CLASSIFICATION OF TRANSFORMER FAULTS USING WAVELET BASED ENTROPY

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ABSTRACT

This paper presents Wavelet based approach for power transformer faults classification. Wavelet transform is applied to extract the features from the raw signal. An entropy based method is proposed to classify the faults. This entropy based method reduces the size of the input features without losing the characteristics of the signal. The data required to develop the algorithm are generated by simulating various faults in MATLAB simulink. The simulation results show that the proposed method provides a robust and accurate method for power transformer faults classification.

Index Terms: Entropy, Inrush Current, Detailed Coefficient, Wavelet Transform, Fault Index

I. INTRODUCTION

In power systems, transformer is one of the essential elements and thus transformer protection is of critical importance. In general, differential relays are used to detect the internal faults of a transformer which involves converting the primary current and secondary currents in a common base and comparing them. The magnetizing inrush current makes the transformer protection a challenge to the researchers. The magnetizing inrush occurs during the energization of the transformer which sometimes results in a high current in the order of 10 times the full load current. This high current might cause the relay to mal-operate. In order to avoid mal-operation of the relay, distinguishing between the magnetizing inrush current and the fault current is required. There are many existing algorithms based on the second harmonic and sometimes also the fifth harmonic restraint concept [l, 2]. Among these algorithms Walsh function, rectangular transform, Harr function, Fourier, least square algorithm, etc. are worth mentioning [2]. In reference [2], the authors experimentally compared *six* such existing methods to find out the best one in terms of speed and reliability. In all the algorithms described in reference [2], the second and fifth harmonics have been chosen so far **as** the indication for determining whether the measured differen tial current is an internal fault or inrush including over excitation. Recent study reports show that in certain cases, the internal fault current might contain considerable amount of second'and fifth harmonics too [3]. Moreover, it has been also reported that the low-loss amorphous core materials in modern transformer produces lower harmonic contents in magnetizing inrush currents [4]. Considering these factors, many researchers continued their work to develop new algorithms for transformer protection [3]-[5].

However, all these algorithms are either based on the transformer equivalent circuit model and/or require some transformer data and thus may become susceptible to parameter variations. There are extensive researches and applications of artificial neural network over the last few years, particularly in the field of pattern recognition. The main advantage of the ANN method over the conventional method is the non-algorithmic parallel distributed architecture for information processing [5]. The ANN algorithm has been successfully implemented in many pattern or signature recognition problems. Since this particular problem can also be considered as a current waveform recognition problem, the use of ANN seems to be a good choice. The ANN is becoming a powerful tool in various fields of for power system protection [7]. In recent years, few works which investigate the feasibility of using intelligent techniques for transformer protection has also been reported [8]-[l0]. Another recent work is wavelet entropy based approach for power system transient classification is presented in [11]. Here[11] neural network is employed for automatic power system transient classification. Based on wavelet transform the idea of entropy and weight coefficient is introduced and the wavelet energy entropy and wavelet entropy weight are defined in [12].

In the proposed work, a novel entropy based method is described and a new algorithm is developed for transformer faults classification. The transient signals of different fault conditions, inrush condition and no fault conditions at different switching instants are captured. Using 'bior' wavelet the faulted signals are decomposed at level2 and d1-coefficients of differential and restraining currents are used for further evaluation. The entropy values of all d1-coefficients are calculated and the sum of entropy values of d1-coefficients of differential currents (sd) and restraining currents (sr) are calculated. Then the ratio of (sd) to (sr) is found from which fault Index is defined for classifying the faults.

II. DISCRETEWAVELETTRANSFORM(DWT)

DWT is an ideal way to capture the transient phenomena for transformer. The wavelet transform gives the frequency information of the signal and also the times at which these frequencies occur. Combining, these two properties make the Fast Wavelet Transform (FWT), an alternative to the conventional Fast Fourier Transform (FFT). Wavelet is a waveform of limited duration. Wavelets tend to be irregular, asymmetric, short and oscillatory waveforms. To detect the transformer faults, only dominant transients within the certain bands play the important role. Therefore the wavelet filter banks are designed to extract the required transient currents. DWT is capable of extracting both fast and slow events in a desired resolution. The DWT of a signal *x* is calculated by passing it through a series of filters. First the original signal x[n] is passed through a half band low pass filter with impulse response $g[n]$, resulting in a convolution of the two.

