Wavelet Transform Implementation to Differentiate Inrush Current and Fault Current in Power Transformer

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***Abstract:** An electrical system is al complex network, to enhance power generation, transmission and distribution transformers play an important role. Power transformer is the heart of the electrical system. Even though electrical power is generated at lower rate in the coastal areas, it can be transmitted easily over hundreds of kilometer with the help of power transformer. So there must proper protection should given to power transformers. But in order to give the proper protection there should be proper discrimination between internal faults and inrush current. If there is no proper differentiation between faults and inrush current phenomena than the protection circuit will not trip when inrush current comes into the picture. But the protection circuit will trip at faster rate than the actual one when the normal faults or internal faults come into the picture. So there should be proper discrimination between inrush current and internal fault current so that the protection circuit will work properly. There are so many techniques available to get differentiation between inrush current and fault current. Fast Fourier transform is one of the method to differentiate between these two currents. Here we are using wavelet transform technique to get the difference between these two currents. The properties of the inrush current obtained from this technique are accurate and distinct from those obtained from the fast Fourier transform. The experimental set up is carried out in matlab simulink and results were discussed as shown below in results.*

***Keywords:** inrush current, wavelet transform, internal fault current , power transformer.*

I. INTRODUCTION

When transformer secondary is open circuited, the primary of the transformer draws maximum value of instantaneous current which is not sinusoidal in nature, this current is known as inrush current in these currents transformer. Even though these currents won't affect much on transformer, but causes unwanted tripping of the circuit breakers which are near to the transformer. Therefore there should be proper differentiation between inrush currents and fault currents.

Based on the transient characteristics of the short circuit and inrush currents, the difference between them can be easily determined by using a technique known as morphological gradient technique [1]. As the inrush current and the short circuit currents are the random signals, the samples of these signals can be taken out and processed by using correlation and digital signal processor and then it is then compared with the standard signals [2].

Directly or indirectly discrimination of signals means ultimately it is nothing but identification of the patterns of the signals. From the faulted data the information regarding harmonics and these data fed into the neural network. The output of the neural network is digital and based on this output the type of the fault signal is determined [3]. Most of the transformers are protected by implementing differential protection. The modern differential relays construction and working will be enhanced by proper identification of fault current and inrush current. An algorithm had prepared which will work on the Hilbert transform and artificial neural network, based on this algorithm the pattern of fault current and inrush current signals can be identified [4]. One of the simple ways to discriminate between the fault current and the inrush current is calculation of average power flowing into the transformer during occurrence of inrush current and internal faults. The power consumed by the internal fault is more than that consumed by the inrush current. Based on this logic the type of the signal is identified. The average power calculation can be done by Hilbert transform technique [5]. The type of the signal whether it is inrush current transient or the fault current transient can be identified by calculating instantaneous inductance of the transformer. The inductance from primary side of the transformer can be calculated and it is then compared with the threshold value, if the calculated inductance is more than the threshold then it can be concluded that the effect is due to inrush current or else it is due to fault current [6]. The characteristics of the fault current and inrush current waveform ca n be studied with the help of singularity features of the waveforms. An algorithm has written based on the waveform singularity factor [7]. The features extracted from the waveforms inrush current signal and fault current signal will be used to identifying the difference between them [8]. The current signal in a power transformer is divided into different parts, then by using morphological filter technique the complexity of the circuit signal wave form is analyzes and the clear difference between fault current and inrush current is determined [9].

Manuscript published on January 30, 2020.
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Both inrush current and internal fault current having different patterns, by using hyperbolic s-transform technique the patterns of both waveforms is identified, which is known is pattern approach technique [10].

II. INRUSH AND FAULT CURRENTS

It is observed that when the transformer secondary circuit is opened and the primary side supply is given primary draws maximum instantaneous current which is several times greater than the normal current, these phenomena is called as inrush current phenomena. This current is non sinusoidal in nature and contains more harmonics. Figure 1 indicates the waveform of inrush current.

