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Enhancement of Differential Protection Performance Using Wavelet Transform

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***Abstract*— A new power transformer differential protection approach, from the point of view of wavelet samples considered, is presented in this work using wavelet transform. Which is a time-frequency transform technique. Single phase power transformer different operating conditions including inrush, load, normal, external faults and internal faults currents are sampled and processed to obtain their wavelet coefficients. Different operating conditions which provide different wavelet coefficients. Which results in some features like wavelet energy calculated by using Parsevals theorem? Wavelet energy is implemented as a discriminative differential protective relaying technique**

***Index Terms*— Transformer, Inrush current, differential protection, Wavelet, FFT.**

I. INTRODUCTION

Power transformers which play their important efficient and reliable role in any power system require the most efficient discriminative protective relaying equipment. Differential protection as one of the power transformer main protective relaying equipment should strongly avoid any mal-operation which lies in non discriminating inrush currents from internal faults current conditions. Differential protective relay should thus operate for conditions of all power transformer internal fault types and block in case of inrush current conditions. Since the transformer inrush current contains a large second harmonic content, digital differential protection operating method is based on differential current harmonic content, where these methods benefit from the fact that the ratio of the differential current second harmonics component to the fundamental component in case of inrush current condition is more than the same ratio in case of the fault condition. Wavelet transform WT technique based on the energy of details coefficient which provides us with efficient discrimination between the current Enhancing differential protection performances [1] [2].

II. DIFFERENIALPROTECTIONTHEORY

Percentage restraint differential protective relays have been in service for many years. Typical differential relay connection diagram is shown in Fig.1.Differential elements compare an operating current with a restraining current. The operating current (also called differential current), IOP, can be obtained as the phase sum of the currents entering the protected element.

IOP is proportional to the fault current for internal faults and approaches zero for any other operating (ideal) conditions. [3]

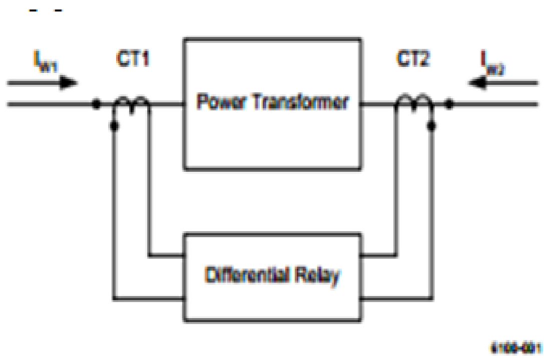

Fig. 1Typical Differential Relay Connection Diagram [3].

III. WAVLET- TRANSFORM AND ANALTSIS

Waveforms associated with fast electromagnetic transients which contain both high-frequency oscillations and localized impulses super imposed on the power frequency and their harmonics are typically non-periodic signals. these characteristics present a problem for traditional Fast Fourier transform (FFT) technique owing to the fact FFT is best reserved for periodic signals. In order to overcome this problems, WT has been used as a powerful tool in the analysis of transient phenomena. WT efficient ability to focus on short time intervals with high frequency components and long intervals with low frequency components has thus greatly improves the analysis of signals with localized impulses and oscillations. For this reason, wavelet decomposition became the most ideal reliable approach for studying and discriminating transient signals.

Continuous wavelet transform (CWT) is defined as the sum over all time of the signal multiplied by scaled and shifted versions of the wavelet function [4].

$$WT(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} x(t)\, g\left(\frac{t-b}{a}\right) dt \quad \dots\dots (1)$$ [4]

Where x(t) is the signal to be analysed , a and b are respectively the scaling (dilation) and time shifting (translation) factors. g(t) is referred to as the "mother wavelet " and its dilates and translates are simply called as " wavelet" . CWT results are many wavelet coefficients, which are function of scale and position. CWT has a digitally implementable counter port; Discrete wavelet Transform (DWT), which is defined as:

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$$DWT(m,k) = \frac{1}{\sqrt{a_0^m}} \sum_n x(n)\, g\left(\frac{k - n a_0^m}{a}\right) \ldots..(2)$$ [4]

Where g(n) is the mother wavelet , and the scaling and translation parameters a and b of (1) are function of an integer parameter m ,a = and b =n .The DWT can be implement with the form of a filter bank, with the variable swap of k for n, (2) can be rewritten as:

$$DWT(m,k) = \frac{1}{\sqrt{a_0^m}} \sum_n x(k)\, g(a_0^{-m} n - k) \;\ldots..(3)$$ [4]

Which has the similar form of Finite Impulse Response (FIR) digital filters.

