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Discrimination of Internal Fault Current and Inrush Current in a Power Transformer using Empirical Wavelet Transform

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Abstract

Transformers are crucial equipment in a power system, which require reliable solutions for their protection to ensure smooth operation. Identification between internal fault current and in rush current is a challenging problem in the design of transformer protection relay. Transformers are often tripped when inrush current flows in the system causing problems in operation and maintenance in addition to the customer disturbance. Conventional identification methods have limitations in providing accurate solution to this problem. This work investigates the scope of a classification method based on EWT and SVM in distinguishing internal fault current and inrush current in a power transformer. Validation of this method is done using generated synthetic data from MATLAB/SIMULINK. Feature extraction of the generated data is done using EWT algorithm. These features are used for training SVM. Later, accuracy of classification is checked using test vectors. Different kernel functions for SVM are also tested for improved accuracy.

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Keywords: inrush current; internal fault current; EWT; SVM; kernel function; MATLAB/SIMULINK.

1. Introduction

Inrush current is a transient over current occurring due to part-cycle saturation of the magnetic core of the transformer at the time of excitation. Inrush current may flow due to various reasons. Energizing inrush current occurs when the system voltage is reapplied on the transformer that has been de-energized. Energizing some other transformer connected to the same network leads to the flow of sympathetic inrush current in the transformer.

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A short circuit on the system reduces the system voltage resulting in recovery inrush current on transformer voltage being restored. Inrush currents may also arise due to out-of-phase synchronization of any nearby generator connected to that transformer. This causes unbalance in the current loop of the differential relay causing unwanted tripping[1],[2].A method to distinguish between internal fault currents (for which the relay should trip) and inrush current (for which relay should not trip) is of importance for ensuring disturbance free operation of power transformer. Effects of inrush currents on power transformer protection relay are well explained in [3],[4].

Existing methods provide solution to this problem by distinguishing both the types of currents by taking the ratio of second harmonics to the fundamental of the current waveform. It is based on the assumption that the magnitude of second harmonic present in the inrush current is more in comparison to the magnitude of second harmonic in internal fault current. But due to the improvement in magnetic property of transformer core material, the level of second harmonics inrush has been reduced .Also in some severe faults; the level of second harmonic component is higher than that in inrush currents. Other sources of second harmonics can also be saturation of CTs, parallel capacitances or disconnected transformers [3].

Nomenclature

CT	Current Transformer
EWT	Empirical Wavelet Transform
SVM	Support Vector Machine
$\hat{\varphi}_n(\omega)$	Empirical wavelets
$\psi(\omega)$	Empirical wavelets
$\mathcal{W}_f^{\epsilon}(n,t)$	Wavelet transforms
Class C1	Class for inrush current
Class C2	Class for fault current
TP	True positive
FP	False positive

In [5], S.R.Praraskar, M.A.Beg and G.M.Dhole worked on an approach based on artificial neural network which is used to discriminate between inrush current and the internal fault current in the transformer. Further in [6], discussion is done on controlling the instant of energising to eliminate the transformer inrush current. Classification of inrush and internal fault current using wavelet transform is discussed in [7] by G.J.Raju. In [8], a classification methodology based on empirical mode decomposition is applied to this problem and results were not satisfactory. In [10] SVM classifier has been used to analyse the power supply quality. In this paper an alternate method is proposed where EWT [9] is used along with SVM [11]to discriminate between inrush and internal fault currents in power transformer. Synthetic data for validating this method are generated using MATLAB/SIMULINK .Methodology and results are described in subsequent sections of this paper.

2. EWT and SVM

2.1 EWT

A wavelet is a mathematical function used to divide a given function or continuous signal in time domain into different frequency components and study each component. The wavelet transform is used to represent the given function in terms of wavelets. In wavelet analysis signal to be analysed is multiplied with the wavelet function and for each segment generated the transform is computed. The width of the wavelet function changes with each spectral component. The wavelets adjust the time width to frequency so that the high frequency wavelets are narrow and the low frequency wavelets are broader. Assuming real signals and $\omega \in [0,\pi]$ and the Fourier support $[0,\pi]$ to be segmented into N segments. ωn is denoted as the limits between each segment, and each segment is given by $\Lambda_n = [\omega_{n-1}, \omega_n]$. Therefore $\bigcup_{n=1}^{N} \Lambda_n = [0, \pi]$.