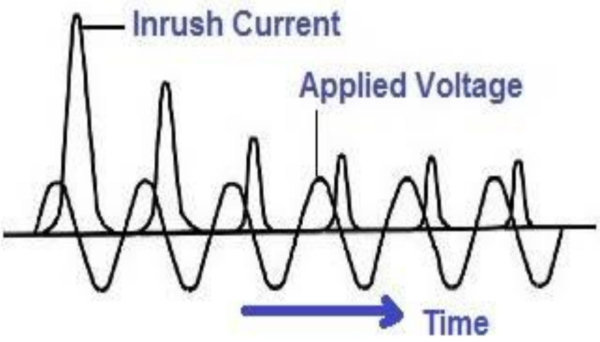

Fig 1: Inrush current in transformer

The faults in a transformer may be either external or internal. The external faults may occur due to lightning stroke or system overloading or it may be due to any natural calamities. But these faults can be easily detected differentiated compare to inrush currents. But the internal faults like the contamination of the oil, phase to phase faults, phase to ground faults and burning of winding the windings due to overheating when high current flows through the windings are very difficult to distinguish with the inrush currents. Figure 2 indicates the waveforms of fault currents in a transformer.

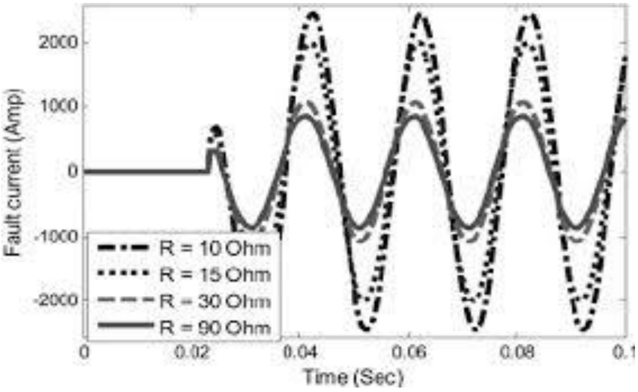

Fig 2: Fault current waveforms

III. SINGLE LINE DIAGRAM OF TRANSFORMER

The figure 3 shows single line diagram of a transformer. two buses we have shown here out of these one bus is treated as generator bus and another bus is slack bus. Circuit breakers are placed next to the buses as shown below. The circuit breakers are connected to the current transformers which measures the current. The current transformer is a step down transformer whose primary is connected to the line and secondary is connected to relay. When fault occurs the relay gets signal from current transformer and sends signal to the circuit breaker to trip.

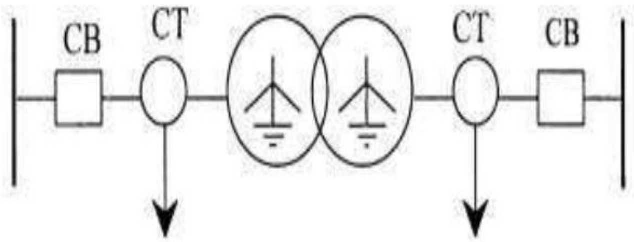

FIG 3: Single line diagram of transformer

IV. METHODOLOGY

Wavelet transform is technique which is used to decompose any signal into different parts with different fundamental frequency. The following equation will be used to differentiate the transients. that is standard deviation method.

$$\sigma = \sqrt{\frac{1}{N}\sum_{s=1}^{N}\left(E_{\psi}(s) - \mu\right)^2}$$

Each decomposed signal can be further studied with their fundamental frequency. As the Fourier transform is used to study the periodic signals but wavelet transform is better tool to decompose the transient signal and to study its features. As the internal fault current and the inrush currents in transformer are transient in nature, if we study their characteristics of these two signals then it is very easy to identify them. So it is better to use wavelet transform theory to study the features of inrush current and faults currents.

Each transient signal is broken into series of small decomposed signals and place at different position of the time axis. These small pieces of the signal sis called as wavelets. So the wavelet transform procedure is to compare the similarity of the signal with each of the wavelet.