Wavelet transforms acts as a group of band pass filters with various central frequencies. It can be zoomed in by scaling and shifting the "mother wavelet". This implies that the wavelet transform can be used to obtain the wanted non-stationary signals and to capture the transient components selectively and accurately. Hence the wavelet transform is an ideal means to extract the different components from the wideband transient signal generated by a fault [5]. The energy of detail coefficient for the wavelet transform was calculated by using [6][7] :

$$Energy = \sum_k |D(j,k)|^2 \ldots\ldots\ldots\ldots\ldots\ldots.(4)$$ [6]

IV. SIMULATION AND RESULTS

This work is implemented on a single phase step down 220/100V, 1000W, 50 Hz differentially protective power transformer simulated model supplied by a source of 220V. WT based on sample frequency of 6400 sample per second would thus result in a wavelet analysis of 32 samples for a quarter cycle of 50Hz. Transformer open & Short circuit conditions were examined. Many test cases had been carried out on the transformer.

A. Case study 1:Magnetizing Inrush Current Only test

The transformer is switched on to the input source at no load condition at the time instant of 0.1 sec, the inrush current magnitude is seen to be equal to 250% of full load current would result in energy magnitude less than the threshold value, the relay would thus do not give a trip signal to circuit breaker as shown in Fig.2.

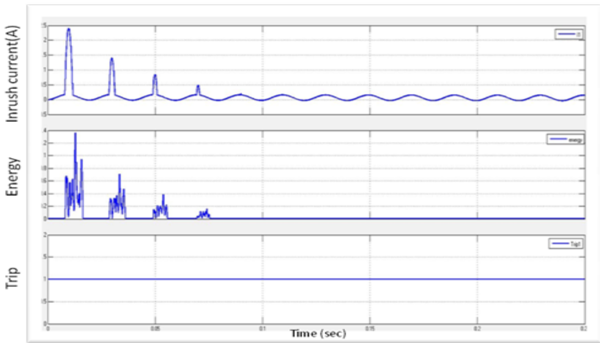

Fig. 2 Magnetizing Inrush Current Only

B. Case study 2:of Inrush current at Full Load Condition test

Full load is applied at the time instant of 0.1 sec, where the inrush current takes its time till vanishing; the relay would not operate as it is still within its restraining reign as shown in Fig. 3.

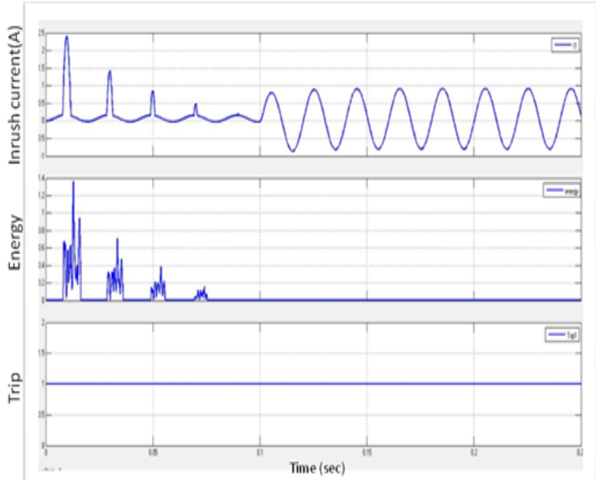

Fig. 3 Magnetizing Inrush Current and Full Load

C. Case study 3: Inrush Current at 150% of Full Load Condition test

150% of full load is applied at the time instant of 0.1 sec, the inrush current would also take its time till vanishing, the relay would also not operate since it is still within its restraining reign as shown in Fig. 4.

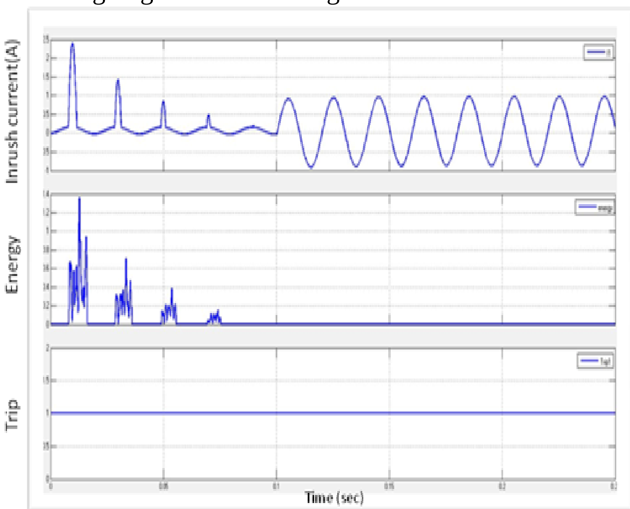

Fig. 4 Magnetizing Inrush Current and 150% Full Load

D. Case study 4: Inrush Current at Full Load with and External Fault test

Full load is applied at the time instant of 0.1 sec, with the existence of an external fault occurring at the same time instant, the inrush current with a magnitude of250% of full load current would result in energy magnitude less than the threshold value, the relay would thus do not give a trip signal to circuit breaker where the energy of the external fault less than the threshold as shown in Fig. 5.

