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Differential Protection of Power Transformer using Wavelet Transform

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Abstract*: This paper presents wavelet transform method for the analysis of differential currents of power transformer which can act as an accurate classifier between magnetizing inrush current and internal faults to avoid the needless tripping of circuit breaker. The differential protection scheme occasionally mal – operate whenever magnetizing inrush occurs in power transformer. The aim is to reduce the rate and time duration of undesired outages of power transformer. This includes the necessities of reliability with zero mal – operation of differential relay. The result shows higher operating speed with less fault clearing time. Wavelet Transform is employed for the analysis of transient signals under various conditions, which extracts data from signals in time and frequency domain simultaneously. The simulation is done in MATLAB environment.

***Keywords*: Differential protection scheme, Internal fault current, Magnetizing inrush current, Power transformer, Wavelet transform**

I. INTRODUCTION

With increased requirement for power and rise in industrialization, the call for a consistent supply of power for today's world has expanded significantly. It further requires zero fault operation of the electrical network. The protection of power transformers from various faults are essential as they are large and expensive devices.

The differential protection scheme occasionally mal – operate whenever magnetizing inrush occurs in power transformer. As inrush is a transient condition, mainly happens during the switching of transformer. This differential relay is unable to identify whether the condition is inrush or an internal fault. This is mainly due to the high magnitude of inrush current. The difficulties produced due to the occurrence of magnetizing inrush are the inappropriate operation of the machines, failure of relay systems, unbalanced voltage in the transformer windings, increase in voltage drop in the power system during energization of power transformer [1].

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The Wavelet transform processes the transient signals which can't be processed by other transforms like Fourier transform. The signals which are non – periodic in nature and contains unwanted harmonics and oscillations can be functioned by using wavelets. The other transforms like Fast Fourier Transform (FFT), Discrete Fourier Transform (DFT) are tools for the analysis of frequency components of signal but they do not comment on the time instant. For the analysis of inrush and fault current signals, it is seen that both the currents are non – periodic signals. Therefore, wavelet transform is needed. The researchers have explored and develop various algorithms to protect power transformer. Some methods are microcontroller-based system for transformer protection [2] wherein result demonstrates the time of classification is around 1.6msec and operating time of differential relay is 633psec. which is fast and reliable.

In other method, differentiation is based on symmetrical components [3]. Here the author introduced a criterion where negative sequence for differential current is different from positive sequence during fault. His results are accurate for the present problem in all the conditions. The Morphological scheme which is focused on wave shape was developed and presented by authors [4]. Their scheme decomposes a current signal into multiresolution levels. It can do discrimination when inrush with a low 2nd harmonic component and a fault current with a high second harmonic component occurs in the system. Some other techniques developed are Auto – correlation method [5], equivalent instantaneous inductance (EII)method [6]. Researches had designed the high-speed variable-percentage differential relay for protection purpose. They developed the technique which does not mal - operate on external fault and inrush current conditions, but it will give trip signal for internal faults [7].

For many years, researchers have formulated a protection method for power transformer using some transform techniques like Fourier transform and Wavelet transform [8], wavelet packets [9]. Main task of Wavelet transform is the extraction and decomposition of transient signal into various resolution levels [10]. Recently, extensive research is going on differentiation techniques based on Artificial Intelligence like Fuzzy logic [11], Artificial neural network [12][13], Probabilistic neural network, Fuzzy – neuro hybrid intelligent system [14]. The cited researchers have developed the differentiation algorithm for the protection, which increases the speed and robustness of present digital relays [15].

In spite of the various proposed algorithms, there still have certain restrictions. Some problems are the large calculation burden, less speed, large memory, harmonic pollution, CT saturation depending upon the transformer parameters. Hence, more reliable, dependable and fast approach for protecting power transformers is employed using Wavelet Transform.

This method is used to accurately detect inrush current and distinguish it with other conditions like normal operation, internal - fault, over – excitation and external fault conditions to avoid the false tripping of circuit breaker.

