

A Survey on Transformer Fault Location using Soft Computing Techniques

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Abstract: The demand for a reliable supply of electrical energy for the exigency of modern world in each and every field has increased considerably requiring nearly a no-fault operation of power systems. The crucial objective is to mitigate the frequency and duration of unwanted outages related to power transformer puts a high pointed demand on power transformer protective relays to operate immaculately and capriciously. The high pointed demand includes the requirements of dependability associated with no false tripping, and operating speed with short fault detection and clearing time. Hence, artificial neural network (ANN), a powerful tool for artificial intelligence (AI), which has the ability to mimic and automate the knowledge, has been proposed for detection and classification of faults from normal and inrush condition. The paper presents a comprehensive survey on soft computing approaches for transformer fault location which is very complex and prone to errors using conventional techniques.

Keywords: Transformer Fault Location, Soft computing, Artificial Intelligence, Artificial Neural Networks, Feature extraction, Accuracy.

I. INTRODUCTION

Power system plant has to be protected against faults, abnormal system conditions and other

undesirable situations. Protective gear relays and systems are provided for this purpose. The demand for a reliable supply of electrical energy for the exigency of modern world in each and every field has increased considerably requiring nearly a no-fault operation of power systems. Power transformers are a class of very expensive and vital components of electric power systems. [1] The crucial objective to mitigate the frequency and duration of unwanted outages related to power transformer puts a high pointed demand on power transformer protective relays to operate immaculately and capriciously. The high pointed demand includes the requirements of dependability associated with no false tripping, and operating speed with short fault detection and clearing time. Protection of large power transformers is a very challenging problem in power system relaying. [2] The protective system includes devices that recognize the existence of a fault, indicates its location and class, detect some other abnormal fault like operating conditions and starts the inceptive steps of opening of circuit breakers to disconnect the faulty equipment of the power system. There are problems which are peculiar to transformer, which are not encountered in other items of power system. One of the major problem is the large magnetizing inrush current, whose magnitude can be as high as internal fault current and may cause false tripping of the breaker. [5] A common differential relay operating on the basis of measurement and evaluation of currents at both sides of the

transformer can't avoid the trip signal during inrush condition. Since the transformer inrush current is rich in second harmonic component therefore to avoid the needless trip by inrush current harmonic restraint logic together with differential logic is used in most of the fault detection algorithm in the digital differential protection of power transformer. These methods utilize the fact that the ratio of the second harmonic to fundamental component of differential current under inrush conditions is greater in comparison to that under fault conditions. Mechanical forces build up under large inrush current condition within the transformer coils compared to those occurring at short circuit which is the reason for damage of large power transformer. Large inrush currents also affect the power quality by adding harmonics. Also the presence of large quantity of harmonics in the inrush current can cause damage to power factor correction capacitor by exciting resonant overvoltage. Hence steps are taken to mitigate the transformer inrush current by controlled switching and use of low loss amorphous core materials in modern power transformer that produce inrush current with low second and fifth harmonic contents.

II. PREVIOUS WORK

Previous work in the domain helps in formulating the problem domain and renders an idea into the basic mechanisms that have been already used for the purpose of transformer fault location. The different contemporary work of authors have been cited here with their merits and approaches.

Jéssika Fonseca et al. in [1] discussed that currently, the differential function has been widely used in transformer protection relay. However, the main issue of this technique is assigned to the relay mis-operation during the

presence of inrush currents and current transformer (CT) saturation. In the literature, these limitations have been overcome with the use of tools based on artificial intelligence and signal processing, such as the methods based on artificial neural networks and wavelet transform. This paper proposes a method based the ANNs and wavelet transform to detect and classify disturbance in the power transformer accurately. The algorithm uses wavelet-based disturbance detector in order to detect any disturbance related to a power transformer, whereas a neural network-based routine is used to classify the disturbance type (internal fault, external fault and transformer energization) appropriately, as well as to classify the internal faults.

Preeti et al. in [2] discussed that the demand for a reliable supply of electrical energy for the need of modern world in each and every field has increased considerably requiring nearly a no-fault operation of power systems. The crucial objective is to mitigate the frequency and duration of unwanted outages related to power transformer puts a high pointed demand that includes the requirements of dependability associated with no false tripping, and operating speed with short fault detection and clearing time. The second harmonic restrain principle is widely used in industrial application for many years, which uses discrete Fourier transform (DFT) often encounters some problems such as long restrain time and inability to discriminate internal fault from magnetizing inrush condition. Hence, artificial neural network (ANN), a powerful tool for artificial intelligence (AI), which has the ability to mimic and automate the knowledge, has been proposed for detection and classification of faults from normal and inrush condition.

