

EFFECT OF RADIAL AND AXIAL MOVEMENT OF WINDING ON COHERENCE FUNCTION IN A 220/132 KV, 100 MVA, AUTO TRANSFORMER

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Abstract: *The short circuit force generated in Power Transformer due to system fault is known to cause movement of the windings. Several diagnostic methods have been employed to identify the movement of internal components of transformer e.g. Core, winding, coil bulging, coil twisting, Inter turn fault etc. The methods include – Sweep Frequency Response Analysis, Current reflection time, wavelet transform and Coherence Function (CF). The present work reports a detail analysis of Coherence Function due to radial and axial movement of coil by theoretically simulating the HV winding of 220/132 kV, 100 MVA autotransformer. The results show a variation in magnitude of CF for dominant frequencies and that even a small changes in radial or axial distances cause significant change in magnitude of CF. It is observed that sensitivity of detection of winding movement by CF is better than Frequency Response.*

Keywords: *Frequency Response Analysis, Transformers, Coherence Function, Winding Movement.*

1. Introduction

Power transformers are subjected to several types of abnormalities. Some of them are overvoltages due

to lighting, switching surges and faults. The currents associated with faults could reach upto several kiloamperes, depending on the distance of fault from the terminal of transformer. Faults closer to terminal of the transformer could lead to high transient currents of several kHz, lower damping and high level of D.C. offset. Thus winding of transformers experience abnormal force causing axial and radial movement. Although, windings are designed and in many cases tested for short circuit, a single fault may not affect the winding geometry. However, cumulative fault may cause the axial or radial movement of winding. Several research papers [1-5] have been published with regard to movement, based on Sweep Frequency Response Analysis[SFRA]. It is used as diagnostic tool for detecting movement of inter winding or windings with regard to core. The SFRA method is very effective in detection of winding displacement and fault. It is opined that the SFRA, though effective for overall movement or distortion of winding, it may not truly detect minor movements and localized bulging in the winding with the same accuracy due to low sensitivity of detection by Fourier Transform. Research work [6-9] have been published for detection of fault by

Coherence Function(CF) method based on analysis of neutral current for simulated turn fault.

It is generally observed that the determination of turn failure on the basis of Sweep Frequency Response Analysis [SFRA] is fraught with uncertainty. Main reason giving rise to uncertainty is that a turn failure leads to a small reduction in inductance due to low percentage reduction in turn compared to overall number of turns. Further, the turn failure in plain disc portion of the winding may lead to increase in overall capacitance. Hence, the frequency could continue to remain almost same. It is also known that most of the dominant frequencies for high voltage power transformer do not exceed 1 MHz. However, Sweep Frequency are considered up to two MHz in actual measurement. Thus any frequency difference that may occur in the vicinity of one MHz and above could contain noise. In such event the CF method of detection is found to provide additional information.

The sensitivity of detection of neutral current variation with the coherence analysis is higher than that of frequency analysis. Hence, method based on CF is evaluated on the basis of difference in neutral current for winding movement. Results of CF based on neutral current analysis with and without P.D.[10,11] have also been found to provide satisfactory information regarding P.D. in windings during impulse test. The effect of small movement in axial and radial direction based on CF technique is observed to provide useful information regarding displacement.

In the present work theoretical simulation of radial and axial variation has been carried out for a 100 MVA, 220 kV/132 kV auto transformer. For each variation, FFT and CF are calculated for neutral current with and without movement of the winding. A comparison of FFT with and without displacement provides the difference with regard to frequencies and respective peak magnitudes. The work reports

the variation of CF with variation in radius of the winding. The radial variation is simulated by varying the oil gap between LV and HV winding with corresponding increase / decrease in radius of the HV winding. The axial variation is simulated by increasing or decreasing the duct height along the Coil Depth(CD). A close examination of FFT result indicates that both the methods are capable of detecting the movement, however the CF is more sensitive than FRA.

2. Modeling of transformer for FFT and CF calculation

In order to simulate the condition for CF calculation, the winding of a high voltage auto transformer of 220/132/11 kV as given in Fig.1 is considered.

