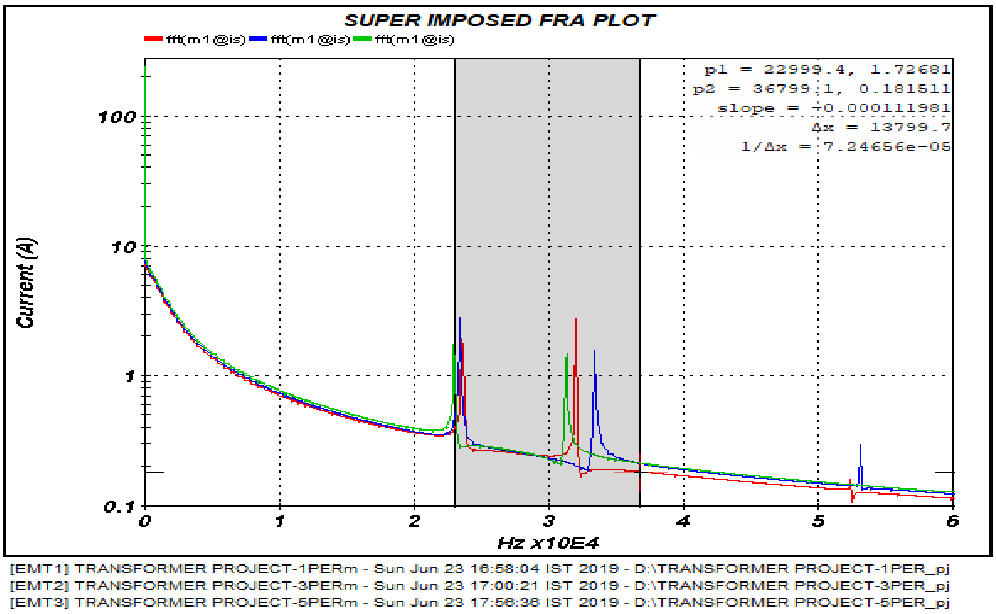

Fig.3. super imposed FRA plot for 1%,3%,5% fault levels

The measured neutral currents and frequency response plots are represented as in Fig.2 & Fig.3, magnitude of neutral current increases as the fault level increases in the windigs, but frequency responses measured with cursor point on graph with first and second peak values as represented in Table.III decreases with increase in percentage of fault level.

Fault level	Short circuited turns	Neutral current (Amp)	FRA Magnitude	
			1st peak (KHz)	2nd peak (KHz)
1%	7 turns	233.12	23.5994	33.0992
3%	18 turns	239.61	23.4994	32.4992
5%	32 turns	242.29	22.9994	31.3992

Table .III. Measured Neutral current's and FRA magnitude's

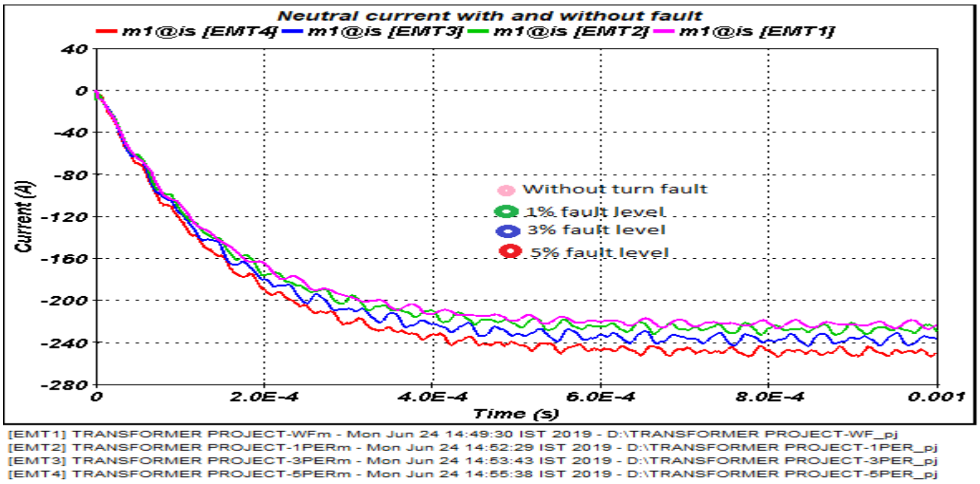

Fig.4. Neutral current with and without turn fault

IV SIMULATION RESULTS FOR MINOR INTERTURN FAULTS

Minor inter-turn faults were considered as single turn, two turn and three turn fault were simulated

Using EM equivalent circuit model. Minor and major faults were compared in the point of view of neutral current and corresponding frequency responses.

