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Artificial Neural Network Based Fault Locator for Single Line to Ground Fault in Double Circuit Transmission Line

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Abstract: This paper presents the Artificial Neural Network based versatile relay to locate single line to ground fault in double circuit line irrespective of its transmission line parameters. The fundamental components of voltage and current signals measured at relay location are used as input to train the Artificial Neural Network. MATLAB® software and its associated *Simulink*® and *Simpowersystem*® toolboxes have been used to simulate the double circuit line lines (220kV, 400kV, 315kV, 500kV line). The effect of variation in fault inception angle, fault resistance and fault distance location has been taken into account. Testing results shows that the maximum absolute error of the proposed scheme is less than 1%. It validates the accuracy and suitability of the proposed scheme.

Keywords: Fault location, Double circuit transmission line, Artificial Neural Network, Versatile relay.

1. Introduction

Transmission line is used to deliver bulk amount of power from power stations to load centers and large industrial consumers. To increase transmission capacity and enhance reliability parallel transmission lines have been widely adopted in modern power systems. In double circuit transmission line, the reason for the occurrence of a fault can be due to several reasons like mutual coupling [1] etc. Most of the researches done in the field of fault location because transmission lines are relatively very long and can run through different geographical terrain. So, its proper operation and protection is necessary to minimize the consequences of faults.

From a past few years the rapid development of Artificial Neural Network techniques, different techniques have been proposed in the literature to solve problems related to power systems. The main advantage of neural networks related to power systems are, it can be trained with both online and offline data. Some other advantages of neural networks are fault tolerant, adaptive learning, self-organization, robustness and real time operations. These ANN based methods do not require a knowledge base for the location of faults unlike the other methods. Neural networks are widely used to achieve greater efficiency in fault location. Once a fault is located, the circuit breaker isolates the faulty part from a healthy part to maintain power system stability. In recent days, the size and complexity of power system grows very rapid. So it becomes necessary to identify the location of fault more accurately by using much more powerful techniques.

Distance location using neural network for single circuit transmission lines has been reported in [2]. Location of single line to ground fault by employing wavelet, fuzzy & neural network to use post-fault transient and steady-state measurements in the distribution lines of an industrial system is proposed in [3].Fault distance location and fault classification for single line to ground faults on double circuit transmission lines using neural networks has been reported in [4],[5] and [6].

This paper presents the ANN based versatile relay for locating faults quickly and accurately on double circuit transmission line irrespective of transmission line parameters (fault resistance, inception angle etc.,) using the modules of the 50/60 Hz fundamental components of fault and pre-fault voltage and current magnitudes which are measured at relay location. In this various system faults at different locations with different parameters are modeled and an artificial neural network is generated to estimate the location of fault. By considering the number of offline tests, the performance of the proposed scheme has been evaluated. It is shown that the proposed scheme is able to locate the fault with the maximum absolute error less than one percent. So it validates the accuracy and suitability of the proposed scheme.

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2. Power System Model

In this paper the studied systems are 220KV, 315KV, 400KV and 500KV three phase double circuit transmission lines with 68 km line length, connected to sources at each end. The single line diagram of all the studied systems which are used to train and test the proposed ANN is shown in Fig. 1. The transmission line is simulated using distributed parameter line model.

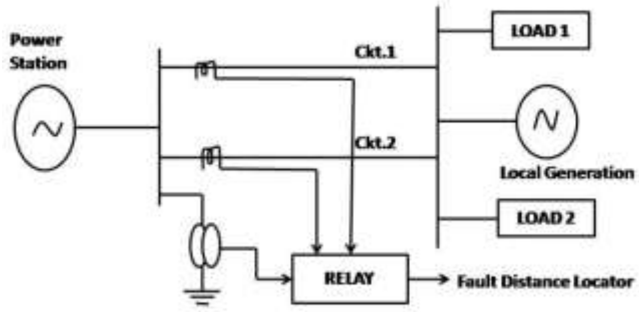

Fig. 1: Single line diagram of simulated power system model.

The data which is used for training of ANN should contain necessary information to generalize the problem. Therefore training patterns were generated by simulating different kinds of faults. Fault type such as single phase to ground, double phase to ground and triple phase to ground, inception angle, fault resistance and fault location were changed to obtain to get training patterns which covers a wide range of different power system conditions. For example a single phase to ground fault ‘AG‘ occurs at 30 KM from source end i.e., 38 KM away from the load with inception angle 900 and fault resistance 55Ω.