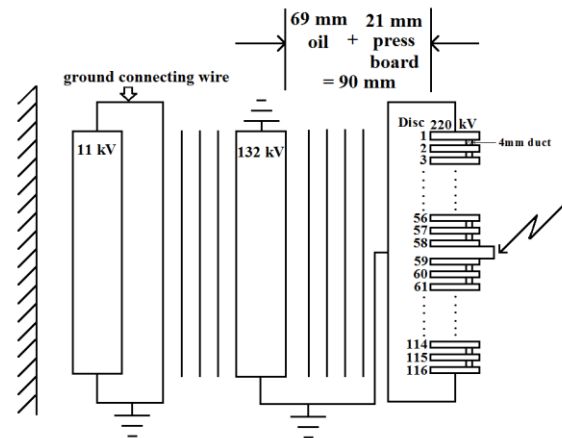


Fig.1 Schematic diagram of 220/132 kV auto transformer.

High voltage winding is divided into twelve suitable sections and remaining all windings are grounded in accordance with the guidelines for standard tests by lightning impulse voltage. Since, the high voltage winding of transformer is centre entry type with two-group configuration, only one half is taken into account for simulation purpose.

The inductance and capacitance associated with the six sections are calculated and required matrices

are formed. A method of calculation of inductance and capacitance parameter, matrix formation, impulse voltage calculation has been reported in earlier publications [12]. The equivalent network comprising self and mutual inductances and series and shunt capacitances is shown in Fig.2.

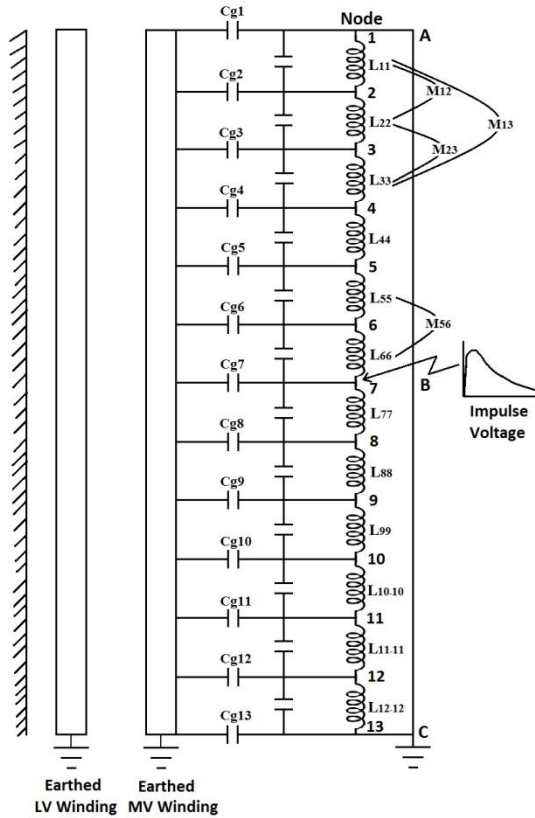


Fig.2 Equivalent circuit of 220/132 kV Transformer.

FFT of neutral currents with and without fault are taken with simulated fault. The comparison between two FFTs provides an indication of the inter turn failure. Larger differences in FR have been observed for winding movement or winding failures. The method of CF calculation using real and imaginary value of FFT is discussed in earlier publications [6,7,10,11]. The present work uses the similar concept for winding movement in radial and axial directions.

3. Results and discussion

In order to simulate radial variation the radial gap between HV winding and core is changed. The neutral current is calculated with HV and core dimensions as per manufacturer details. The average radius of HV Winding as per design is specified to be 673.5mm. The oil gap is increased by increasing the radius to 673.6 mm and once again neutral current is calculated. The neutral currents calculated for the two conditions are given in Fig3.