Fault level	Short circuited turns	Neutral current	FRA Magnitude	
			1st Peak (KHz)	2nd peak (KHz)
1%	1 turn	221.51	21.8000	28.6000
3%	2 turn	223.64	22.0000	28.6000
5%	3 turn	228.88	22.4000	29.4000

Table.IV Measured neutral current's and FRA magnitude's

The measured neutral current's and magnitude's of FRA responses shown in Table IV shows that magnitudes are very close to the major and minor faults

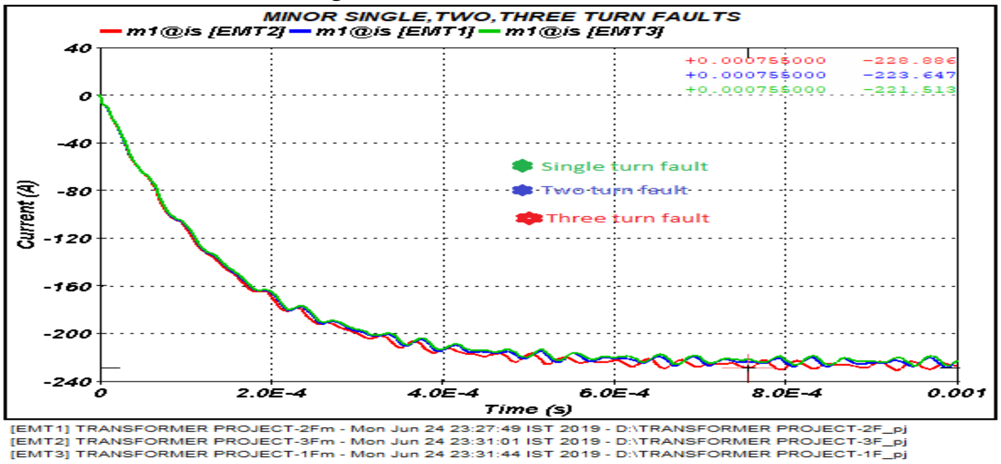

Fig .5 superimposed neutral current with single, two and three turn faults

When neutral currents and FRA magnitudes were superimposed as represented in Fig.5&6 the plot of single and two turn were overlapped at most of the frequencies but small deviation with three turn fault. So minor faults with single two turn faults cannot identified easily with simulated plots.

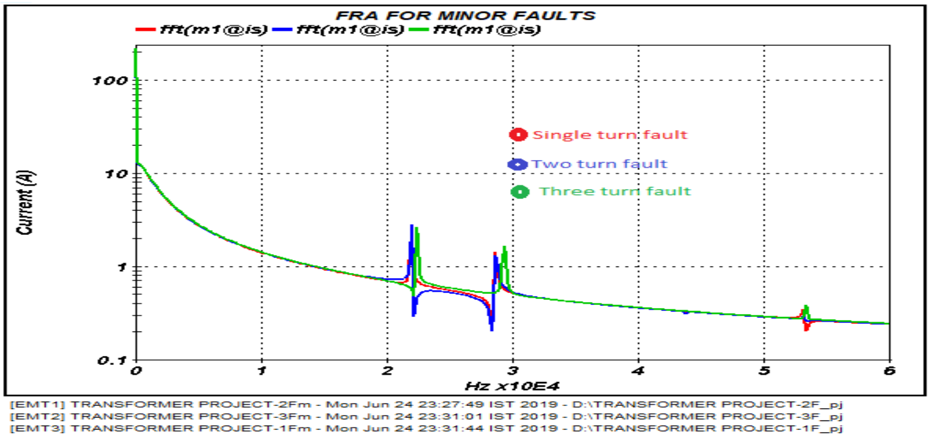

Fig.6 Superimposed FRA responses with single, two and three turn faults

V.CONCLUSIONS

The presented simulations of 160MVA, 220/66 KV transformer with major and minor faults simulations shows the following conclusions.

- The variation in neutral current magnitudes shows that with the severity of fault current magnitudes are increasing, but the magnitude of neutral current values are very close with minor inter-turn faults for single, two turn fault level.
- Resonant frequencies increases as the inter-turn short circuit develops when analysed for major and minor turn faults, but no appreciable difference in frequencies with minor turn fault only small change in magnitude of current.
- FRA is not very sensitive for detection minor faults particularly single, two and three turn faults.

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