3. Description of Fault Location using ANN

The following flowchart explains the basic procedure which was used to implement the ANN based fault distance location steps in double circuit transmission line:

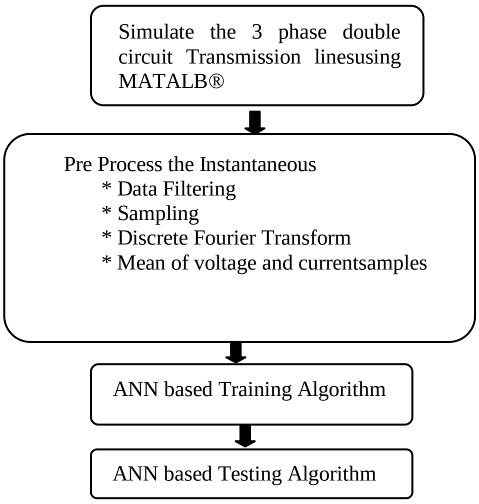

Fig. 2: Proposed Fault Locator Flow Chart

During Pre-processing, three phase voltage and six current input signals were sampled at a sampling frequency of 1.2 kHz and further processed by simple 2nd-order low-pass Butterworth filter with cut-off frequency of 480 Hz. Then one full cycle Discrete Fourier transform is used to calculate the fundamental components of voltages and currents. The input signals were normalized in order to make the ANN input level between +1 or -1.

The most important aspects of the fault location systems are network architecture, selection of learning rule, training method, and testing the fault locator based on ANN.

3.1. Selection of Inputs and Outputs

To create an artificial neural network, the inputs and outputs of the neural network have to be defined. The inputs of the network must give a true representation of the situation under consideration. The inputs chosen here are the magnitude of the fundamental components (50 Hz and 60 Hz) of three phase voltages and currents of each circuit i.e., of from all the four circuits. Thus the inputs of fault location detector are

I/P =[Vaf , Vbf ,Vcf , Iaf , Ibf , Icf , Idf , Ief , Iff],

O/P =[L_f] where L_f = Fault Distance

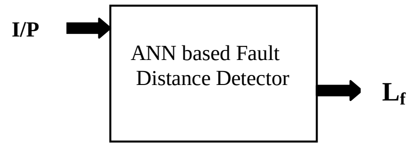

Fig. 3: Block diagram of ANN based Fault Distance Locator

3.2. Selection of Network Architecture

The ANN architecture includes the number of inputs and outputs to the network, number of hidden layers between input layer and output layer, and number of neurons in the hidden layers. The inputs to the fault distance locator i.e. distance relay are magnitudes of voltage and current. Therefore the magnitudes of the fundamental components of voltages and currents measured at relay location. The distance to the fault in km with regard to the total line length should be the only output provided by the fault location network.

The next task after deciding the number of inputs and outputs that the network should have, the number of hidden layers and the number of neurons per layers must be considered. As there is no theoretical analysis available about the number of hidden layers the network should have [7], by due analysis i.e. by hit and trial method it was decided to use a neural network with four layers, with nine neurons in the input layer, thirty three and twenty nine neurons in the first and second hidden layers and one neuron in the output layer for fault distance location. The architecture of the ANN based fault distance locator is shown in figure 5. After analyzing the various possible combinations of transfer function for both the hidden layers and out layer, Hyperbolic Tangent Sigmoid transfer function for two hidden layers and output layer has been used.

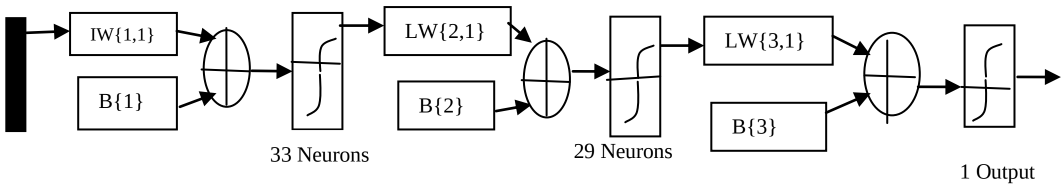

Fig. 4: Architecture of ANN Based Fault Distance Locator

3.3. Learning Rule Selection

Since the simple back-propagation learning rule method is slow as it requires small rates for stable learning. Therefore improvement techniques can be used to make back-propagation more reliable and faster, such as momentum and adaptive learning rate or an alternative method to gradient descent, Levenberg–Marquardt optimisation, can be used. Various techniques were applied to the different network architectures, and it was concluded that the most suitable training method for the architecture selected was based on the Levenberg–Marquardt (Trainlm) optimization technique [8].