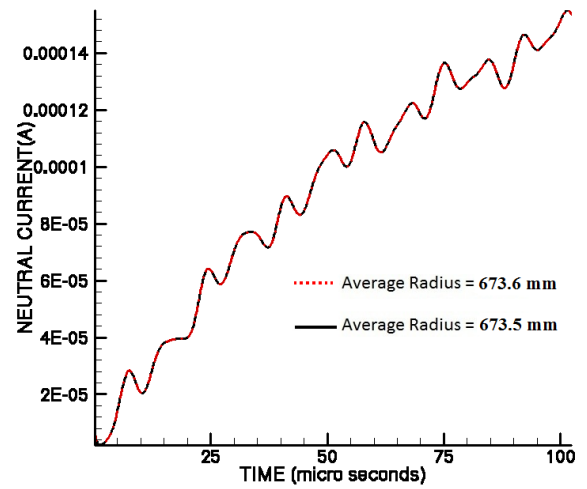


Fig.3 Neutral currents for radii 673.5 mm and 673.6 mm.

The FFT of the neutral current corresponding to the above condition is shown in Fig.4a and their CF is Fig.4b.

The neutral currents for the two radii as shown in Fig.3 indicate a marginal difference in the magnitude of neutral current over the entire time range.

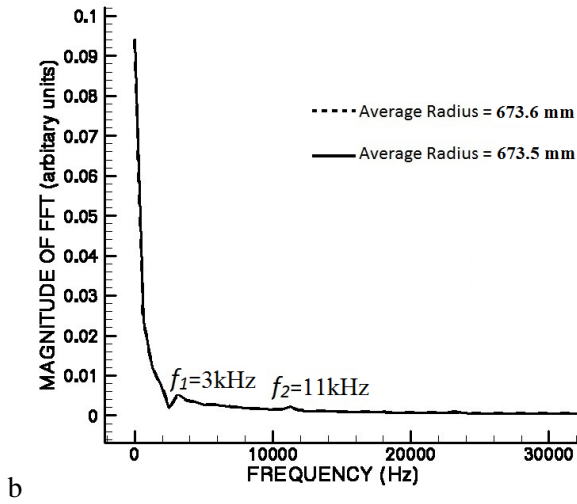


Fig.4a FFT of neutral currents for two radii

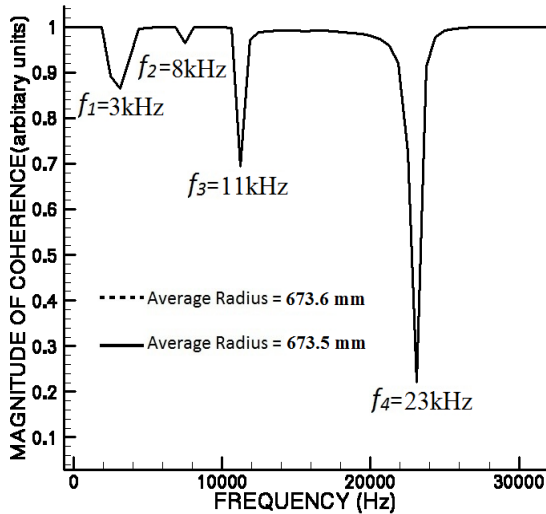


Fig.4b Coherence between neutral currents of Fig.3.

Similarly, it is observed from Fig.4a that there is a negligible difference between the two with regard to FFTs in respect of both frequency and magnitude. However, there is a considerable deviation in CF from unity for the above neutral currents at the associated frequencies as given in Fig 4b. As shown there are four dominant frequencies where considerable deviations from unity has occurred. These frequencies remain almost same for small radial variation upto 1mm from 672.5mm to 673.5mm.

No definite trend is established between CF and radius for a given frequency. This is probable due to presence of other frequencies as seen in Fig.4a and 4b and changes in CF related to those frequencies.

Similar calculation is performed by varying coil depth (CD) from 1915 mm to 1972 mm. The variation in CD is achieved by varying the oil duct gap uniformly along the height of winding. For every variation in duct thickness, neutral current and FFT are calculated. CF is calculated for original duct and reduced/increased duct size. Fig.5a shows the FFT of neutral current for CD of 1915 mm and 1972 mm.