II. DISCRIMINATION METHOD

A. Wavelet Transform

The Wavelet transform (WT) processes the transient signals which can't be processed by other transforms like Fourier transform. The signals which are non – periodic in nature and contains unwanted harmonics and oscillations can be functioned using wavelets. WT breaks up the signal into scaled and shifted versions of the mother wavelet. The other transforms like Fast Fourier Transform (FFT), Discrete Fourier Transform (DFT) are tools for the analysis of frequency components of signal but they do not comment on the time instant. For the analysis of inrush and fault current signals, it is seen that both the currents are non – periodic signals. Therefore, wavelet transform is needed. WT can be represented by following equation:

$$X(a,b) = \frac{1}{\sqrt{a}} \int_{\infty}^{-\infty} \Psi\left(\frac{t-b}{a}\right) x(t)\, dt$$

where x(t)is the signal to be analyzed; a and b are scaling and time shifting factors; Ψ(t) is the mother wavelet.

The type of mother wavelet, among Haar, Daubechies, Symlets, Coiflets and Bior, choosen increases the performance of differential protection scheme, and it gives an accurate classification of various conditions by protecting power transformers. Daubechies (dB) wavelet is chosen since it gives a more accurate result in detecting fast decaying transient signals and minimum error during the occurrence of magnetizing inrush condition. The wavelet tree simulated in this paper is shown in figure 1.

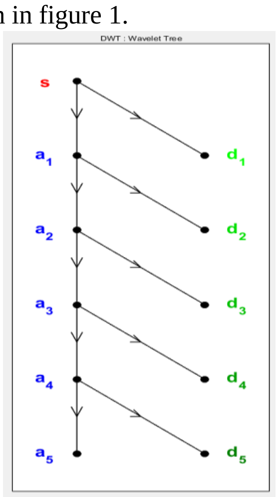

Fig. 1. Wavelet decomposition tree

B. Simulation of Power System

A power system network, shown in Figure 2 is simulated in MATLAB environment. Parameters of the power transformer are given in Table 1. The primary and secondary currents are measured through current transformers and the wavelet analysis is performed on signals obtained under three conditions such as normal operation, magnetizing inrush and internal fault. The simulation is carried out for 0.04 sec and the data is captured for two cycles which has 800 samples. The classification of different conditions is summarized in steps:

- Obtain the primary and secondary current signals from Current Transformers
- Apply wavelet transform for the signals obtained in step 1 and calculation of differential current
- Identify the type of condition by interpretation of detailed wavelet coefficients of differential current shown in figure 5 and figure 6
- Differentiate between magnetizing inrush, internal fault and normal operating conditions.

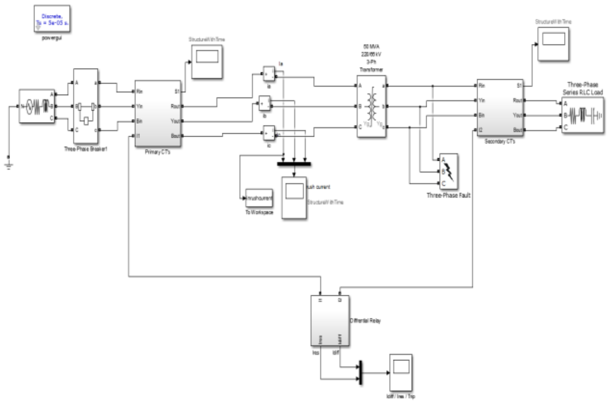

Fig. 2. Simulation diagram of power system

Table- I: Power transformer parameters

S.No.	Power Transformer	
	Parameters	***Rated Value***
1.	Rated Power	50 MVA
2.	Primary Voltage	220 kV
3.	Secondary Voltage	66 kV
4.	Rated Frequency	50 Hz
5.	Winding resistances	R_1= 0.002pu R_2= 0.002pu
6.	Winding inductances	L_1= 0.08pu L_2= 0.08pu
7.	Magnetising Resistance (Rm)	500 pu
8.	Magnetising Reactance (Lm)	500 pu

Figure 3 shows the flow chart of proposed discrimination method for differential protection of power transformer.

