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Intelligent Protection Scheme For Power Transformer

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ABSTRACT: Transformer protection is a critical issue in Power System as the issue lies in the accurate & rapid discrimination of Magnetizing Inrush Current from internal fault current. This paper gives new scheme for Protecting power Transformer. This technique implements the wavelet transform i.e a new approach for protection of power transformer is presented using time-frequency transform known as wavelet transform, to extract the transient components from the captured Transformer current. The Function Of Discrete Wavelet Transformer (DWT) is analysing non-static signal is capable of extracting predominant transient signal energized by transformer internal fault .In this analysis of extracted transients, high selecting of proposed relay can be achieved. The advantages are high speed response, immunity to the CT Saturation ,ability of detecting low level Internal Faults &Inrush Current etc. Different operating conditions provide variations in wavelet coefficients. Different operating conditions like entropy, skewness, Standard deviation , RMS , peak etc. are used as a input to SVM (Support Vector Machine) for fault classification . The proposed algorithm provides more accurate results even in the presence of noise inputs and accurately identifies inrush and fault currents. Overall classification accuracy of the proposed method is found to be excellent. Simulation of the fault (with and without noise) was done using PSCAD and analysis is in the MATLAB software.

KEYWORDS: Power transformer, Differential Protection, Transient based Protection ,Discrete wavelet transform, Transformer Inrush MATLAB, PSCAD,SVM.

I.INTRODUCTION

Power transformers are important elements of power system. So it is very significant to avoid any mal-operation of required protective system. For many years, differential protection has been used as the primary protection of power systems. It contains the differential relay, which operate for all internal fault types of power transformer and block due to inrush current. The major drawback of the branch of differential protection relays, its potential malfunction resulting from transient inrush current that flows when the transformer is energized(1). The input current contains a large second harmonic component. Most methods for digital transformer differential protection are based on the harmonic content of the current differential.
These methods are based on this fact that the ratio of the second harmonics to the fundamental component of differential current in inrush current condition is greater than the ratio in the fault condition(2,3). However, the second harmonic may also be generated during faults on the transformers. It might be due to saturation of CTs, parallel capacitances or disconnected transformers. The second harmonic in these situations might be greater than the second harmonic in inrush currents. Therefore, the commonly used conventional differential protection based on second harmonic restraint will face difficulties in distinguishing the input current and internal faults(2). Therefore, an improved technique for protecting discriminate between the input current and internal faults requires.

To overcome this difficulty and prevent the mal-function of differential relay, many methods have been presented to analyze and recognize non-stationary signals, wavelet based signal processing technique is an effective tool for power system analyze and feature extraction . However, the methods based on wavelets are better able to time-frequency analysis, but usually require long data windows and are also sensitive to noise(6). The method presented in WT used to discriminate internal fault from inrush current. Since the values of the wavelet coefficients in detail are used for pattern recognition process, the algorithm is very sensitive to noise. This paper present a new protection scheme for transformer fault. This proposed algorithm extract fault and inrush generated transient signal using DWT(3) . When a

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fault occurs in the system , the specially designed relay captures the fault transient currents via CTs installed at the primary and secondary sides of transformer respectively. The signals are then tuned by DWT multi resolution filter bank to filter out the unwanted components .

In this paper, we proposed using wavelet transform combined with SVM is proposed. Wavelet algorithm has been used for analyzing power system transients [4]. In [5-7] authors have used discrete wavelet transform for differential protection. In another approach [8] have used wavelet packet algorithm to extract certain features of the differential current likelike entropy ,skewness ,Standard deviation , RMS , peaketc have discriminated inrush and fault currents using wavelet coefficients and wavelet energy. Feature extraction of differential current is also needed to reliable distinguish inrush and fault currents. The [9,10] features using wavelet transform. In [11,12] have utilized wavelet transform for feature extraction. A new technique for discriminating between inrush current and internal fault current is presented in this paper by combining wavelet transform and SVM. Initially wavelet transform is applied to decompose the differential currents signals in to series of wavelet coefficients.DB8 has been used as mother wavelet function [13]. SVM has been tested and trained using features of fault classification