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k].\, g[n-k] \qquad \ldots\ldots(1)$$

where x is the signal in discrete time function., the sequence is denoted by x[n], n is an integer, g[n] is the impulse response of the low pass filter and y[n] is the output of the filter. The signal is also decomposed simultaneously using a half band high-pass filter *h[n]*. The outputs from the high pass filter give the detail coefficients and the outputs from the low-pass filter give the approximation coefficients. It is important that the two filters are related to each other and they are known as a quadrature mirror filter. However, since half of the frequencies of the signal have now been removed, half the samples can be discarded according to Nyquist's rule. The filter outputs are then down sampled by 2.Hence the equation 1 becomes,

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k].\, g[n-k] \quad \text{.......... (2)}$$

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k].\, g[2n-k] \quad \text{.......... (3)}$$

This decomposition has halved the time resolution since only half the number of samples now characterizes the entire signal. However, this operation doubles the frequency resolution, since the frequency band of the signal now spans only half the previous frequency band. The Block diagram of filter analysis is shown in figure1.

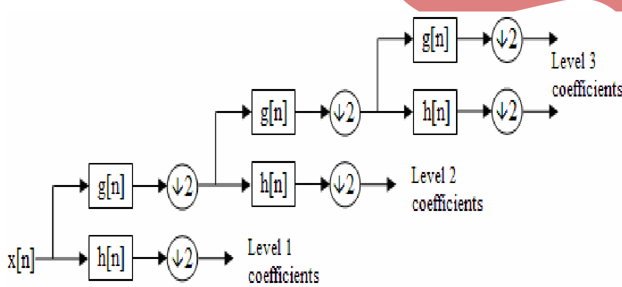


Fig. 1: Block Diagram of Filter Analysis

III. ENTROPY

The wavelet coefficients such as approximation and detail coefficients are obtained by finding the wavelet transform of the disturbance signals using Multi Resolution Analysis (MRA) technique. Most useful features must be first selected from these coefficients to reduce the dimension of feature vectors. A feature selection algorithm based on Shannon (non normalized) entropy is developed . The entropy [13] is a measure of irregularities of states such as imbalance and uncertainty. Since power quality disturbance signals have the imbalance, the non stationary, the different frequency component and the different energy distribution, the Shannon entropy is

proposed to extract the features from different power system transient. Entropy is a common concept in many fields, mainly in signal processing. Many others are available and can be easily integrated.

Entropy [14] is a common concept in many fields, mainly in signal processing. In thermodynamics, entropy is a measure of quantifying the imbalance degree of thermostate. In mathematics, entropy is used to measure the uncertainty of problems. While in information science, entropy is the average uncertainty of information source. In other word, entropy is a measure of irregularity of states such as imbalance, uncertainty. A method for measuring the entropy appears as an ideal tool for quantifying the ordering of non-stationary signals. Various wavelet entropy measures were defined in [14].In this paper, the non normalized Shannon entropy is used. Let the disturbance signal be U= {Uj j=1,2,…….N}.The Shannon (non normalized) entropy of the j^{th} point is represented as

$$SE_j = \sum_{k=1}^{N} Ejk \log E_{jk} \ldots\ldots (4)$$

where E_{jk} *is* the wavelet energy spectrum at scale *j* and instant k and is defined as follows.

The wavelet energy spectrum for detail and approximation coefficients in each decomposition level is obtained from the wavelet multi-resolution analysis of different disturbances and can be calculated as follows:

$$ED_{jk} = |D_j(k)|^2 \ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

$$EA_{jk} = |A_j(k)|^2 \ldots\ldots\ldots\ldots\ldots\ldots..(6)$$

Where j=1,2,………..J

ED_{jk} and EA_{jk} are the energy spectrum for detail and approximation coefficients respectively. *Dj(k)* is the detailed coefficients *and Aj (k)* is the approximation coefficients. Where *J* represents the total number of resolution levels. The extracted features help to distinguish a disturbance signal from another. The frequency bands with higher entropy values, which contain useful information, are selected from the entropy distribution of the wavelet detailed coefficients and the remaining frequency bands with zero entropy values are rejected.

