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Locatiing Faults in Radial Distribution Line Using Neural Network

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ABSTRACT

Background: Distribution line protection plays a major role in power system engineering because it provides a link between electric power system and consumers. An accurate fault location and estimation is necessary for reliable operation of power equipment and satisfaction of customer. **Objective:** To detect and locate the faults occurring in high voltage Distribution lines. **Results:** Neural Network technique is for the detecting and locating faults in distribution line. The relative error in finding fault location is much less than 1% for all the three operating conditions. **Conclusion:** From the simulation results, it is observed that the proposed fault distance locator is an accurate and robust fault analysis Method.

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INTRODUCTION

The main objective of the power system is to provide continuity of service to customers. Hence, Power system protection is equipped with relays to provide maximum sensitivity to faults. The speed and accuracy of digital relays of Distribution lines can be improved by accurate and fast fault detection and classification method. Hence, an accurate fault location and estimation is necessary for reliable operation of power equipment and satisfaction of customer. Many researchers have made a research in fault detection in power system. Salim *et al*. (2009) proposed an Extended Fault-Location Formulation for Power Distribution Systems. The proposed method uses the voltages and currents as input data to detect the fault. Alsafasfeh *et al*. (2010) formulated a electrical protective relaying framework to detect and classify any fault type in an electrical power system is presented. This work use readings of the phase current only during the first $(1/4)^{th}$ of a cycle in an integrated method that combines symmetrical components technique with the principal component analysis (PCA) to declare, identify, and classify a fault. Fault Analysis of Multiphase Distribution Systems Using Symmetrical Components was proposed by Mamdouh Abdel-Akher *et al*. (2010). Dustegor *et al*. (2010) investigated how the model-based fault detection and location approach of structural analysis can be adapted to meet the needs of power systems, where challenges associated with increased system complexity make conventional protection schemes impractical. Sujatha *et al*. (2011) formulated On-Line Monitoring and analysis of Faults in Transmission and Distribution Lines using GSM technique. Ghorbani *et al*. (2012) presented a decentralized multi agent system (MAS) which works in real time with a power distribution system for fault detection applications. The agents use local voltage and current RMS values to locate a fault. Faig (2010) proposed location of single-phase faults in power distribution systems with distributed generation by means of impedance-based methods.

Recently, several methods have been developed for automated fault location in distribution system. Thus the fault detection and location on high voltage Distribution lines [8] can be classified into the following three categories:

1. Impedance method
2. Travelling theory based method
3. Intelligent systems

Ningkang *et al*. (2010) presented a general approach to locate any type of fault on either a single-circuit or a double-circuit transmission line when only current magnitude measurements are available. Mokhlis (2011), evaluated the Fault Location based on Voltage Sags Profiles. The test results presents the strength and limitation of the method when applied for different fault resistances, loading variation and load models Mohammad Abdul

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Baseer (2013) proposed travelling Waves for finding the fault Location in Transmission Lines. This wavelets can provide multiple resolutions in both time and frequency domains. This method identifies the fault using the return time of the pulse wave. Frantisek Janıcek *et al*. (2007) presented a novel approach in distribution protection technique of fault line selection based on analysis of generated transient and the potential of using discrete wavelet transform in protective relay is examined. Zamanan *et al*. (2011) presented a wavelet based technique for detection and classification of abnormal conditions that occur on power distribution lines. The proposed technique depends on a sensitive fault detection parameter (denoted SFD) calculated from wavelet multi-resolution decomposition of the three phase currents. Atthapol Ngaopitakkul *et al*. (2011) proposed Combination of discrete wavelet transform and probabilistic neural network algorithm for detecting fault location on transmission system. Soumyadip Jana and Gaurab Dutt (2012) formulated Wavelet Entropy and Neural Network for detecting fault in Non Radial Power System Network. Samantaray *et al*. (2009) proposed a intelligent approach for high impedance fault (HIF) detection in power distribution feeders using combined Adaptive Extended Kalman Filter (AEKF) and probabilistic neural network (PNN). The AEKF is used to estimate the different harmonic components in HIF and NF (no-fault) current signals accurately under non-linear loading condition. Thus these traditional approaches to fault problems have usually involved human experts. This may leads to error in fault detection. In this environment, artificial-intelligence-based techniques such as neural networks, fuzzy logic [Onojo Ondoma James *et al*. 2012] and genetic algorithms can enhance a system's performance for accurate fault detection. AI based techniques model the adaptive and highly complex processes to formulate solutions to such open-ended problems, where traditional approaches cannot be applied. Among the AI based techniques, Artificial Neural Networks [Sarvi *et al*. 2012] (ANNs) based methods are widely used. However, the tools proposed so far exhibit limitations regarding the magnitude of the training set and the poor resolution.

