SYMmetric AND ASYMmetric WAVElet TECHniques FOR MINOR FAULT DETECTION IN TRANSFORMer WINdings

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Abstract— Any weakness of insulation in a transformer winding may result in its deformation and hence, in the failure of the transformer. Comparison of neutral currents is a technique widely used for the detection of fault in the power transformer winding insulation during impulse test, any shift in the recorded waveforms confirms the existence of fault. In the present work, a 61MVA, 11.5/230 kV generator transformer has been considered for analysis. Faults have been created in the discs of the HV windings at specific locations. High voltage impulse is applied to the winding and the neutral currents for the healthy case and the faulted discs windings have been recorded using digital oscilloscope and these recorded neutral currents were subjected to analysis after proper processing & neutral current oscillographic methods are used for fault identification using symmetric & asymmetric mother wavelets by wavelet transform technique.

Index Terms—Power Transformer, Neutral currents, Wavelet transform.

I. INTRODUCTION

High voltage power transformers are one of the most expensive elements in a power system and their failure is a very costly event. When a transformer is subjected to high through fault currents, the mechanical structure and windings are subjected to severe mechanical stresses causing winding movement and deformations. It may also result in insulation damage and turn-to-turn faults are most likely. Winding deformations in transformers are difficult to establish by conventional methods of diagnostic tests like ratio, impedance/inductance, magnetizing current etc. Deformation results in relative changes to the internal inductance and capacitance of the winding. These changes can be detected externally by low voltage impulse method.

A wavelet is a small wave, which has its energy concentrated in time, and a tool meant for analysis of transients and non-stationary or time-varying signals. The Fourier analysis consists of ecomposing signals of sine waves and at various frequencies. Similarly, wavelet analysis is the breaking up of a signal into shifted and scaled version of mother wavelet. The Continuous wavelet transform (CWT) of a signal \( x(t) \) can be defined as

\[
CWT_x(\tau, s) = \frac{1}{\sqrt{s}} \int \frac{x(t) \Psi^*(t - \tau)}{s} dt
\]

Where, the function \( \Psi(t) \) is the mother wavelet. It is a prototype for generating the other window functions, which are dilated or compressed and shifted versions of mother wavelet. 't' \([4-5]\) is the operator (translation), 's' is the scaling function and '*' stands for complex conjugation. Wavelet transform maps a time-domain signal into a two dimensional array of coefficients, thus localizing the signal in both time and frequency domain simultaneously, whereas, Fourier transform can only give the frequency information. However, CWT is computationally expensive and also generates a lot of redundant data.

To circumvent these drawbacks, an effective implementation applicable to discrete signals, called Discrete Wavelet Transform (DWT) was formulated using suitable low-pass and high-pass filters, which satisfy certain mathematical constraints \([1-11]\).

II. TRANSFORMER DESCRIPTION & EXPERIMENT

The experimental studies were carried out on a Generator Transformer of 61 MVA power rating and 11.5/230kV voltage rating as shown in Fig.1. A low voltage impulse of 100V magnitude was applied from a Recurrent Surge Generator (RSG) at the central entry of High Voltage (HV) winding of transformer \([12]\).

Figure 1: Experimental setup
The schematic representation of the experimental setup is shown in Fig. 4.

The HV winding is of two group construction with centre-entry type, having a total of 112 discs with 22 turns in each disc. The HV winding is symmetrical about the centre-entry with 56 discs in each half. The tapping winding consists of 40 plain discs of 4 turns each [13-16]. The schematic representation of the windings is shown in Fig 3.

A portion of pressboard cylinder is removed to have an easy accessibility to the high voltage discs; such removal facilitates shorting of any conductor with other conductor or discs. In order to carry out the experiment, the paper insulation of the outer turn of large number of discs in axial direction is removed to have an access to bare conductor. These bare portions of the conductors were physically shortened to create short circuits and hence the disc faults.

An impulse voltage of magnitude 100 volts from RSG was applied at 40th disc of tap winding and the neutral current was recorded on the digital oscilloscope across a 20Ω shunt. Currents were recorded for healthy coil as well as for shorted discs and turns. The following recordings were carried out on shorted turns: 39th disc with tap not shorted i.e., disc in healthy condition (original signal), in the 39th disc 5th turn shorted, 9th turn shorted, 17th turn shorted, 21st turn shorted and 29th turn shorted.

Daubechies’s wavelets with different N values were chosen for denoising the neutral current waveforms and their integrity in identifying the noise is proposed in this work. Explicit computational algorithms have been developed for generating wavelets with varying degrees of symmetry or asymmetry. The terms symmetric and asymmetric have been used in reference to the actual wavelet coefficient. To prove the validity of the proposed method, test image of different noise forms were used and the analysis was performed by scripts in MatLab platform, for comparing the results in the proposed algorithm [17-19].

III. RESULTS AND DISCUSS

To assess the perfection of the winding in a high voltage power transformer a comparison of applied voltage and resultant neutral current signal at reduced and full voltage levels is used. Any difference in the wave shape of the recorded current and voltage signals shows the existence of fault in the transformer winding.

The tapping winding consists of 40 plain discs of 4 turns each. Initially without shorting the winding manually the neutral currents are recorded as shown in Fig 4.

Further using wavelet transform technique the signal is denoised. The noisy signal is to be denoised for proper fault detection, as the magnitude of fault is very small it is sometimes misinterpreted as fault. Daubechies wavelet is used for understanding the noise in the original signal and denoising signal.
A comparison plot of original and denoised signal is shown in Fig5.

Figure 5: Comparison of original and denoised signals

Daubechies wavelet with N values 7, 9 and 10 are used for understanding the effectiveness of symmetric and asymmetric wavelets in noise elimination of the neutral current waveforms. Shifting of peaks at different instances of time in a39th disc with 5th and 9th turn faults are shown in Fig6 and Fig7 respectively.

Figure 6: Shifting of peaks at different instants for 5th turn fault in the 39th disc of tapping winding

Figure 7: Shifting of peaks at different instants for 9th turn fault in the 39th disc of tapping winding

It is evident that symmetric and asymmetric wavelets showed different shifts for the same neutral current waveform. However, we observed that symmetric wavelets are best and they are shape preserving wavelet compared to asymmetric wavelets.

CONCLUSION

Daubechies wavelets were successful in denoising the images as can be seen in Figures 5. Choosing appropriate threshold values for denoising is a crucial step and here soft, scaled and global threshold was applied with global threshold values of 130, 20 and 130 for Db 7, 9 and 10 wavelets respectively. For speckle noise type Db 7 wavelet was effective in denoising when compared to Db’s 9 &10 this could be attributed due to soft thresholding and edge smoothening of least asymmetric wavelet.

REFERENCES