IVSINGLE LINE DIAGRAM

The single line diagram of a three phase power transformer is as shown in fig. 2 given below. It consists of circuit breakers, current transformers, and a Y-Δ connected three phase power transformer. Simulation is carried out by using Matlab simulink.

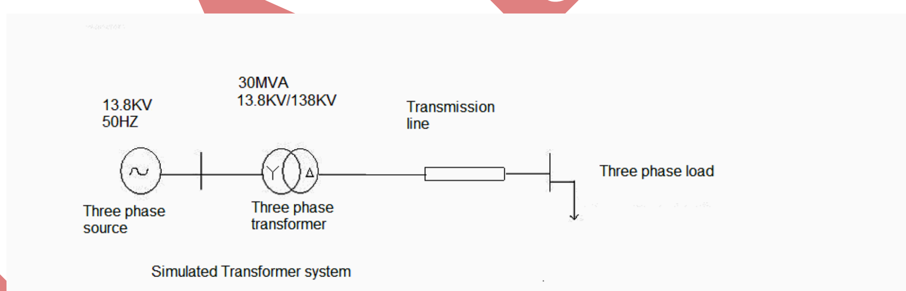


Fig. 2 Single Line Diagram

Table I

4.1 Block Parameters

Three Phase voltage source

Phase – Phase RMS Voltage	138KV
Frequency	50Hz
Phase Angle of Phase a	0^0

Table II

4.2 Three Phase Transformer Block Parameters

Three Phase Power	15MVA
Nominal Power	1MVA
Frequency	50Hz

V SIMULATION RESULTS

The data required to develop the algorithm are generated by simulating various faults in MATLAB simulink. Because of the facility to allow the use of variable window length, WT is useful in analyzing transient phenomena such as those associated with line faults and/or switching operations. Unlike FT, wavelet analysis has the ability to analyze a localized area of a signal and can reveal aspects of data like break points, discontinuities, etc. WT is thus useful in detecting onset of a fault and in realizing non stationary signals comprising both low and high frequency components. The inrush current and A few examples of plots of d1-coefficients for different fault cases are shown below