In order to overcome the shortcomings of the existing procedures, this work proposes a new neural network based method for determination of fault detection along with fault location in a radial distribution system. It employs voltage and current signals obtained at the distribution substation as input variables to detect and locate the fault.

System Design:

Faults in Distribution Systems:

Most of the faults in distribution systems are one phase conductor to the ground. In addition to that, faults between phases with or with out ground are also possible. There are 11 possible fault types resulting from the different combinations of three phases and the ground. The fault resistance range from a few ohms, as occur incases of arc between phases, to hundreds of ohms, as occur in cases when a fallen conductor touches a dry surface. The fault resistance has considerable effect on the accuracy of fault location algorithms. Over current relays and fuses are responsible for isolating permanent faults.

Among these types of faults, this works consider Line to line fault, Double line to ground fault and Three phase short circuit fault.

1. Line to Line fault

In this the high voltage Distribution line has been simulated by shunting phase A to B. The transient current has amplitude, as great as 10 times the normal current value.

2. Double line to ground fault

This condition has been created by shunting phase A and B to ground with ground resistance.

3. Three phase short circuit fault

This condition has been created by shunting phase A, B and C.

Artificial Neural Network (ANN) Application For Fault Location In Distribution Systems:

Initially, the entire data collected is subdivided into two sets namely the training and the testing data sets. The first step in the process is fault detection. Once a fault has occurred on the line, the next step is to classify the fault into the different categories based on the phases that are faulted and the third step is to pin-point the position of the fault on the line. Thus, the input variables for fault location are the voltages and currents of the feeder. First, the input parameters are evaluated and fault type is determined using ANN. Each possible faulty circuit and fault type has a corresponding ANN. Then, the fault distance is evaluated as a function of the output of the activated ANN.

Modeling of Proposed System:

In this work, Fault detection, fault classification and fault location have been achieved by using artificial neural networks. Artificial neural network (ANN) is made up of many computational processing elements called neurons or nodes. These nodes operate in parallel and are connected together in topologies that are loosely modeled after biological neural systems. The training of ANN is carried out to associate correct output responses to particular input pattern. Block diagram of proposed approach is shown in Figure 1.

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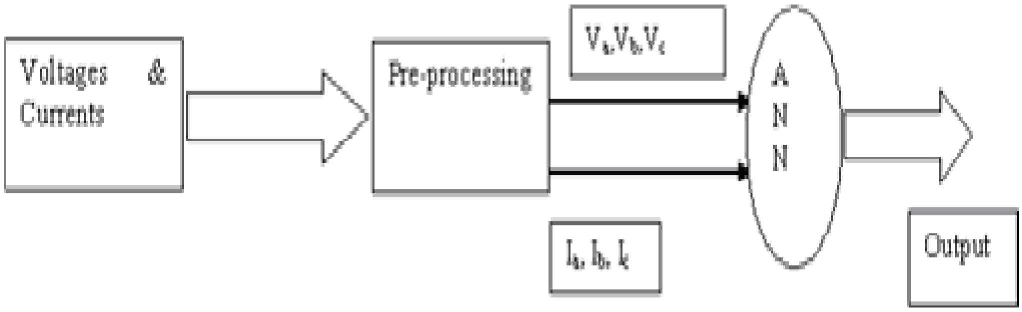

Fig. 1: Block Diagram of the Proposed System.

Data acquisition block simulated in MATLAB software has been used to collect the three phase voltage and current signals. A combination of different fault situations and the training patterns were generated by simulating fault breaker. The pre-processing of three phase voltage and current signals will improve the speed and accuracy of the ANN. The pre-processing process is depicted in Figure. 2.

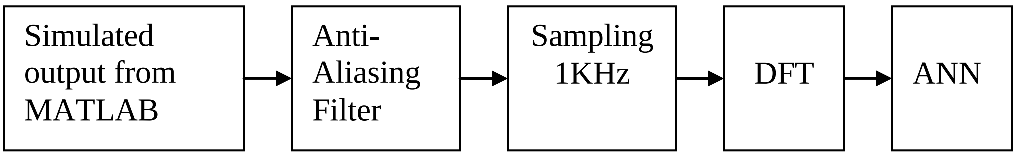

Fig. 2: Pre-Processing Process.