V. MODEL DIAGRAM

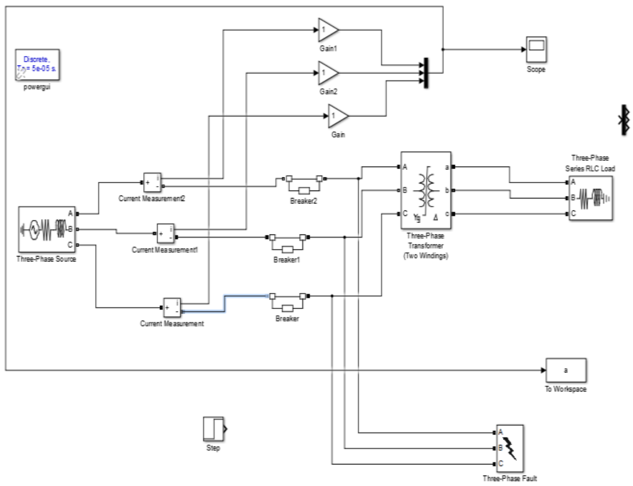

Fig 4: MATLAB simulink

Figure 4 shows the matlab simulink model to perform the analysis. A three phase transformer is used for this study. Three phase supply is taken from the source. The transformer is being protected from the circuit breakers which are connected to each phase of th supply. A three phase RLC load is supplied by the transformer as shown in the circuit. A three phase fault is injected across three phases of the circuit breakers and the model has run. The waveforms of all the phases are obtained from the output and analyzed. similarly the transformer is ran by keeping its secondary opened and the inrush and current is allowed to flow. The clear difference between the waveforms can be studied with the help of wavelets for different kinds of faults as shown in results section.

VI. RESULT

The performance of power transformer under different conditions and the wavelet transform effect will be studied in this section. We have also considered different the various types of faults and analysis has done for all the types of faults. Figure 5 shows the waveforms of all the three phase currents under optimal conditions which are supplied to RLC load and are displaced 120 degree electrically. The horizontal axis shows the time duration and the vertical axis gives the magnitude of the current under healthy conditions of the system.

Table 1: Coefficients of wavelets for inrush current

Transient signals	Max scale detection	Wavelet Coefficient – Bank no. 1 Transient switching inrush current					Result
		$I_{A\,max}$ (post)	$I_{B\,max}$ (post)	$I_{C\,max}$ (post)	Z_{chk}	$I_{positive}$	
Threshold	12	0.1136	0.0724	0.0548	0.00000	0.0852	Normal
Base Case	9	2.8576	0.6551	0.8003	0.00000	2.1432	Abnormal
PIR	9	0.6816	0.1558	0.1856	0.00000	0.5112	Abnormal
PII	12	0.1192	0.1113	0.1242	0.00000	0.0894	Normal
CLR	9	2.8073	0.6499	0.7997	0.00000	2.1055	Abnormal
6% Reactor	10	1.0653	0.2936	0.4341	0.00000	0.7990	Abnormal
Syn. closing	12	0.1249	0.1240	0.1297	0.00250	0.0936	Normal

Table2: Coefficients of wavelet for fault currents

Transient signals	Max scale detection	Wavelet Coefficient – Bank no. 1 Transient fault current					Result
		$I_{A\,max}$ (post)	$I_{B\,max}$ (post)	$I_{C\,max}$ (post)	Z_{chk}	$I_{positive}$	
Threshold	12	0.1136	0.0724	0.0548	0.0000	0.0852	Normal
Base Case							
AG	3	637.99	0.0000	0.0000	212.58	212.702	Abnormal
ABG	3	637.804	80.244	0.0000	88.512	294.714	Abnormal
AB	3	652.670	652.670	0.0000	0.0000	489.502	Abnormal
ABC	3	637.92	80.202	265.741	0.00000	478.443	Abnormal
Current Limiting Reactor							
AG	6	86.358	0.0129	0.0129	29.0248	28.667	Abnormal
ABG	6	85.871	9.9620	0.0031	12.4943	39.160	Abnormal
AB	6	72.728	72.732	0.0000	0.00000	54.546	Abnormal
ABC	6	85.444	10.101	36.788	0.00000	64.083	Abnormal
6% Reactor							
AG	10	0.9620	0.0017	0.0088	0.37250	0.2962	Abnormal
ABG	10	0.9259	0.0533	0.0087	0.29060	0.3179	Abnormal
AB	12	0.2865	0.1239	0.0336	0.00000	0.2149	Abnormal
ABC	10	0.8854	0.0448	0.6368	0.00000	0.6641	Abnormal