II. PRINCIPAL OF FAULT DETECTION

The system configuration of proposed relay mainly consists of analogue interface , modal mixing , wavelet filter bands ,differential and average computations, internal fault detection , inrush identification and logic design unit . In this the relay is interfaced with primary system through twosets of CTs which are connected to high tension and low tension side of transformer respectively in different groups , i.e Y and Δ, to compensate the phase shift of Δ/Y transformer. The signal from CTs are first combined in modal mixing unit so as to remove the background noise effectively. To detect the transformer fault , only dominant transient within the certain bands play the important role .[18] Therefore the wavelet filter bank are designed to extract the wanted transient current from the modal signals .In fact the wavelet transform , a powerful tool to analyse a non static signal , functions are moving window with different scales . As a wavelet with a certain scale move along the time axis , the signal is compared with the wavelet and the signal component matching with the wavelet are extracted It is acknowledged that DWT is capable of extracting both fast ad slow events desired resolution. Hence, DWT is a ideal means used to capture the transient phenomenon for transformer protection.

III. DISCRETE WAVELET TRANSFORM

One of the initial important steps in this work to design the model of power transformer to accurately collect the needed data. The needed data consists mainly magnetizing inrush (unloaded) for different switching angles and internal fault currents (single phase to ground, phase to phase and turn to turn fault current) and external fault current. The collected data are able to be employed for selecting both the mother wavelet and number of level of resolution.

Magnetizing inrush current depends on many factors such as: the residual magnetism loading condition of power transformer and switching angle. ;In power transformer there are different kind of fault which can occur. The different internal faults considered for data collection in this work include single phase to ground fault and turn to turn fault or inter turn fault currents. Very large of power transformer failures arises from fault between turns. Inter turn fault may occur due to mechanical forces between turns originated by external short circuit.

Transients in a Power system are initiated every time whenever there is a change of system operational conditions these can be analyzed using Wavelet transform. Extensive research shows that transients of a power system, especially those generated by a fault, are very rich in operational information of a power system. So, wavelet analysis is suitable for transient signal analysis as measured by protective relays. The WT is an efficient signal processing tool used in power system analysis. The WT and STFT allow different frequency components to be time localized, with fixed window width function as in STFT. This results in prior determined frequency and time resolution. However the WT using wavelets as the analyzing function have a self-adjusting capability to the time widths in relation to frequency thereby creating a Inversely related frequency / width wavelet, i.e greater frequency - narrow width and vice versa. Transients create higher frequency components and have shorter time intervals, in contrast to lower frequency components and higher time intervals. WT has the inherent advantage of focusing on shorter time intervals, thereby picking transients for analysis. For this reason, to study transient signals, for achieving reliable discrimination based on current characteristics, Wavelet decomposition is ideal.

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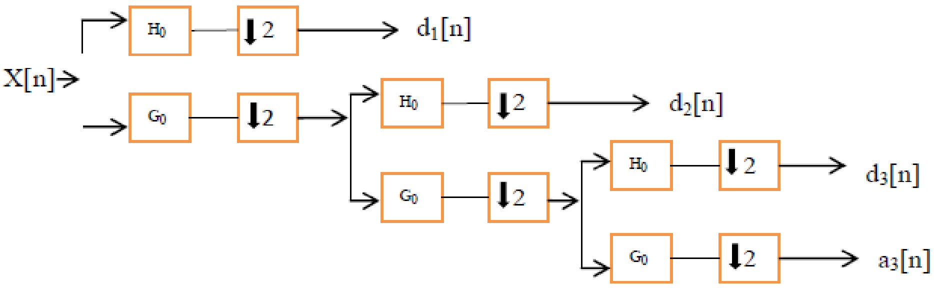

Fig1: Implementation of Discrete Wavelet Transform

Fig1 illustrates the implementation Discrete WT (DWT), S -Original signal, LPF and HPF: low-pass and high-pass filters respectively. The analysis is done by successive decomposition of the signal i.e. the signal is bifurcated and the two components passed through HPF and LPF. The output of the LPF is again bifurcated and sent through HPF and LPF and this process is repeated up to a predetermined level of decomposition. According to Nyquist's theorem , a signal of frequency Fs should be sampled 2Fs times to get the complete characteristics while reconstruction , and as a corollary sampling Fs times would give so on a maximum frequency Fs / 2 . thus Fs /2 ,Fs /4 ; Fs /4 , Fs /8 and so on are the frequencies in the first , second details and so on .