The anti-aliasing filter removes the unwanted frequencies from a sampled waveform and removes the harmonics above half the nyquist frequency to prevent corruption. A simple 2^{nd} order low pass buffer worth filter with cut-off frequency of 400Hz has been used to filter higher order harmonics. In order to produce a more accurate results high sampling rate is required. So the signals from the anti-aliasing filter are resampled at 1 KHz. The sampled three phase voltage and current signals are converted into a fundamental frequency phasor representation using DFT. The Preprocessed voltage and current signals are processed through ANN is used to detect the type of the fault and to locate the fault distance. The Table 1 shows the voltage and current values that are scaled with respect to their pre-fault values and used for training set. Va, Vb and Vc are the post fault voltage and current sample values and Va(pf), Vb(pf) and Vc(pf) are the corresponding pre-fault values.

Table 1: Voltage and Current Training Set for Neural Network.

Va	Vb	Vc	Ia	Ib	Ic	Fault Type
.997	.9991	.9985	.9978	.9988	9984	No fault
0.334	1.194	1.172	3.335	0.981	0.979	A to G
1.172	0.334	1.194	0.981	3.335	0.979	B to G
1.194	1.172	0.334	0.981	0.979	3.335	C to G
0.471	0.650	.986	5.379	5.379	0.983	A to B
0.986	0.471	0.650	0.984	5.379	5.379	B to C
0.471	.986	0.650	5.379	0.984	5.379	A to C
0.205	0.205	1.188	7.187	7.855	0.985	A to B to G
1.188	0.205	0.205	0.985	7.187	7.855	B to C to G

In order to analyze the accuracy of the proposed method, radial distribution system of 33/11kv network is designed. The distribution system consists of 132/33/11kv 45 MVA, 132/33kv 40 MVA, and 132/33kv 60 MVA power transformers. The values of the three-phase voltages and currents are measured and modified accordingly and are ultimately fed into the neural network as inputs. The SimPowerSystems toolbox has been used to generate the entire set of training data for the neural network in both fault and non-fault cases.

Fault Detection:

The first stage which is the fault detection phase, the network takes in six inputs at a time, which are the voltages and currents for all the three phases (scaled with respect to the pre-fault values) for different faults and also no-fault case. Hence the training set consists of about a set of six inputs and one output in each input-output pair. The output of the neural network is 1 or 0 depending on whether fault has been detected.

Fault Classification:

Once a fault has been detected on the power line, the next step is to identify the type of fault. This section presents an analysis on the fault classification phase using neural networks .Fault classifiers based on neural employed the back-propagation learning strategy. Line to line fault, Double line to ground and three phase short circuit fault are common faults that occur in distribution line. The data required to differentiate between these types of faults are the three phase voltages and currents. The designed network takes in sets of six inputs (the three phase voltage and current values scaled with respect to their corresponding pre-fault values). Each of the neurons in the output layer would indicate the fault condition on each of the three phases (A, B and C) and the fourth neuron is to identify if the fault is a ground fault. An output of 0 corresponds to no fault while an output of 1 indicates that the phase is faulted. Figure. 3 shows architecture of the back Propagation NN for Fault Classification

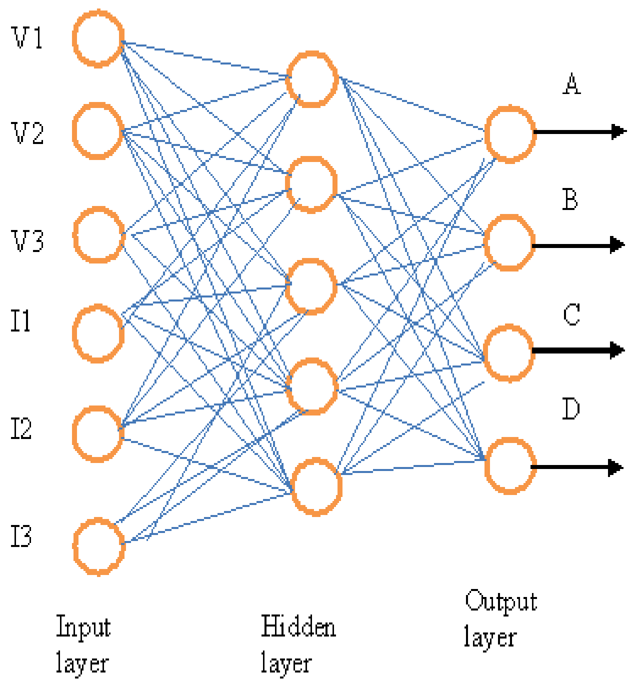

Fig. 3: Back Propagation Nn For Fault Classification

Propagation Nn for Fault Classification:

The input and output layers has fixed six (three phase voltages and currents) and four neurons respectively. The hidden layer has five hidden neurons. The activation function at input layer is linear function while it is a logistic function at hidden layer and output layer. The proposed neural network should be able to accurately distinguish between the possible categories of faults. The truth table representing the faults and the ideal output for each of the faults is illustrated in Table 2.

Table 2: BPNN Classification Network Truth Table.

Fault Situation	A	B	C	G
A-G	1	0	0	1
B-G	0	1	0	1
C-G	0	0	1	1
A-B	1	1	0	0
B-C	0	1	1	0
C-A	1	0	1	0
A-B-C	1	1	1	0

Fault Distance Location Estimation:

This section discusses about the design, development and the implementation of the neural network based fault locators for each of the various types of faults. This forms the third step in the entire process of fault location after the inception of the fault. Detection of fault location has to be done for the purpose of isolating the faulty section of the system. The inputs to distance relay are mainly the voltages and currents. The magnitude of three consecutive post fault samples of each phase voltage and current have been selected as input to neural network After selecting inputs to NN, the number of layers and number of neurons per layer and training algorithm has to be decided.

Back – propagation neural networks have been surveyed for the single line – ground fault location. In order to train the neural network, several single phase faults have been simulated on **the** distribution line model. The voltage and current samples for all three phases (scaled with respect to their pre-fault values) are given as inputs

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to the neural network. The output of the neural network is the distance to the fault. Different single phase faults have been simulated on different phases with the fault distance being incremented by 10Km in each case and the percentage error in calculated output has been calculated. The same procedure is adopted for other two fault location also. This test conducted on the neural network (6-16-1) architecture.

For double line - ground fault location, ANN structure with 6 neurons in the input layer, 2 hidden layers with 21 and 11 neurons in them and 1 neuron in the output layer is chosen.

For three-phase faults , 6 neurons in the input layer, 1 hidden layer with 21 neurons in it and 1 neuron in the output layer is considered as a ANN structure.

Prediction of Fault Location:

This section deals with the various kinds of faults and their error performances individually. The performance of proposed algorithm have been tested for both phase to phase faults and phase to ground faults involving one or three phases. The distance estimation error, its dependency with the fault location, has been used to find out the effectiveness of the proposed method. Hence, to find out the maximum deviation of the estimated distance L_f from the actual fault location L_a, the resulted estimated error "e" is expressed as a percentage of total length of the distribution feeder.

$$e = \frac{Lf - La}{L} * 100$$

where L – Length of the distribution feeder.
L_f - Estimated Distance
L_a - Actual fault location
The test results of ANN including different fault locations for each fault type are shown in Table 3.

Table 3: Percentage Errors as a Function of Fault Distance.

Fault	L-G		L-L		LLL/LLLG	
Distance (km)	Calculated Distance (km)	% error	Calculated Distance (km)	% error	Calculated Distance	% error
30	30.19	0.19	29.99	-0.01	30.17	0.17
40	39.32	-0.68	40.12	0.12	40.56	0.56
50	50.04	0.04	49.88	-0.12	50.17	0.17
60	59.69	-0.31	60.91	0.91	60.96	0.96

From this, it is evident that the fault location method based on NN has high accuracy because the relative error is much less than 1% for all the three operating conditions. In addition to that, the total processing time is less than 5 ms so that it reduces the processing burden to the processor.

Conclusion:

This work has studied the usage of neural networks as an alternative method for the detection, classification and location of faults on distribution line. The method makes use of the phase voltages and phase currents (scaled with respect to their pre-fault values) as inputs to the neural networks. Various possible kinds of faults namely single line-ground, line-line, double line-ground and three phase faults have been taken into consideration into this work and separate ANNs have been proposed for each of these faults. Performance result obtained in a variety of fault situations comprising various fault types, fault locations shows that the proposed fault distance locator is an accurate and robust fault analysis Method.

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