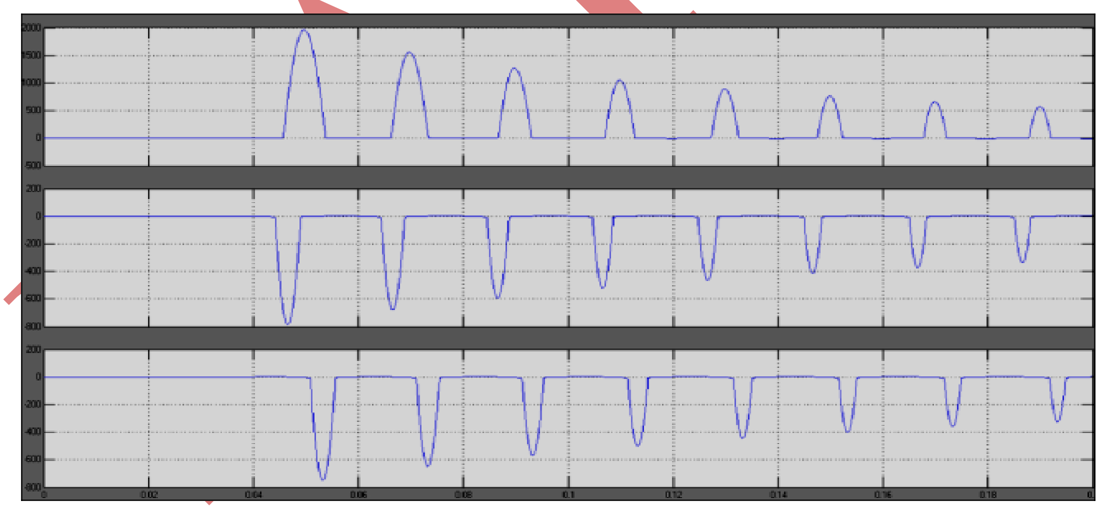


Fig3.Inrush in phases A, B, C

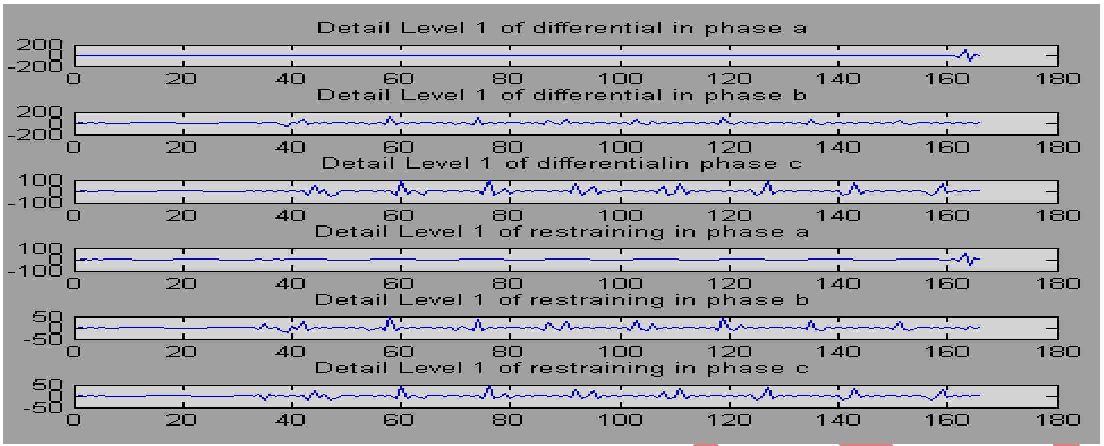


Fig.4 D1-Coefficients of Differential and Restraining For Inrush

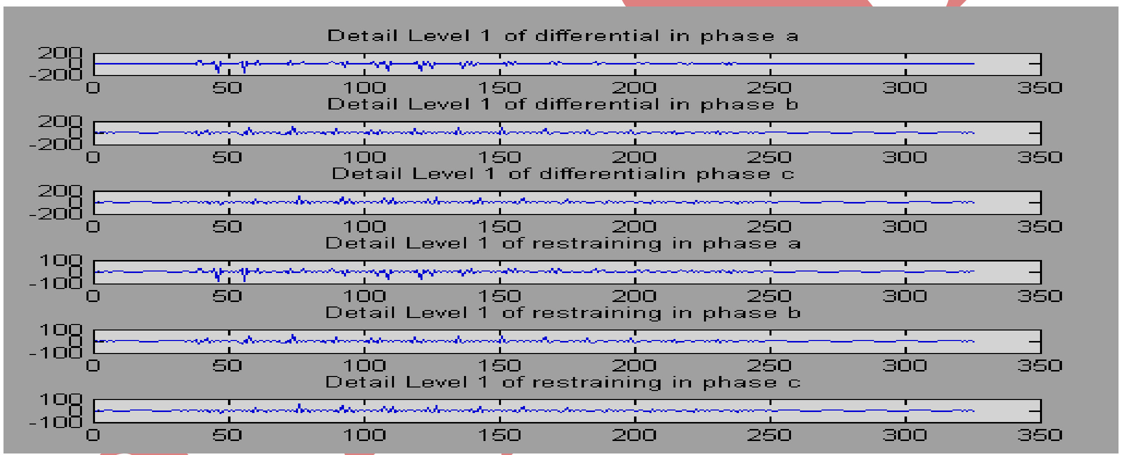


Fig.5 D1-Coefficients of Differential and Restraining For Healthy Operation

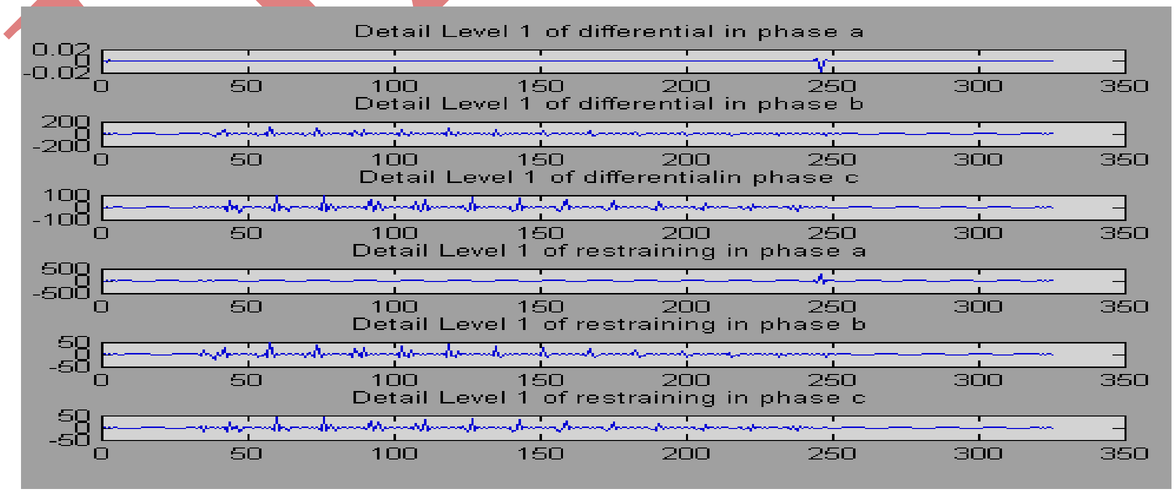


Fig6 D1-Coefficients of Differential and Restraining For External A-G

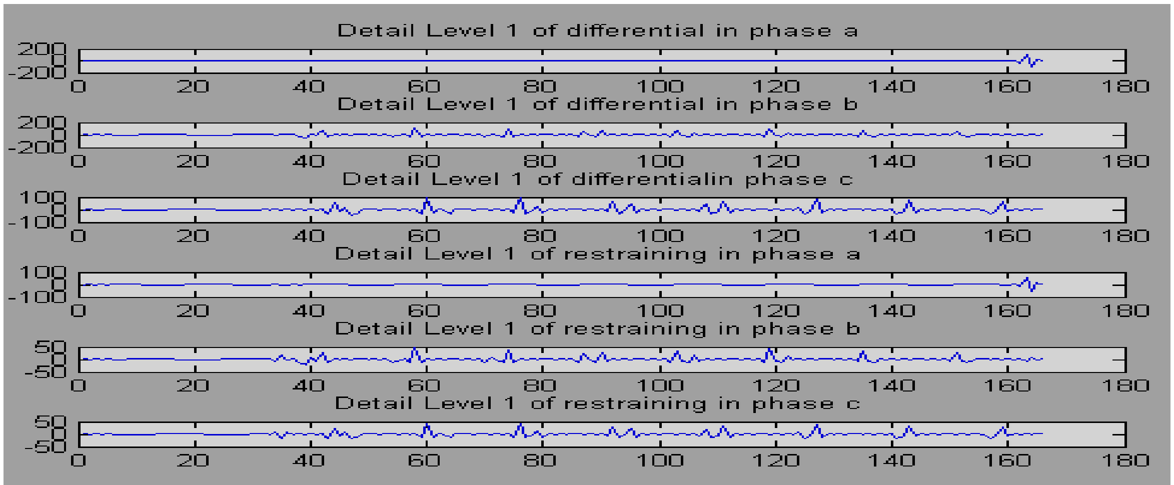


Fig.7 D1-Coefficients of Differential And Restraining For Internal A-B Fault

After number of simulations at different switching instants the different ranges of values of ratios of (sd) to (sr) are tabulated in Table.II

TABLE II

Ratio of (sd) and (sr) for different fault cases

Sl.no	Fault type	Ratio=(sd)/ (sr) (Range of values)
1	Internal	>4.8249 but≤5.7839
2	External	≤ 1.7348
3	inrush	> 1.7348but≤ 4.8249
4	Healthy case	≥ 6.0798

For the sake of classification the ratio of external fault is taken as the reference value

i.e. 1.7348 = 1 unit (Fault Index, I)

