DETECTION AND CLASSIFICATION OF FAULTS FOR ELECTRICAL TRANSMISSION LINE USING ANN

Rishmek C. Kachhadiya[1], Asst.Prof.Vishal Thakkar[2]
[1]M.E student, [2]Assistant Professor, Electrical Engineering (power system),
Kalol Institute of Technology and Research. India

ABSTRACT: This paper focuses on the use of back-propagation neural network architecture as an alternative technique for fault detection and classification on transmission line. The three phase current and voltages of one end are taken as input in the purposed scheme. In this paper, three common faults were discussed which are single line to ground fault, double line to ground faults and double line faults. The result provides a reliable and an alternative approach for the development of a protection system for transmission line. The values of three phase voltages and currents have been used as input for the proposed scheme. The feed forward neural network along with back propagation algorithm has been used for detection and classification of the fault for analysis of each of the three phases. The various simulation and analysis of signals has been done in the MATLAB.
Key Words: Fault Location, Fault Classification, Artificial Neural network, Back-Propagation algorithm.

I. INTRODUCTION

Since many years, there has been rapid growth in power system all over the world which increases the installation of transmission and distribution lines. Deregulation in the power system network increased the need for reliable and uninterrupted power supply to the end user who is very sensitive to power outages [1]. Fault is one of the most important factors which is hinder the continuous supply of electricity and power [2]. In the power system's component, any abnormal flow of current is known as fault. These faults cannot be avoided completely since part of these faults occurs due to natural reasons which are beyond the control of mankind. So, it is very necessary to have a well-coordinated system that detects any kind of abnormal flow of current in the power system. Mostly faults can be detected by devices and faulty section isolates from the rest of the power system.

Faults can be of various types namely transient, persistent, symmetric or asymmetric and the fault detection process for each of these faults is distinctly unique in the sense, there is no universal fault location method for all these kind of faults. The high voltage transmission lines are more prone to the occurrence of a fault compare than local distribution lines cause of no insulation around the transmission line cable unlike the distribution line. Faults can be occur by several reasons like momentary tree contact, bird or an animal contact or due to other natural reasons such as thunderstorms or lightning [1]. When a fault occurs on transmission line, the voltage at the point of fault suddenly reduces to a low value. Fault location estimation is very important issue in power system in order to clear faults quickly and restore power system as soon as possible with minimum interruption. This is necessary for healthy power system and satisfaction of consumer. Most of the research done in the field of protective relaying of power systems concentrates on transmission line fault protection due to the fact that transmission lines are relatively very long and can run through various geographical terrain and hence it can take anything from a few minutes to several hours to physically check the line for faults [6]. Since few years, Intelligence based methods have been used for accurately finds out location of fault on transmission line. This paper presents a method for detection and identification type of faults. Back propagation neural network approach is studied and implemented three major artificial intelligence based techniques have been widely used in the power system industries [6]:

- Expert system technique
- Artificial neural network
- Fuzzy Logic system

From these available techniques, Artificial Neural Network has been used in this paper for fault location on electric power transmission lines. These ANN based methods do not require a knowledge base for the location of faults unlike the other artificial intelligence based.

II. ARTIFICIAL NEURAL NETWORK

Artificial neural network can be described as a set of elementary neurons that are usually connected in biological inspired architectures and organized in several layers [5]. It is capable to solve the non linear problems so easily. The problems in which information available and it the massive form can be dealt with. ANN is able to learn with experiences by examples. They are widely accepted and used in the problem of fault detection and fault classification cause of following features [1]:

- Number of Transmission line configuration are possible as there can be any possibility from short length, long length, single circuit transmission line to double circuit transmission line.
- There are several methods to simulate the network with different power system conditions in a fast and reliable manner.
- The conditions of the electrical power system change after each and every disturbance. Here, Neural network is capable to incorporate the dynamic changes in the power systems.
- The artificial neural network is very fast, reliable

and accurate depending on the training, because its working depends upon a series of very simple operation.