AAP Bísvaro et al. in [3] proposed a methodology for automated disturbance analysis

and fault location on electric power distribution systems using a combination of modern techniques for network analysis, signal processing, and intelligent systems. New algorithms to detect, classify, and locate power-quality disturbances are developed. The continuous process of detecting these disturbances is accomplished through statistical analysis and multilevel signal analysis in the wavelet domain. The behavioral indices of the current and voltage signals are extracted by employing the discrete wavelet transform, multi-resolution analysis, and the concept of signal energy. These indices are used by a number of independent Fuzzy-ARTMAP neural networks, which aim to classify the fault type and the power-quality events. The fault location is performed after the classification process. A real life three-phase distribution system with 134 nodes-13.8 kV and 7.065 MVA-was used to test the proposed algorithms, providing satisfactory results, attesting that the proposed algorithms are efficient, fast, and, above all, intelligent

E. Abdallah in [4] presented a review of different protection approaches used with transformer differential protection to discriminate between internal fault current, magnetizing inrush current during energization, magnetizing inrush current. These approaches include harmonic restraint, voltage and flux restraints, the inductance based method and pattern recognition. The pattern recognition approach has mainly been designed using artificial intelligence (neural networks, fuzzy logic), wavelet transforms and hybrid techniques.

Santosh Kumar Nanda in [5] discussed about how Inrush currents in power transformers are detected based on magnitude of second harmonic component. To avoid the harmful effects of inrush, amorphous core is widely used in recent

days. Transformers with amorphous core cause low magnitude inrush current and hence the second harmonic of inrush current is comparable with that during internal faults. This increases the chances for relay mal operation when classical techniques of discriminating inrush from other faults are used. To overcome this, advanced signal processing techniques like wavelets, S-transform, H-transform and pattern recognition tools like fuzzy logic, neural network, support vector machine etc. are being used in recent days. A combination of wavelets and neural network is found to give satisfactory solution to the above problem

A. Pavithra in [6] proposed a new differential protection scheme based on Artificial Neural Network (ANN), which delivers effective distinguish between internal faults in a power transformer with the other disturbance such as various types of inrush currents and overexcitation conditions. In existing method, the internal faults only considered and the linear programming method detects the faults at one set value of the system i.e. it detects the faults only one particular type and it could not detect all the faults simultaneously. So, the above problem is overcome by detecting the various types of faults in the system. In the proposed method, Artificial Neural Network (ANN) techniques are used to detect all the types of faults in the power system. The Back Propagation Neural Network (BPNN) algorithm is used to train the process quickly.

ManojTripathy in [7] discussed about many methods that have been used to discriminate magnetizing inrush from internal faults in power transformers. Most of them follow a deterministic approach, i.e. they rely on an index and fixed threshold. This article proposes two approaches (i.e. NNPCA and RBFNN) for power transformer differential protection and address the challenging

task of detecting magnetizing inrush from internal fault. These approaches based on the pattern recognition technique. In the proposed algorithm, the Neural Network Principal Component Analysis (NNPCA) and Radial Basis Function Neural Network (RBFNN) are used as a classifier. The principal component analysis is used to preprocess the data from power system in order to eliminate redundant information and enhance hidden pattern of differential current to discriminate between internal faults from inrush and over-excitation condition.

Sendilkumar Subramanian et al. in [8] presented a Wavelet packet transform with entropy features and support vector machine (SVM) based differential protection of power transformer by using internal fault and inrush current. The wavelet packet transform one of the powerful signal-processing tool and it is used to extract the information of differential current from third level using Db 9 mother wavelet. A two cycles of transformer fault current data is processed through wavelet packet transform to obtain wavelet coefficients and then features are extracted by using Shannon entropy principle. Subsequently, the extracted features are applied as inputs to SVM for distinguishing inrush current from internal fault. The application of this method is studied through detailed simulation of different faults on a power transformer using MATLAB/SIMULINK software. The results of the proposed new technique were found to be reliable, fast and accurate in identifying the fault condition.

