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Application of Signal Analysis for Fault Diagnosis in Transformer by Discrete Wavelet Transform

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Abstract

Traditional protection gives only terminal condition on the basis of protection of transformer. Discrimination between an internal fault and a magnetizing inrush current has long been recognized as a challenge for power transformer protection. To characterize and discriminate the transient arising from magnetization and inter-turn faults are presented here. This characterization will give value added information for improving protection algorithm.. The detection method can provide information to predict fault ahead in time so as that necessary corrective actions are taken to prevent outages and reduce down time. The data is taken from different test results like normal (magnetization) and abnormal (inter-turn fault) in this work, Discrete Wavelet Transform concept is used. Feature extraction and method of discrimination between transformer magnetization and fault current is derived by Discrete Wavelet Transform (DWT) Tests are performed on 2KVA, 230/230Volt custom built single phase transformer. The results are found using Discrete and conclusion presented.

Index Terms—Inrush current, internal fault, second harmonic component power transformer, wavelet transform.

1. Introduction

To avoid the needless trip by magnetizing inrush current, the second harmonic component is commonly used for blocking differential relay in power transformers. The major drawback of the differential protection of power transformer is the possibility for false tripping caused by the magnetizing inrush current during transformer energization.[5] In this situation, the second harmonic component present in the inrush current is used as a discrimination factor between fault and inrush currents. In general, the major sources of harmonics in the inrush currents are nonlinearities of transformer core; saturation of current transformers; core residual magnetization; and switching instant. Over the years, various incipient fault detection techniques, such as dissolved gas analysis and partial discharge analysis have been successfully applied to large power transformer fault diagnosis. Since these techniques have high-cost and some are offline, a low-cost, online internal fault detection technique for transformers using terminal measurements would be very useful.[1]

A powerful method based on signal analysis should be used in monitoring. This method should discriminate between normal and abnormal operating cases that occur transformers such as internal faults, magnetizing inrush. There have been several methods, based on time domain techniques, frequency domain techniques or time frequency domain techniques. In previous studies, researchers have used Fourier transform (FT) or windowed-Fourier transform. In recent studies, wavelet transform based methods have been used for analysis of characteristics of terminal currents and voltages .Traditional Fourier analysis, which deals with periodic signals and has been the main frequency-domain analysis tool in many applications, fails in transient processes such as magnetizing inrush and internal faults. The wavelet transform (WT), on the other hand, can be useful in analyzing the transient phenomena associated with the transformer faults. Since the FT gives only frequency information of a signal, time information is lost. Therefore, one technique known as windowed FT or short-time FT (STFT) has been developed. However, the STFT has the limitation of a fixed window width. So it does not provide good resolution in both time on other hand, WT provide great resolution in time for high frequency component of signal and great resolution in frequency for low frequency components of a signal. In a sense, wavelets have a window that automatically adjusts to give the appropriate resolution.[1] This work proposes a new wavelet-based method to identify inrush current and to distinguish its from inter turn faults.

2. Need of Frequency Information.

Often times, the information that cannot be readily seen in the time-domain can be seen in the frequency domain like ECG signal (Electro Cardio Graph, graphical recording of heart's electrical activity). The typical shape of a healthy ECG signal is well known to cardiologists. Any significant deviation from that shape is usually considered to be a symptom of a pathological condition. This, of course, is only one simple example why frequency content might be useful. Today Fourier transforms are used in many different areas including all branches of engineering. Although FT is probably the most popular transform being used (especially in electrical engineering), it is not the only one. There are many other transforms that are used quite often by engineers and mathematicians. Hilbert transform, short-time Fourier transform (more about this later), Wigner distributions, the Radon Transform, and of course our featured transformation , the wavelet transform, constitute only a small portion of a huge list of transforms that are available at engineer's and mathematician's disposal. Every transformation technique has its own area of application, with advantages and disadvantages, and the wavelet transform (WT) is no exception. For a better understanding of the need for the WT let's look at the FT more closely. FT (as well as WT) is a reversible transform, that is, it allows to go back and forward between the raw and processed (transformed) signals. However, only either of them is available at any given time. That is, no frequency information is available in the time-domain signal, and no time information is available in the Fourier transformed signal. The natural question that comes to mind is that is it necessary to have both the time and the frequency information at the same time? The particular application, and the nature of the signal in hand.