The algorithm which employed ANN programming offers many advantages, but it also suffers with many disadvantages as well which are very complex in nature. Some of the important factors are the selection of type of network, architecture of the network, termination criteria etc. Here the neural network is trained by using these six inputs which are shown in table 1. The total number of outputs of the neural network is four, i.e three phases A, B, C and fourth is ground of three phase transmission.

III. BACK PROPAGATION NEURAL NETWORL(BPNN)

The back propagation was created by generalizing the windrow-Hoff learning rule to multiple layer neural networks and non linear differentiable transfer functions. Input vectors and corresponding target vectors are used to train a network until it can approximate a function, associate input vectors with specific output vectors. The back propagation algorithm is to eliminate one of the constraints on two layers ANNs, i.e. similar inputs lead to the similar outputs. The error for each iteration and for each point is calculated by initiating from the last step and by sending calculated the error backwards. The weights of the back propagation algorithm for the neural network are chosen randomly; feeds back in an input pair and then obtain the result. After each step, the weights are updated with the new ones and the process is repeated for entire set of inputs-outputs combination available in the training data set which is provided by developer. This entire process is adopted by each and every layer in the entire the network in backward direction. This algorithm uses the mean square error technique for calculating the error in each iteration.

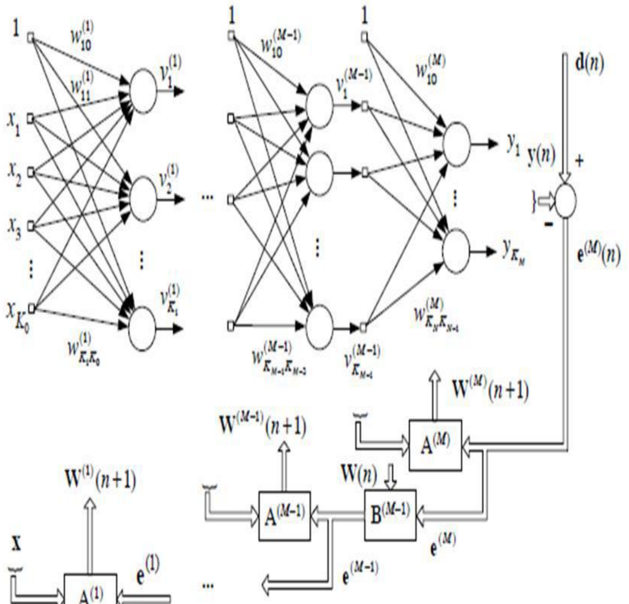

Figure 1 Structure of back propagation algorithm

The corresponding weighing vectors are shown in blocks A(M), A(M-1),…, A(1) and the errors that are propagated to the lower layers are calculated and stored in the blocks B(M-1), B(M-2),…, B(2).The back-error-propagation algorithm has been implemented in many ways but the basic idea remains the same. The only thing that changes in each of these implementations is the method used for the calculation of the weights that are iteratively upgraded when passed backward from layer to layer in the neural network. The modifications involved are also used in the training process of recurrent networks. The rate at which the learning process takes place can be estimated by keeping a check on the correction values in successive stages. The total number of iterations required to achieve satisfactory convergence rate depends on the following factors [1]:

- size of the neural network
- structure of the network
- the problem being investigated
- the learning strategy employed
- size of the training/learning set

The efficiency of a chosen ANN and the learning strategy employed can be estimated by using the trained network on some test cases with known output values. This test set is also a part of the learning set. Hence the entire set of data consists of the training data set along with the testing data set. The former is used to train the neural network and the latter is used to evaluate the performance of the trained artificial neural network.