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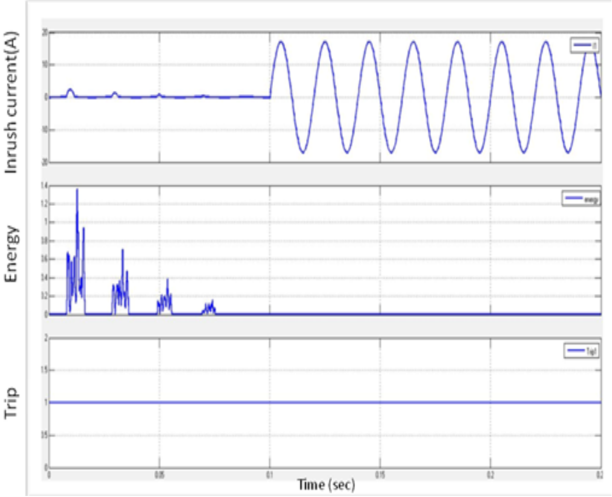

Fig. 5 Magnetizing Inrush Current and External Fault

E .Case study 5: Inrush Current and External fault with Full Load test

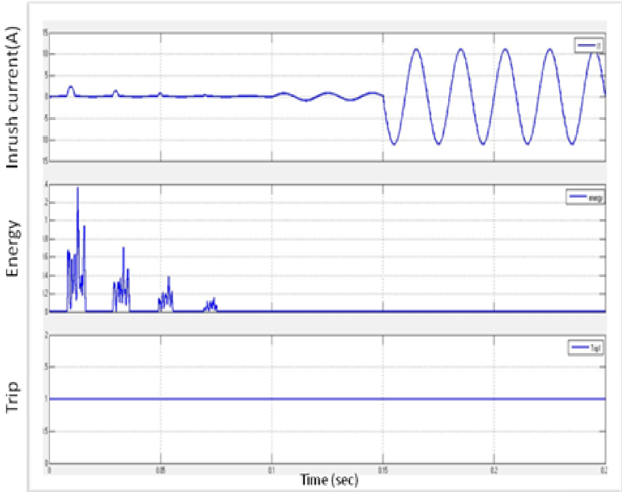

Fig. 6 Magnetizing Inrush Current and External Fault with Full Load

F. Case study 6 : *Inrush Current with an External Fault at 150% of Full Load test*

150% of Full load is applied at the time instant of 0.1 sec, inrush current value of 250% of full load current. An external fault occurs at0.15 sec time, the relay would not operate as it is still within its restraining reign as shown in Fig. 7.

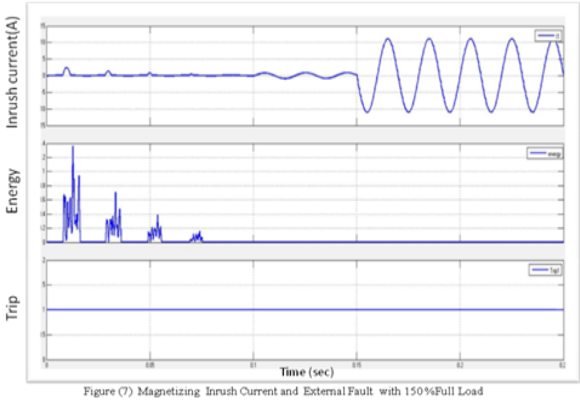

Fig. 7 Magnetizing Inrush Current and External Fault with 150% Full load

G. Case study 7: Inrush Current and Internal Fault test.

Unloaded transformer is switched on to the input source at the 0.1 sec time instant, An internal fault current occurs at same time instant, inrush current magnitudeis2.5timesfull load current. Internal fault energy exceeding threshold value, the relay would thus give a trip signal as shown in Fig. 8.

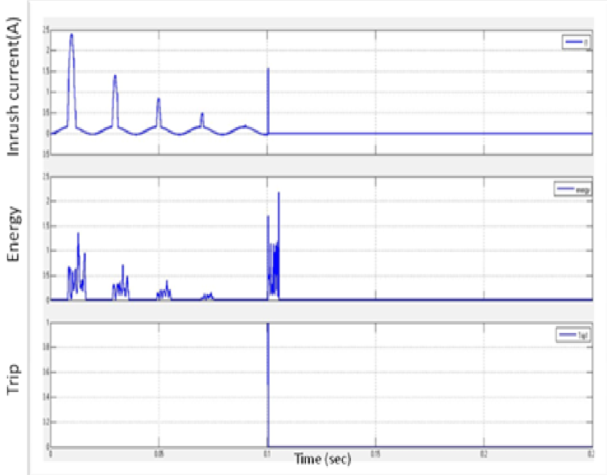

Fig. 8 Magnetizing Inrush Current and Internal Fault

H. Case study 8 : Inrush Current and Internal fault with Full Load test

Full load is applied at the time instant of 0.1 sec, the inrush current value of 250% of full load current. An internal fault occurs at time instant of 0.15 sec, the relay would operate as it exceeds its restraining reign as shown in Fig. 9.