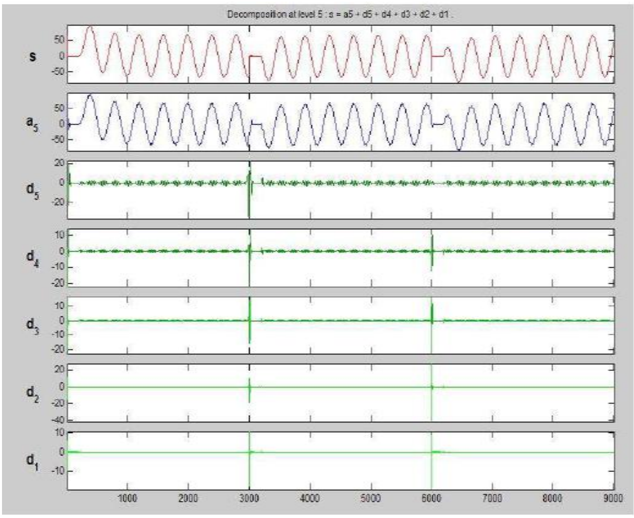

Fig 6: wavelet operation neglecting saturation

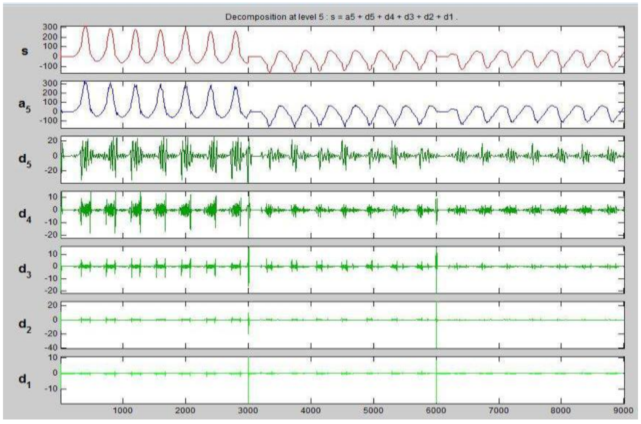

Fig7: wavelet analysis of inrush current

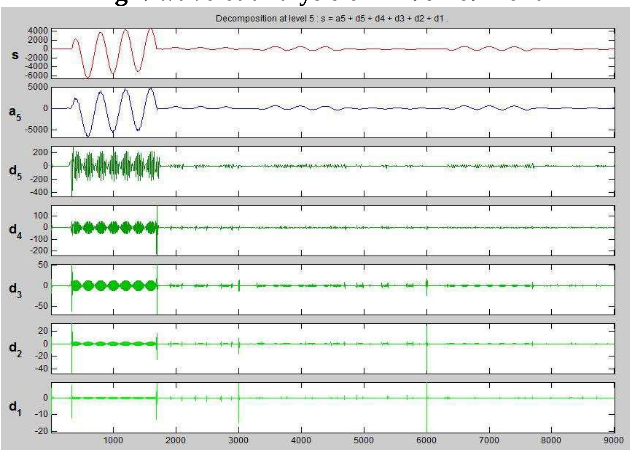

Fig 8: Wavelet analysis of fault current

VII. CONCLUSION

The simulation has done for all kind of faults like line to ground, double line to ground and phase to phase faults. Wavelet transform method is very essential tool to decompose the transient singles. Even we can perform this analysis by using fast Fourier transform but this method holds good for period signals. As the fault current and inrush currents are transient in nature so it is convenient to apply wavelet transform method to discriminate between inrush current and fault current.

ACKNOLEDGEMENT

We sincerely give our heart full thanks to our director and principal dinesh seth and Dr.K.Veeresh who supported and motivated us every time. We also thanks to our colleagues who continuously supported us. Also we used thinks our all lab technicians who helped us.

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