IV. MODELING THE POWER TRANSMISSION LINE SYSTEM

Here, we used 500kv transmission line system to develop and implement the proposed strategy using ANN. Fig.1 shows a one line diagram of the power system which has been used throughout the research. It consists two generators of 500 kv and each generator located on either ends of the transmission line along with a three phase fault simulator used to simulate faults at various position on the transmission line. The line has been modeled using distributed parameters so that it more accurately describes a very long transmission line.

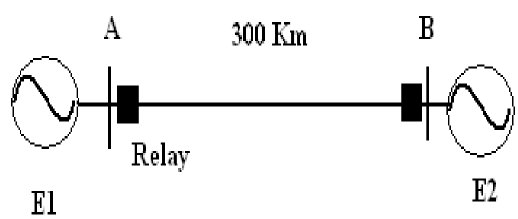

Fig.2 Studied system of one line diagram

The power system was simulated using the sim Powersystems toolbox of MATLAB. A snapshot of the model used for obtaining the training and test data sets which is shown in fig.3.

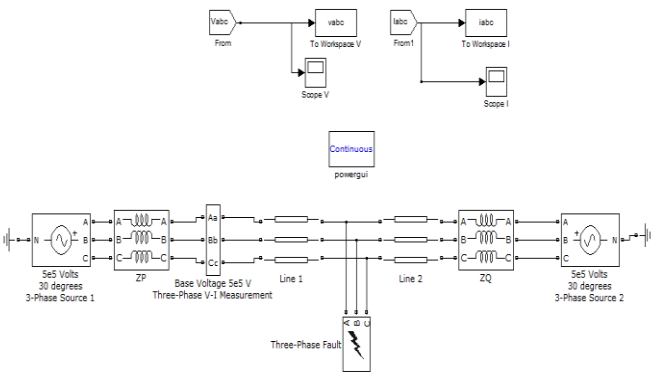

Fig.3 studied model's snapshot in sim power system

The transmission line is 300 km long and three phase simulator used to simulate types of faults at varying location along the transmission line with different fault resistance. ZP and ZQ are the source impedance of the generators on either side. The three phase V-I measurement block is used to measure the voltage and current samples at the terminal A.

The values of the three phase voltages and currents are measured and modified accordingly fed into the neural network as inputs. The sim power system tool box has been used to generate the entire set of training data for the neural network in both fault and no-fault case. Faults can be classified mostly into four different categories[6]:

- Line to ground faults
- Line to Line faults
- Double line to ground fault
- Three phase fault

V. MEASUREMENT VOLTAGE AND CURRENT AND PREPROCESSING OF DATA

A reduction in the size of the neural network improves the performance of the same and this can be achieved by performing feature extraction. By doing this, all of the important and relevant information present in the waveforms of the voltage and current signals can be used effectively. Voltage and current waveforms have been generated and were sampled at a frequency of 720 Hertz. The voltage and current samples of all the three phases are noted along with the corresponding pre-fault values.