3. Wavelet Application

In recent years, researchers in applied mathematics and signal processing have developed powerful wavelet techniques for the multiscale representation and analysis of Signals These new methods differ from the traditional Fourier techniques Wavelets localize the information in the time-frequency plane; in particular, they are capable of trading one type of resolution for another, which makes them especially suitable for the analysis of non-stationary signals. One important area of application where these properties have been found to be relevant is power engineering. Due to the wide variety of signals and problems encountered in power engineering, there are various applications of wavelet transform. These range from the analysis of the power quality disturbance signals to, very recently, power system relaying and protection. The main difficulty in dealing with power engineering phenomena is the extreme variability of the signals and the necessity to operate on a case by case basis. Another important aspect of power disturbance signals is the fact that the information of interest is often a combination of features that are well localized temporally or spatially (e.g., transients in power systems). This requires the use of analysis methods sufficiently which are versatile to handle signals in terms of their time-frequency localization. Our discussion is organized into two main parts: (1) a discussion of the main properties of WT and their particular relevance to power engineering problems and (2) a critical review of power engineering applications. In Section II, we start by examining the properties of WT that are most relevant to power engineering problems. we consider the primary power engineering applications, provide the reader with the relevant background information, and review recent wavelet developments in these areas.

3.1 Time-Frequency Localization

Wavelets are families of functions generated from one single function, called an *analyzing wavelet* or *mother wavelet*, by means of scaling and translating operations. Some mother wavelets are shown in Fig.1. The difference between these wavelets is mainly due to the different lengths of filters that define the wavelet and scaling functions. Wavelets must be oscillatory, must decay quickly to zero (can only be non-zero for a short period), and must integrate to zero. The scaling operation is nothing more than performing “stretching” and “compressing” operations on the mother wavelet, which in turn can be used to obtain the different frequency information of the function to be analyzed. The compressed version is used to satisfy the high frequency needs, and the dilated version is used to meet low frequency requirements. Then, the translated version is used to

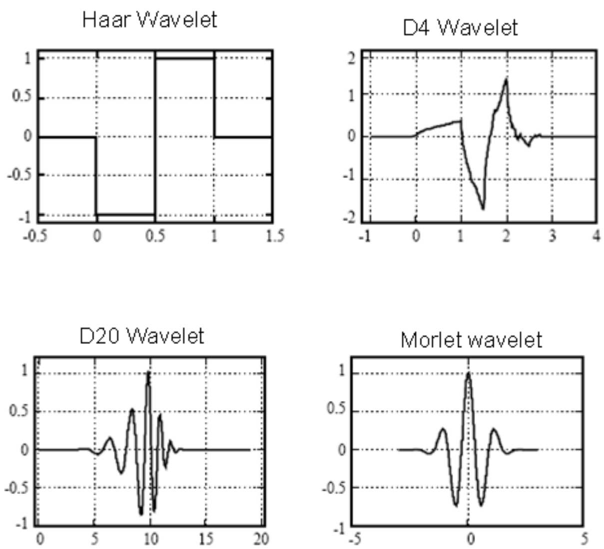


Fig.1. Four mother wavelets often used in wavelet analysis

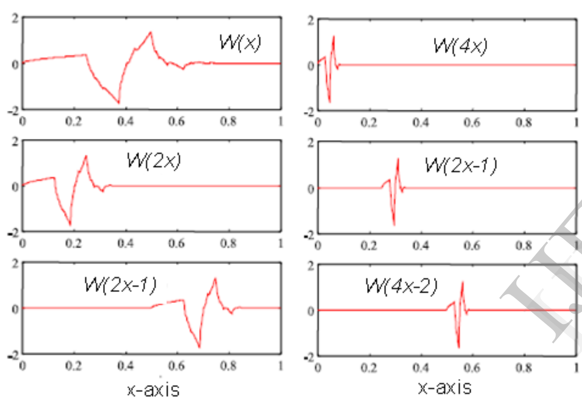


Fig.2 Scaled and translated version of D4 wavelet

obtain the time information of the function to be analyzed. In this way, a family of scaled and translated wavelets is created and serves as the base, the building blocks, for representing the function to be analyzed. The scaled (dilated) and translated (shifted) versions of the Daubechies mother wavelet are shown in Fig.2. Daubechies wavelets belong to a special class of mother wavelets and actually are used most often for detection, localization, identification and classification of power disturbances.