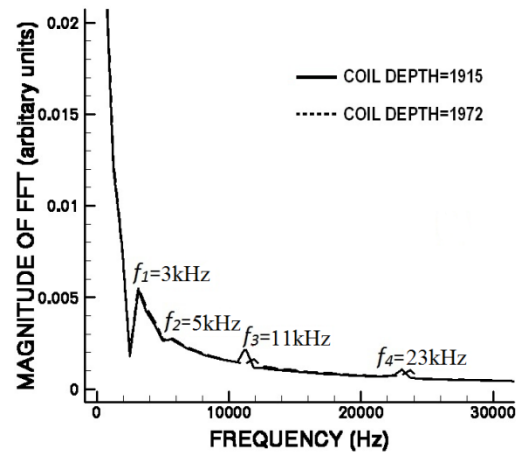


Fig.5a FFT of neutral current for various Coil Depth (CD).

It is observed that there are four dominant frequencies 3 kHz, 5 kHz, 11 kHz and 23 kHz. The magnitude and phase differences related to these frequencies are relatively low as seen in Fig.5a. A plot of CF as shown in Fig.5b indicates a marked deviation from unity, having the lowest values of 0.21 at 11 kHz.

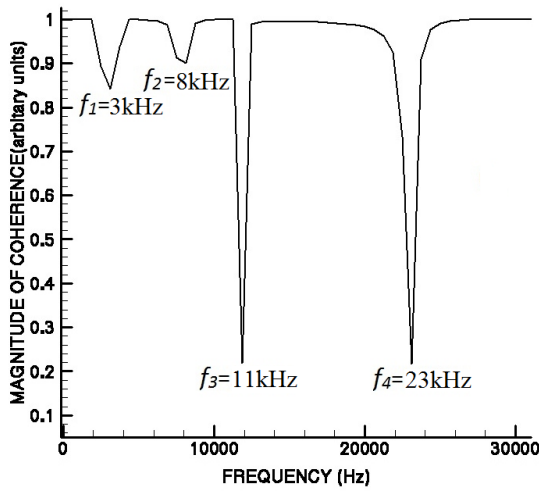


Fig.5b CF for the FFT of Fig.5a.

To understand the variation of CF by varying coil depth results are obtained as shown in Fig.5c.

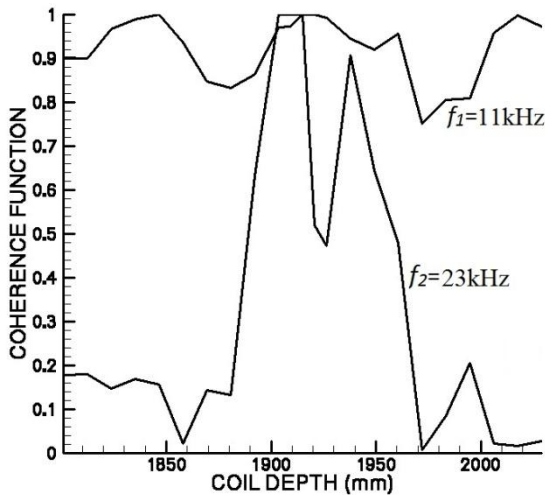


Fig.5c variation in CF for two dominant frequencies.

As seen in Fig.5c, the CF for two frequencies viz. 11 & 23 kHz have dominant variation. In each frequency there is a variation in magnitude for a range of CD between 1800 mm. min. to 2050 mm. max. No specific trend for a given frequency is observed since; new frequencies appear as a result of change in L and C. However, from all the results

discussed above, it can be inferred that there exists a deviation in CF value from unity if the axial or radial variation of winding occurs and that its sensitivity of detection is higher than that obtained in FFT. Since the fault in a system gives rise to high current in transformers, hence the force generated due to fault current introduces variation in radial and axial direction. Therefore, Coherence Function can be used as an advantageous diagnostic tool.

4. Conclusion

Paper describes a method of determining CF for radial and axial variation in the winding of a transformer. The axial variation is achieved by varying the duct thickness uniformly along the height of the winding. The radial variation is done by varying the oil gap between HV and medium voltage winding. Calculation shows that both FFT and CF of neutral current can detect the movement in the winding. However, sensitivity of CF is relatively higher than FFT.

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