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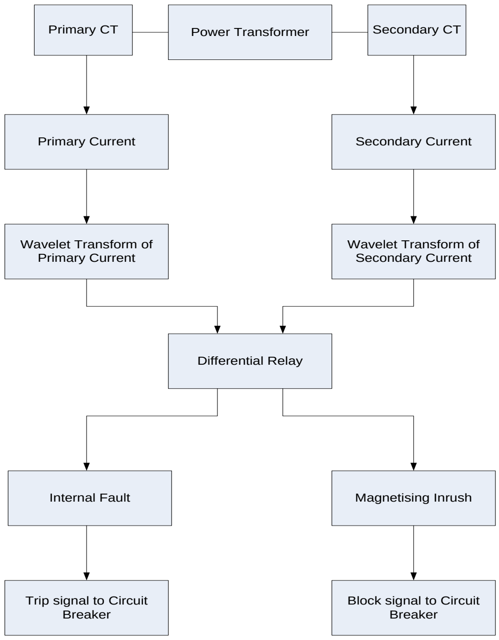

Fig. 3. Fault detection flow chart for differential protection of power transformer

III. SIMULATION RESULTS

A. Normal operation

Figure 4 shows the normal operating current waveform for phase A. The value of rated current for the simulated transformer is 131 A. Figure 5 shows the wavelet decomposition of normal condition with approximate and detailed coefficient with five levels. It is simulated for two cycles (0.04 sec) having 800 samples.

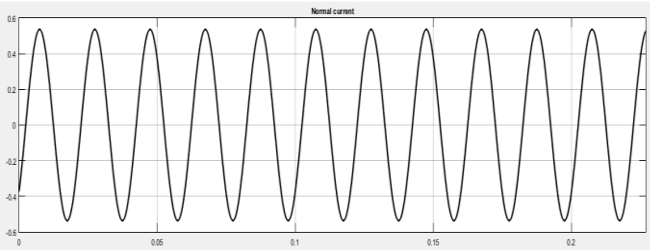

Fig. 4. Normal operating current waveform for phase A

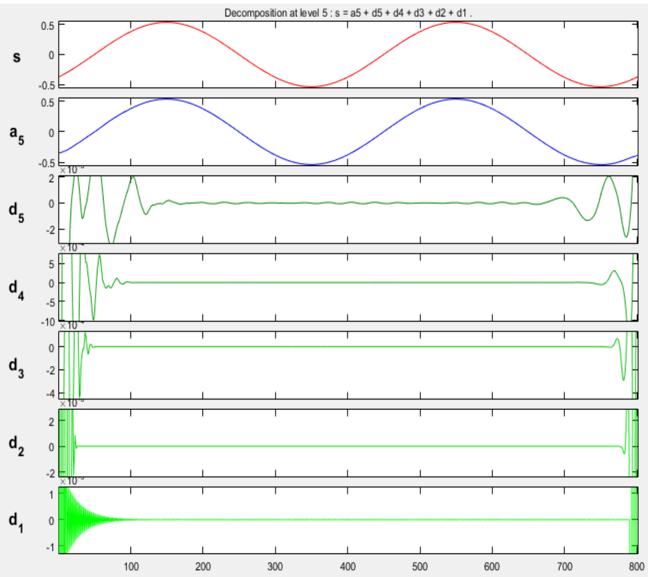

Fig. 5. Wavelet decomposition of normal current waveform for phase A

B. Magnetizing Inrush condition

Whenever a power transformer is initially energized on no – load, there is a sudden inrush of primary current. The peak value achieved by the flux is over twice the normal flux. The core is driven far into saturation which results in magnetizing inrush current having a very high peak value. Figure 6 shows the magnetizing inrush waveform for phase A simulated for 0.5 sec. The magnitude of inrush current is 380 A, which is around three times the rated current. Therefore, this high current appears like a fault to the differential relay and it gets tripped. Flux in a transformer is function of residual flux; switching instant and magnetic properties of core.

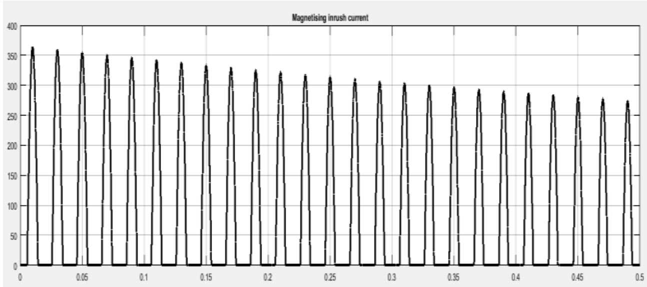

Fig. 6. Magnetizing inrush current waveform for phase A

In this paper, dB6 level 5 is used for wavelet analysis. Figure 7 shows the wavelet decomposition of magnetizing inrush current for phase A. with approximate and detailed coefficient with five levels. It is simulated for two cycles (0.04 sec) having 800 samples