From here we can see that in case of DWT we can assign different time intervals for different frequency components. In the top block we have assigned a lower time interval and hence a higher frequency while in the bottom one we have assigned longer time interval and a low frequency.

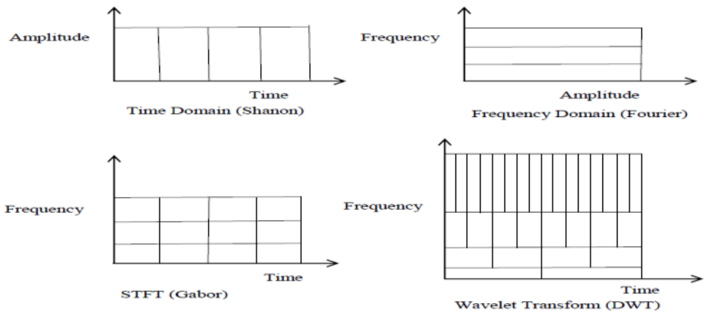

Figure 2: Different Transforms Methods

Wavelet transform is a powerful signal processing tool used in power system analysis. The wavelet transform (WT) like the short time Fourier transform (STFT), allows time localization of different frequency components of a given signal, however with one important differences STFT uses a fixed width windowing function. As result, both frequency and time resolution of the resulting transform will be a prior fixed but in the case of wavelet transform, the analyzing functions, which are called wavelet, will adjust their time widths to their frequency in such a way that, higher frequency wavelets will be very narrow and lower frequency wavelets will be wide. It has been found using wavelet for the proposed power system model it shows for internal fault currents window is narrow; for inrush, current window is very wide. It can be defined as follows:

$$f(x)=\sum_{i,j}\psi i,j\,(x) \qquad (1)$$

Where *i*and *j* are integers, the functions $\Psi i,j(x)$ are the wavelet expansion functions and the two parameters expansion coefficients *ai,j*are called the discrete wavelet transform (DWT) coefficients of *f*(*x*). The coefficients are given by

$$a_{i,j}=\int_{-\infty}^{+\infty} f(x)\psi i,j\,(x) \qquad (2)$$

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The wavelet basis functions can be computed from a function $\Psi i,j(x)$ called the generating or mother wavelet through translation and scaling (dilation) parameters

$$\Psi i,j(x) = 2^{-i/2}\psi(2^{-i/2}x - j) \qquad (3)$$

Where j is the translation parameter and $i$is the scaling parameters.Mother wavelet function is not unique, but it must satisfy a small set of conditions. One of them is Multiresolution condition and related to the two-scale difference equation

$$\varnothing(x)=\sqrt{2}\sum_{k}h(k)\ \varnothing(2x-k) \qquad (4)$$

Where $\varphi(x)$ is scaling and $h(k)$ must satisfy several conditions to make basis wavelet functions unique, orthonormal and have a certain degree of regularity. The mother wavelet is related to the scaling function as follows

$$\psi(x)=\sqrt{2}\sum_{k}g(k)\ \varnothing(2x-k) \qquad (5)$$

Where $g(k) = (-1)kh(1 - k)$. At this point, if valid $h(x)$is available, one can obtain $g(x)$. Note that h and g can be viewed as filter coefficients of half band low-pass and highpass filters, respectively. J-level wavelet decomposition can be computed with (6) as follows:

$$f_0(x)=\sum a_{0,}k\varnothing_{0,k}(k)=\sum_{k} a_{j+1,k\varnothing j+1}+\sum_{k} d_{j+1,k\psi j+1,k(x)} \quad j=0 \qquad (6)$$

Where coefficients $a0, k$ and coefficients $aj+1, n$ and $dj+1, n$ at scale $j + 1$ are given. Multiresolution analysis leads to a hierarchical and fast scheme. This can be implemented by a set of successive filter banks. Fig.1 illustrates the implementation procedure for discrete wavelet transform in which $X(n)$ is the original signal, $h(n)$ and $g(n)$ are low pass filter and high pass filter respectively. At the first stage, an original signal is divided in to two halves of the frequency bandwidth and sent to both HPF and LPF then the output of the LPF is further cut in half of the frequency bandwidth and sent to the second stage, this procedure is repeated until the signal is decomposed to a predefined certain level.