III. MATERIALS AND METHODS

Artificial Neural Networks

An Artificial Neural Networks: Neural

Networks can be considered as the machine or artificial counterpart of the human brain. It is capable to mimic the functionalities of the human brain. The mathematical model of the neural network is shown below.[12]

Assume a parallel stream of data X enter the neural network. The summation of the data streams take place at the neural network interface. The experiences created by the network based on the received inputs is designated as the weights of the ANN

$$y = \sum_{i=1}^n X_i \cdot W_i + \theta_i \quad (1)$$

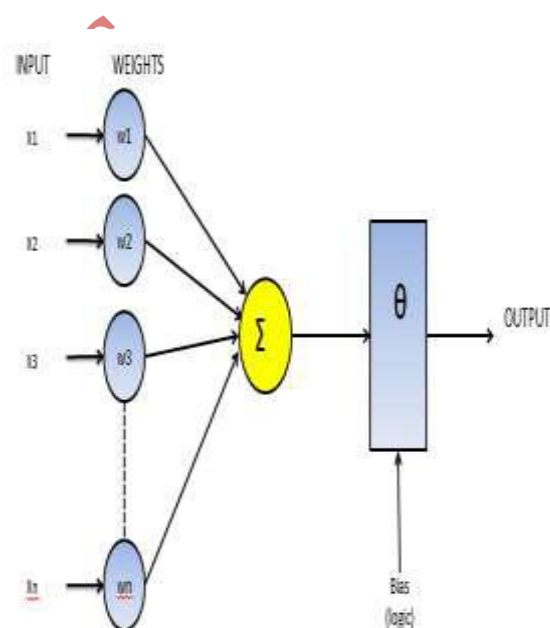


Fig.1 Mathematical Model of A Neural Network

The entire mathematical model of the neural network can be explained as:

X represents the parallel inputs

Y represents the output of the ANN

θ represents the bias

W represents the weights associated with the inputs received the ANN.

In the recent years there has been much big technological advancement in terms of

automation. The one area which has been showing tremendous growth and application potential is the field of Artificial Intelligence.[13] Artificial Intelligence is the field where machines show the capability of doing many tasks that the humans can perform. Usually computers are programmed to do work or function in a certain way by getting instructed through a set of instruction codes. But humans are different, in the sense that they possess a certain self learning ability which makes their thinking process unique. So use of artificial intelligence prudently employed for highly accurate classification problems. The neural network is often conceptualized as a combination of three layers.[15]

1) Input Layer (I): This layer receives the input data

2) Hidden layer (H): This layer is responsible for data analysis and processing. It is in this layer that the weights are adaptively decided [11]

3) Output Layer (O): This layer produces the output after the analysis is over. Needless to say, it receives input from the hidden layer.

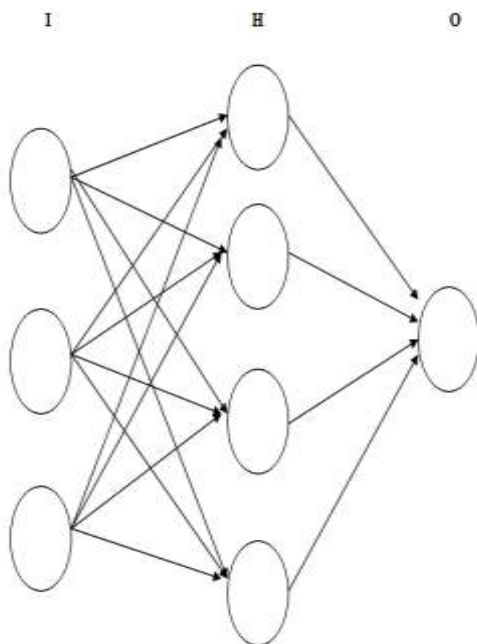


Fig.2 Conceptual Internal Structure of ANN

IV. EVALUATION PARAMETERS

Often an artificial intelligence based approach is used for the classification and renders the following issues.[10]

1. **True Positive (TP):** It is indicative of the true or correct cases of the data to be in a particular class.
2. **True Negative (TN):** It is indicative of the true or correct cases of the data not to be in a particular class.
3. **False Positive (FP):** It is indicative of the false or incorrect cases of the data to be in a particular class.
4. **False Negative (FN):** It is indicative of the false or incorrect cases of the data not to be in a particular class.

Sensitivity (S_e): It is indicative the ratio in which a data set is categorized Mathematically it can be defined as:

$$S_e = \frac{TP}{TP+FN} \quad (2)$$

Accuracy (Ac): It is an indicative of the accuracy of classification of the algorithm for data classification,

Mathematically its defined as:

$$A_c = \frac{TP+TN}{TP+TN+FP+FN} \quad (3)$$

Conclusion: From the present study, we have concluded that the signals for different cases for a power transformer are to be analyzed using wavelet transform for extraction of feature vector (containing statistical data) to train the ANN. The performance of trained ANN is successful for the classification of various cases. From the study and analysis carried out in this dissertation, the performance of neural networks has been found to surpass the performance of conventional methods, which need accurate sensing devices, costly equipment and an expert operator or engineer. The classification ability of the ANN in combination with advanced signal processing technique opens

the door for smart relays for power transformer protection with very less operating time and with desirable accuracy.

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