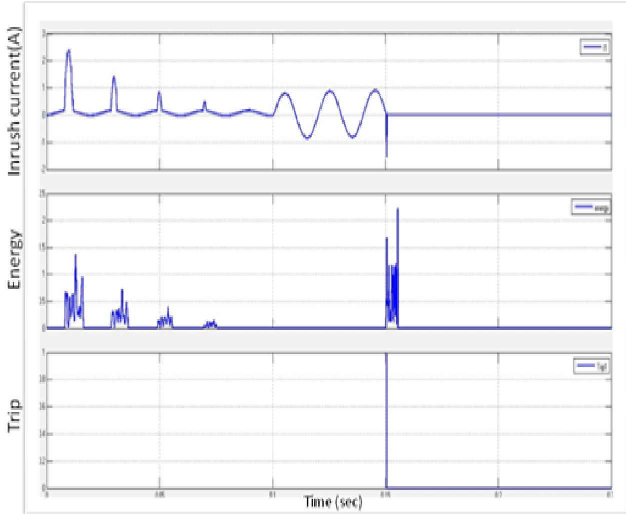

Fig. 9: Magnetizing Inrush Current and Internal Fault with Full Load

I. Case study 9: Inrush Current and Internal fault with 150% load test

150% of Full load is applied at the time instant of 0.1 sec, inrush current value of 250% of full load current. An internal fault occurs at 0.15 sec time, the relay would operate as it exceeds its restraining reign as shown in fig. 10. Fig. 11 shows the relay internal fault trip Signal applied to the circuit breaker at the time instant of 0.4 msec.

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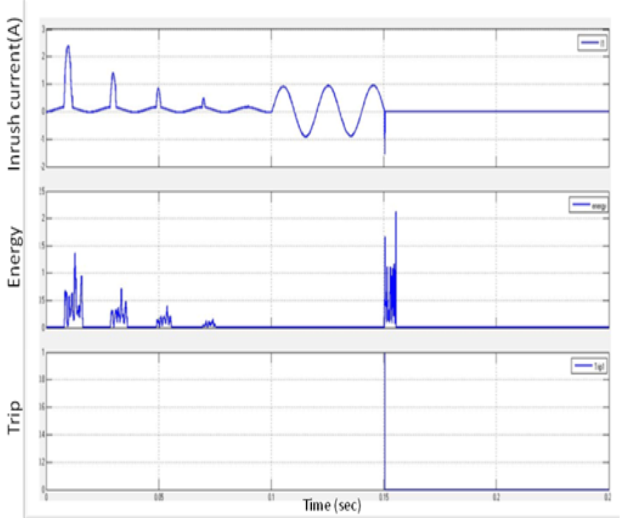

Fig. 10 Magnetizing Inrush Current and External Fault with 150% Full load

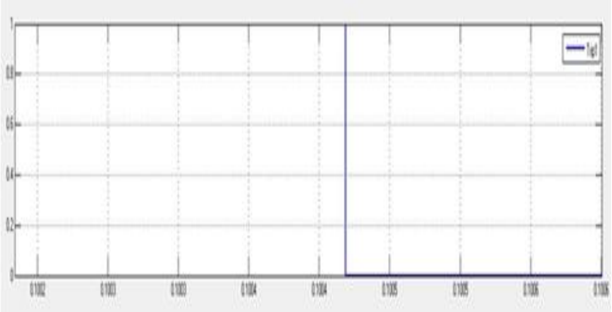
Fig. 11 Trip

V. CONCLUSIONS AND FUTURE ENHANCEMENT

Finally it can be concluded that, the transformer operating conditions including no load, non faulted full load, non faulted150% of full load, externally faulted no load, externally faulted full load, and externally faulted 150% of full load, had been resulted in wavelet energy values not exceeding the differential relay threshold values. while the transformer operating conditions including internally faulted no load, internally faulted full load, and internally faulted 150% of full load, had been resulted in wavelet energy values exceeding the differential relay threshold values and hence the internal fault wavelet energy technique has its objective discriminating role in detecting power transformer internal faults. The suggested approach is effective in discrimination of different faults and inrush phenomena. The Future Enhancement, The effect of saturated for (CT) on the operate Differential Relay by Using Wavelet Transform technique and combine The Wavelet Transform With Fuzzy- Neural Network.

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