In this paper, transformer different operating conditions are decomposed to five levels; a4 is the approximation level containing the fundamental frequency component and d1 to d4 are detail levels with high frequencies. The ninth order Daubechies (db8) wavelet filter was used for wavelet decomposition.Wavelet transform has been found very efficient in discrimination of inrush current and fault current by many authors [14,15]. Application of wavelet transform has been used in many power engineering applications like power quality [16], transmission line fault analyze, also in various other fields like ECG signal analysis, automotive generator fault , Engine fault analysis . It has ability to analyze the local discontinuous of signals. Wavelet transform has a special feature that they have variable window size, being wide for low frequencies that exist for inrush current and narrow for high frequencies occurred form internal fault current.

IV. SUPPORT VECTOR MACHINE (SVM)

There are mainly two methods for selecting the parameters for SVM classifier. One method is user-determined directly, but there is no law to follow.
The main procedures of the other method are described as follows:

Step1. Divide sample data into training set, validation set and test set by a certain proportion;

Step2. Assign values for SVM classifier parameters.

Step3. Execute the SVM classifier training with the training set and estimate the SVM classifier performance with validation set.

Step4. Repeat Step2 and Step3until the SVM classifier performance meets the conditions.

Step5 .Test the SVM classifier using the test set.

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However, fixed training set and validation set for SVM classifier training, assessment and selection can only ensure that the selected parameters are optimal in the selected training set Therefore the generalization ability of the SVM classifier will be affected.In this study, the SVM classifier with parameters optimized by cross validation and genetic algorithm is used for fault diagnosis of power transformer (CVGA-SVM). Cross validation (CV) is widely accepted as a standard procedure for choosing proper model parameters and estimating model performance in data mining and machine learning community currently. And genetic algorithm (GA) is one of the most common optimization techniques. It is an effective means for combinatorial optimization. Thus, GA is suitable for selecting appropriate SVM classifier parameters. In this study, GA is adopted to optimize the SVM classifier parameters. CV is used to estimate the performance of SVM classifier with different parameters during the optimizing process and the estimation result is used as the fitness functionof GA.[19] It ensures that the optimized SVM classifier had better generalization ability.

Support vector machine is a new learning machine which implements the following idea it maps the input vectors into some high dimensional feature space Z through some nonlinear mapping chosen apriority .In this space a linear decision surface is constructed with special properties that ensure high generalization ability of the network .Two problems arise in this approach :one conceptual and one technical [20].The conceptual problem is how to find a separating hyper plane that will generalize well .The technical problem is how computationally to treat such high dimensional spaces.

The conceptual part of this problem was solved by Vapnik (1965) by introducing the concept of optimal hyper planes for separable case[22] .An optimal hyper plane is defined as linear decision function with maximal margin between the vectors of the two classes) The technical problem was solved by Boser and Vapnik (1992) by stating that the order of operations for constructing a decision function can be interchanged i.e. instead of making a non linear transformation of the input vectors followed by taking their dot product or some distance measure and then make a non linear transformation of the value of the result.

The Optimal Hyper plane Algorithm

The set of labeledtraning patterns

$(y_1,x_1)\ldots\ldots\ldots\ldots(y_1,x_1)$, $y_i \varepsilon(-1,1)$

Is said to be linearly seperable if there exists a vector ‘**W**’ a scaler ‘b’ such that the inequalities

$\mathbf{W}.\ x_i+b\geq 1$ if $y_i= 1$

$\mathbf{W}.\ x_i =b\leq 1$ if $Y_i=-1$

Are valid for all elements of the traning set.

The optimal hyper plane

$\mathbf{W_0}\ .\mathbf{x}=b_0=0$

Is the uniqe one which seperetes the traning data with a maximal margin . this distance $\rho(W,b)$

$P(\mathbf{w_0},b_0)= \frac{2}{\sqrt{w_0.w_0}}$

Thus to construct a optimal hyper plane ,one has minimize a funcytional

Φ=w,w

Subjects to constraints $y_i(x_i.w+b)\geq 1$. i=1,……,1

To do this standerdlagrangian optimization technique is used .