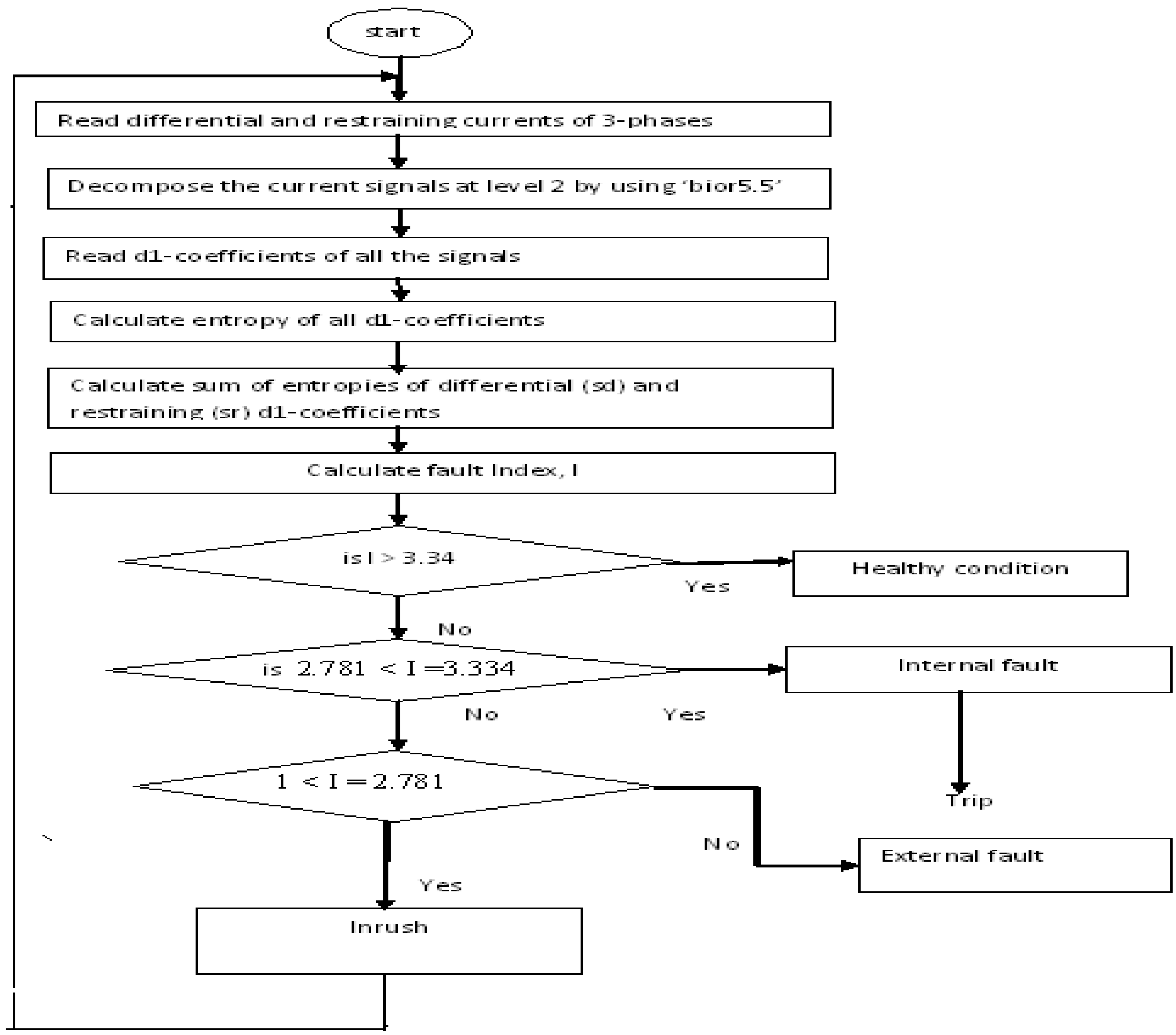
The correspondent fault index(I) values are tabulated in Table. III

Table. III

Sl.no	Fault type	Fallt Index (I)
1	Internal	2.781 < I ≤3.334
2	External	≤ 1
3	inrush	1 < I ≤ 2.781
4	Healthy case	>3.334

Based upon the above observation a Flowchart is developed as shown below

VI. FLOWCHART OF PROPOSED METHOD



VII. CONCLUSIONS

In this paper, a new entropy based method is proposed for automatic power transformer fault classification. The d1-coefficients are extracted using wavelet transform and Shannon entropy method is used to select the relevant features. The most important advantage of the proposed method is the reduction of data size as well indicating the main characteristics of signal without losing its distinguishing characteristics. Further, it reduces the memory requirement and increases computation speed.

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