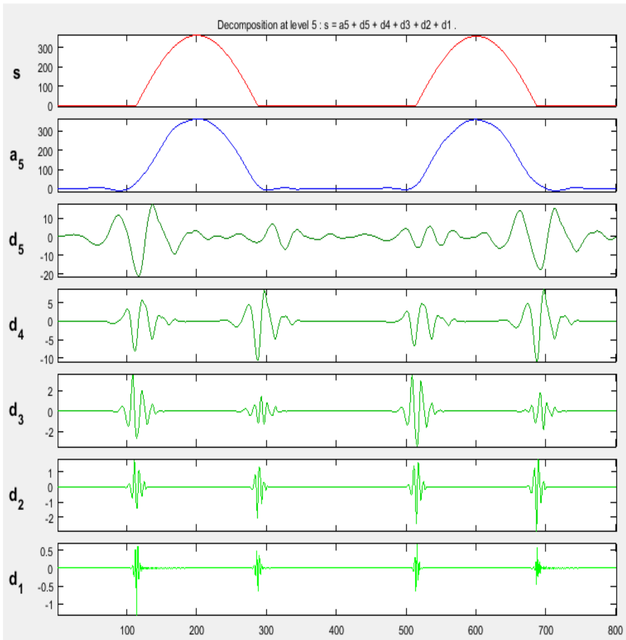

Fig. 7. Wavelet decomposition of magnetizing inrush waveform for phase A

B. Internal Fault condition

A 3 - phase to ground fault is applied at the secondary side in the model shown in figure 2. Figure 8 shows the Internal fault current waveform for phase A simulated for 0.5 sec. The magnitude of fault current is 2100 A.

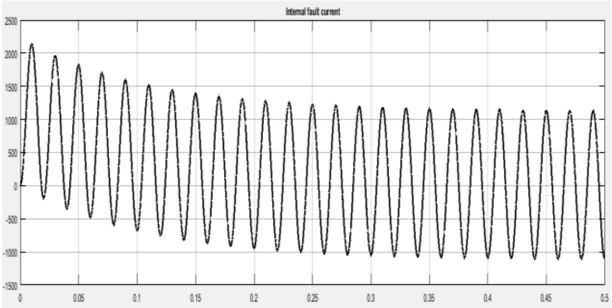

Fig. 8. Internal fault current waveform for phase A

Figure 9 shows the Internal fault waveform (phase a) for 2 cycles(0.04 sec)Wavelet – decomposition at level 5 (6 db)

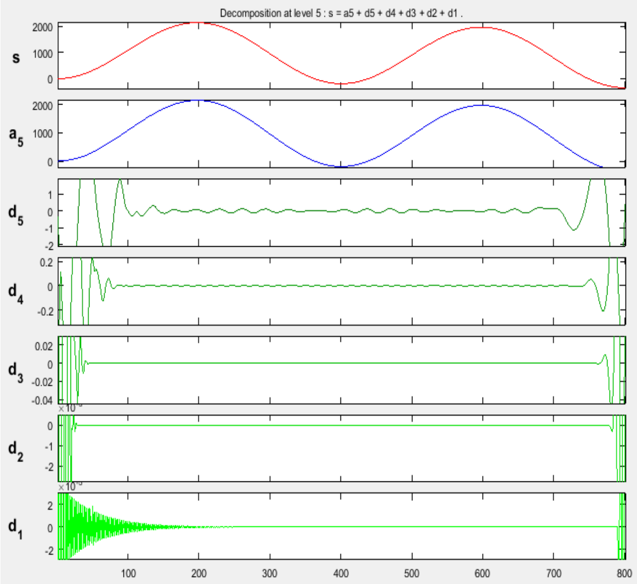

Fig. 9. Wavelet decomposition of internal fault current waveform for phase A

IV. CONCLUSION

This work shows a wavelet transform based differential protection of power transformer. The wavelet decomposes a transient signal into both time and frequency simultaneously, allowing for a complete and efficient description of signal. The information obtained from different coefficients can be used as an input to the classifier algorithm to differentiate between fault and non-fault conditions, since the quality of any classifier algorithm depends on the input parameters. It is seen from the coefficients that the fault is localized.

The wavelet transform is applied to normal operation, magnetizing inrush and internal fault condition. It is concluded from the obtained results that this method is superior in classification and differentiation of faults. Application of wavelet transforms for differential protection of power transformer enhances the drawbacks arising in conventional differential protection method as fault localization and classification is accurate.

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