The ultimate problem becomes maximize function

$W(\Lambda)=\Lambda^T 1-\frac{1}{2}\Lambda^T D\Lambda$

With respect to $\Lambda^T\ (\alpha_1,\ldots\ldots\ldots\ldots\alpha_l)$

Subject to constraints

$\Lambda\geq 0$

$\Lambda^T Y=0$

Where $\Lambda^T = (\alpha_1,\ldots\ldots\ldots,\alpha_l)$is the vector of non- negative lagrange multipliers,

$Y^T =(y_1,\ldots..Y_l)$

D= symmetric matrix with elements

$D_{ij} = Y_i\, Y_j X_i\, X_i$

The algorithm described above constructs hyperplane in the input space. To construct a hyperplane in a feature space one first has to transform the n-dimensional input vector **x** into an N dimensional feature vector.

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The first algorithm implemented based on differential logic and utilizing SVM. In the algorithm, the first step is the calculation of the direct and differential currents using the sampled quantities. After that, the relay verifies if there is a significant differential current using a differential characteristic curve of the type shown in Fig.3 In the case where you have a significant differential current, the SVM will discriminate a fault condition from the other situations mentioned earlier.

This procedure would replace the conventional algorithm using harmonic restraint based on the Fourier technique. It must be emphasized that in this approach, no reconstruction action is implemented concerning the saturated signals mentioned before. The only precaution for this case is that in the training process, cases of differential current without saturation as well as some cases including the saturated condition as well used as mentioned If a fault condition is detected, the fault counter is verified, and after confirmation, a trip signal will be sent.

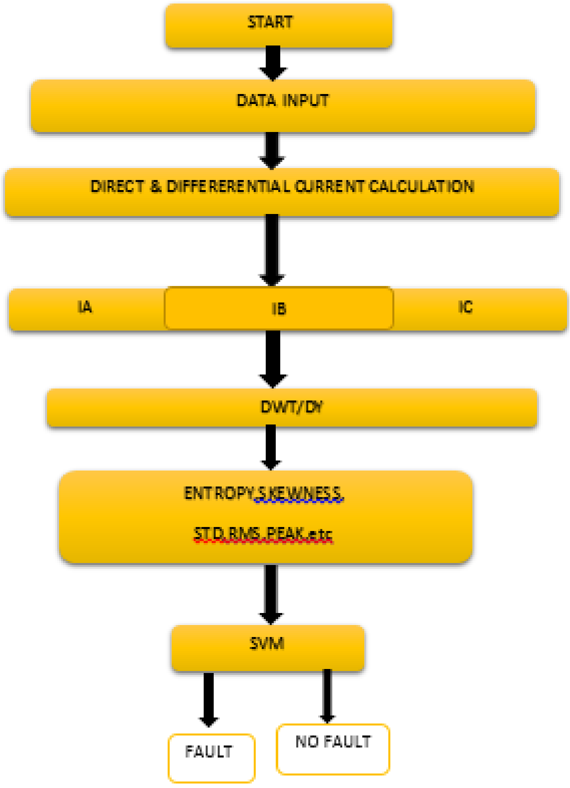

Figure 3: Proposed Algorithm

V. CONCLUSION

In this work , a three phase transformer with different operating condition such as normal condition, magnetizing inrush , internal and external fault condition in were created in PSCAD .The DWT predict the internal fault in three phase transformer and also discriminate it with magnetizing inrush and external fault..

The proposed techniques concentrate on the transient current which is energized by a fault. In the relay , the DWT filter banks are designed to extract the transient signals effectively. In addition, successfully able to infiltrate the proposed relay successfully with internal fault. An application of Support Vector Machine (SVM) Classifier for Power Transformer Protection has been presented in which it is able to distinguish internal disturbance from the conditions of various non-internal faults, which cover the effect of the various magnetizing inrushes such as initial inrush including residual inrush, and sympathetic inrush.

The work of this thesis was initiated with the aim of reducing the limitations of existing systems and developing a new SVM-based classification system for processors. This simulation should be done in the future using a model that

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produces an automatic defective degree developed in PSCAD. The proposed algorithm based on SVM has been developed in the MATLAB software.

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