3.4. Training Process

Two important steps in the application of neural networks for any purpose are training and testing. During training process the neural network learns from the inputs and updates its weights accordingly. In order to train the neural network a set of data called the training data set is needed which is a set of input output pairs fed to the neural network. Once a network is trained it can be considered as an expert which can provide the solution to a new given situation. To obtain enough examples to train the network, a software package MATLAB® 2010a is used.

By using SIMULINK & SIMPOWERSYSTEM toolbox of MATLAB each type of fault at different fault locations between 68 km of line length and fault inception angles 0 & 90 ° have been simulated as shown in Table I. The total numbers of faults simulated are 4[2x6x9x10] = 4320 and from each fault cases ten numbers of post fault samples have been extracted to form the data set for neural network. Thus the total number of patterns generated for training, testing and validation are 43200 for the fault location task using versatile relay. One no fault sample is also considered in input matrix. Thus the total size of the matrix is 9*4321.

Table I. Training Patterns Generation for Versatile Relay

Parameter	Set Type
Transmission Line Voltage Rating in KV	220,315,400,500
Fault Type	LG:AG,BG,CG,DG,EG, FG
Fault Location in KM	0.1,3,5,10,20,30,40,50,60,65
Fault Inception Angle (φ)	0^0 , 90^0
Fault Resistance(Ω)	0.01,4,8,15,40,55,70,85, 100

After generating the input matrix, the mean of it was considered i.e., mean of every ten samples (individual fault). As mentioned earlier, the lower the number of inputs, the smaller the network can be therefore the time taken to train the network will be very less and efficient. The mean of input matrix was considered to successfully decrease the size of input matrix and ensured to provide the sufficient input data to characterize the problem.

Table II. Size of Matrices

Name of Matrix	Size of Matrix
Generated Input Matrix	9 x 43200
Mean Training Matrix	9 x 4321
Mean Target Matrix	1 x 4321

The ANN based fault distance locator was trained using Levenberg-Marquardt training algorithm using neural network toolbox of Matlab. The mean of the data matrices helps this learning strategy to converge quickly and the Mean Squared Error (mse) decreases in 668 epochs to $9.99e^{-07}$ in around eight minutes and forty seconds. The time taken to train the network by taking mean data is quite less when compared to training the network using normal data.

3.5. Test Results of ANN Based Fault Locator

After training the Network, the ANN based fault distance locator is tested by presenting samples of faults which have not been used during training time. Testing results of single phase to ground fault is shown in table III. It can be seen that all results are correct with reasonable accuracy. At various locations different types of faults were tested to find out the maximum deviation of the estimated distance L_f measured from the relay location L_a. Then the resulted estimated error "e" is expressed as a percentage of total line length L as

$$e = \frac{L_e - L_a}{L} X100\%$$

In all the fault cases, the results have shown that the errors in locating the faults are less than -0.8% to +0.0025%.

Table III. ANN based Fault distance locator results

Rating of Transmission Line(KV)	Fault Type	Fault Resistance (Ω)	Fault Inception Angle(φ)	Actual Fault Location(L_a) KM	Estimated Fault Location(L_e) KM	Error e(%)
200	AG	3	0^0	0.2	0.1021	-0.14397
200	BG	15	90^0	13	12.9818	-0.02676
200	EG	82	90^0	57	56.9997	-0.00044
315	CG	35	0^0	23	22.9885	-0.01691
315	DG	53	90^0	45	45.0499	0.07338
315	FG	92	90^0	66	65.7591	-0.35426
400	AG	1	90^0	0.6	0.1097	-0.72102
400	CG	45	90^0	34	34.0482	0.07082
400	DG	75	0^0	52	51.9851	-0.02191
400	EG	90	90^0	61	61.0017	0.00250
500	AG	3	0^0	0.15	0.1075	-0.0625
500	FG	88	90^0	67.9	67.3320	-0.83529

4. Conclusion

This paper proposed a fault location strategy based on versatile relay of ANN. The results obtained show that the global performance of the ANN based versatile relay was highly satisfactory concerning precision. The proposed scheme has several advantages: a single ANN for all the different ratings of transmission lines and irrespective of transmission line parameters like effect in variation in type of fault, fault inception angle, fault distance and fault resistance for all six types of single line to ground faults. Accuracy of the algorithm is good in most of the fault cases.

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