4. Experimentation and Data Collection

The setup for experiments has a custom built 230V/230V, 2KVA, 50Hz, single-phase transformer with externally accessible taps on both primary and secondary to introduce faults. The primary winding and secondary winding has 272 turns respectively. The load on the secondary comprises of static and rotating elements.

Data acquisition card by Tektronix Instruments was used to capture the voltages and current signals. The Tektronix DSO TPS2014B, with 100MHz bandwidth and adjustable sampling rate 1GHz is used to capture the currents and voltages. The Tektronix current probes of rating 100mV/A, input range of 0 to 70Amps AC RMS, 100A peak and frequency range 0 to 100Khz are used. These signals were recorded at a sample rate of 10,000 samples/sec.

Different cases of inter turn short circuit are staged, considering the effect of number of turns shorted on primary and secondary on load condition. Experimental set up is as shown in fig .3 and fig.4 The current and voltage signals were captured for inrush and faulted condition, The captured data are stored in excel sheet with the notations Vp-Primary voltage, Ip-Primary current ,Vs-Secondary voltage, Is- Secondary current, Ts- Sampling time and FEQ-frequency of supply voltage at captured instant .

4.1 Procedure for data collection

1. The magnetization current is captured at primary side.
2. Inter-turn faults are done on primary and secondary winding through contractor under load condition.
3. The difference of primary and secondary is done sample by sample. The fifth channel is set in Math function which directly gives differential current.
4. Current transformer and Voltage transformer are used to capture the current and voltage, The analog signals are sampled at rate of 10000sample/sec. by Tektronix Digital Oscilloscope(DSO).
5. The data is stored in excel sheets using Data Acquisition Card by Tektronix DSO.

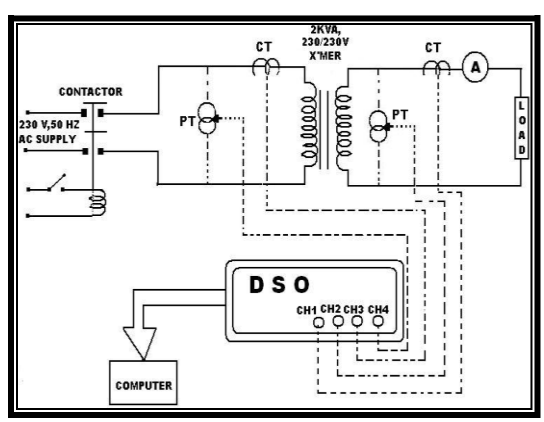


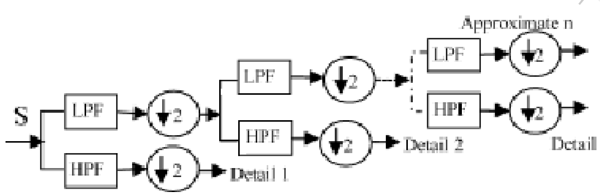
Fig.3 Experimental set up

Fig.4 Photo of practical setup

5. Wavelet Analysis

At the first stage an original signal is divided in to two halves of the frequency bandwidth, and sent to both Low Pass Filter (LPF) and High Pass Filter (HPF). The coefficients of filter pairs are associated with the selection of mother wavelet, the Daubechies Db-4type wavelet is used as mother wavelet. Then the output of LPF is further cut in half of the frequency bandwidth and then sent to the second stage, this procedure is repeated until the signal is decomposed to a pre-defined certain level. If the original signal were being sampled at Fs Hz, the highest frequency that the signal could contain, from Nyquist's theorem, would be Fs/2 Hz. This frequency would be seen at the output of the high pass filter, which is the first detail 1; similarly, the band of frequencies between Fs/4 and Fs/8 would be captured in detail 2, and so on. The sampling frequency is taken to be 10 kHz and Table I shows the frequency levels of the wavelet function coefficients.

Fig.5 Implementation of DWT



Decomposition Level	Frequency Components, Hz
D1	5000-2500
D2	2500-1250
D3	1250-625
D4	625-312.5
D5	312.5-156.25
A5	0-156.25

Table I: Frequency levels of Wavelet Functions Coefficients

The waveforms of inrush and fault along with decomposition levels are shown.

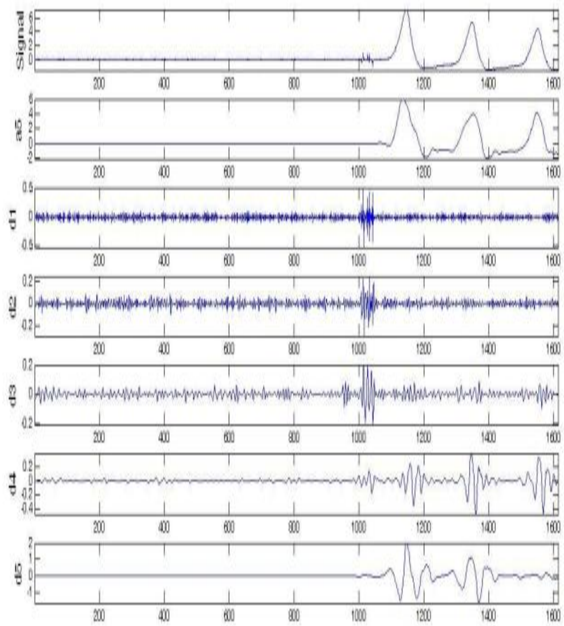


Fig 6 Wave form and decoposition levels of Inrush differtial current

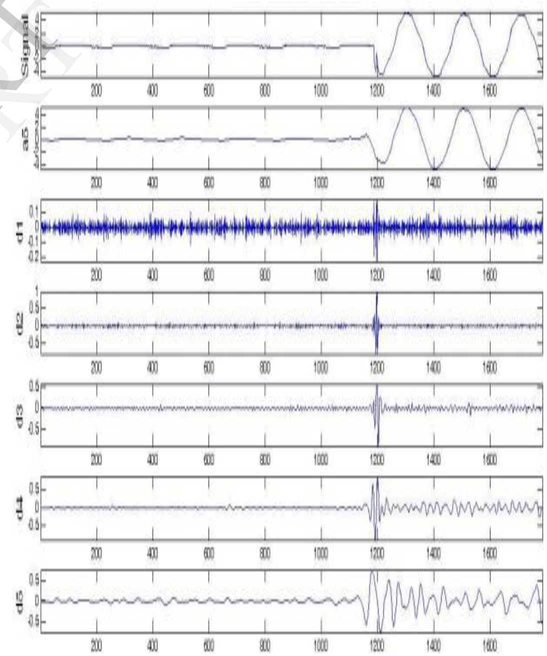


Fig 7 Wave form and decoposition levels of Primary fault differtial current

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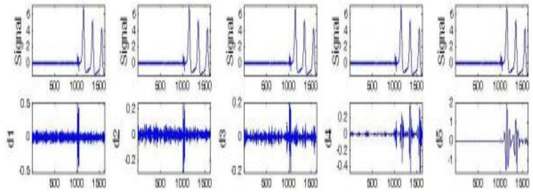

Fig 8 (a) Wave form and decoposition levels of magnitization inrush differtial Current along orignal signal.

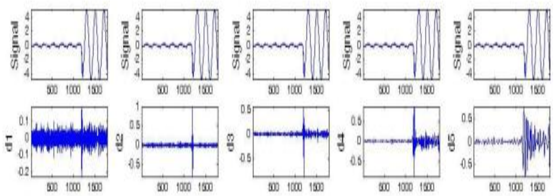

Fig 8 (b) Wave form and decoposition levels of primary fault differtial Current along orignal signal

From visual inspection of fig 6 and fig 7 characterize the transient and discriminate between magnetization inrush and interturn fault. In these two figures d1 and d2 are nearly similar and discrimination is difficult. By keen obseration at decomposition level d3 and d4 of figure 6, the wavelet coefficients are corresponds to magnetization peek. Whereas in fig 7, the large wavelet coefficients for the decomposition level d3 to d5 appears at the instant of swiching and attenuates with the length. fig 8(a) and fig 8(b) shows the each decomposition level along with orignal signal for readly justification of above lines.

6.Conclusion

This paper discussed efforts to characterize transients for transformers, resulting from various types of faults. The experiments were conducted on a single-phase transformer model. The data were obtained from experiments for several cases related to the transformer operation such as magnetizing inrush, external system short circuits, internal short circuits.The data were analyzed using discrete wavelet transforms (DWTs). The characteristics of the cases and differences between cases were presented. The results show great potential for using this method for predictive maintenance and maintaining reliability of transformers. Proposed technique is discussed in depth and validated through the practical results obtained on custom-built transformer.

7.References

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BIOGRAPHY

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