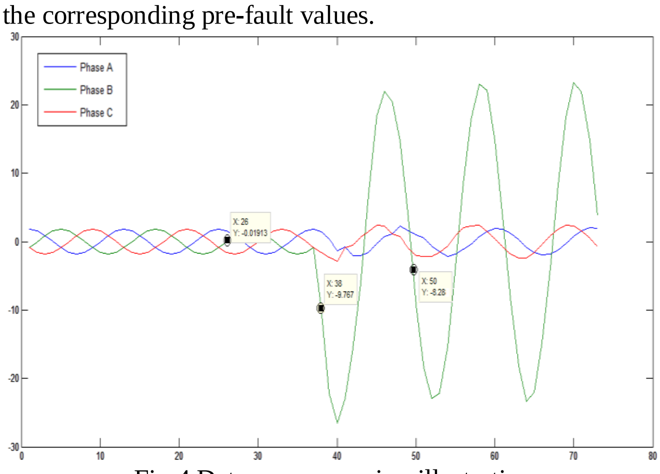

Fig.4 Data pre-processing illustration

Fig.4 shows the current waveform of a phase B-ground fault at a distance of 60 km from terminal A on a 300 km transmission line. The waveform is the plot of the samples sampled at a frequency of 720 Hz. Hence there are 12 samples per each cycle. A reduction in the overall size of the neural network improves the time performance of the neural network and this can be achieved by optimizing feature extraction. All of the important and relevant information present in the waveform of the voltage and current signals can be used effectively. The inputs used to the neural network are the ratios of the voltages and currents in each of the phases before and after the occurrence of fault. The advantage of performing this scaling is to reduce the training computation time. For the sake of illustration, the Table 1 shows the voltage and current values that are scaled with respect to their pre-fault values and used as a part of the training set. In Table 1, 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 as illustrated earlier. The given table depicts the values for all the various types of faults and also during the no fault case. The fault has been simulated on a 300 km long transmission line at a distance of 100 km from the terminal A.

Case no.	Input Vector						Fault type
	Va/Va(pf)	Vb/Vb(pf)	Vc/Vc(pf)	Ia/Ia(pf)	Ib/Ib(pf)	Ic/Ic(pf)	
1	0.615	0.970	1.035	1.70	0.507	0.872	A to G fault
2	0.654	0.732	0.830	0.403	27.68	1.72	B to G fault
3	1.26	0.921	0.751	1.50	-1.52	-4.75	C to G fault
4	-0.19	0.604	1.000	4.902	20.65	0.999	A to B fault
5	1.000	0.552	0.325	1.000	33.82	-7.119	B to C fault
6	1.159	1.000	0.92	-1.604	1.002	-2.25	C to A fault
7	-0.128	0.584	0.904	2.97	30.42	1.474	A to B to G fault
8	0.936	0.515	0.383	0.926	35.30	-6.75	B to C to G fault
9	0.987	0.915	0.84	0.623	-1.288	-5.029	C to A to G fault
10	0.314	0.437	0.499	1.865	35.99	-6.58	A to B to C fault
11	1.000	1.000	1.000	1.000	1.000	0.999	No fault

Table 1- sample of inputs to the neural network for various fault cases

VI. OVERVIEW OF THE TRAINING PROCESS

Two important steps in the application of neural networks for any purpose are training and testing. The first of the two steps namely training the neural network is discussed in this section. Training is the process by which the neural network learns from the inputs and updates its weights accordingly. In order to train the neural network we need a set of data called the training data set which is a set of input output pairs fed into the neural network. Thereby, we teach the neural network what the output should be, when that particular input is fed into it. The ANN slowly learns the training set and slowly develops an ability to generalize upon this data and will eventually be able to produce an output when a new data is provided to it. During the training process, the neural network's weights are updated with the prime goal of minimizing the performance function. This performance function can be user defined, but usually feed forward networks employ Mean Square Error as the performance function and the same is adopted throughout this work. As already mentioned in the previous chapter, all the voltages and currents fed into the neural network are scaled with respect to the corresponding voltage and current values before the occurrence of the fault. The outputs depending upon the purpose of the neural network might be the fault condition, the type of fault or the location of the fault on the transmission line. For the task of training the neural networks for different stages, sequential feeding of input and output pair has been adopted. In order to obtain a large training set for efficient performance, each of the ten kinds of faults has been simulated at different locations along the considered transmission line. Apart from the type of fault, the phases that are faulted and the distance of the fault along the transmission line, the fault resistance also has been varied to include several possible real-time fault scenarios.

- The fault resistance has been varied as follows: 0.25 ohm, 0.5 ohm, 0.75 ohm, 1 ohm, 5 ohm, 10 ohm, 25 ohm, 50 ohm.
- Fault distance has been varied at an incremental factor of every 3 km on a 300 km transmission line.

VII. OVERVIEW OF TESTING PROCESS

As already mentioned in the previous section, the next important step to be performed before the application of neural networks is to test the trained neural network. Testing the artificial neural network is very important in order to make sure the trained network can generalize well and produce desired outputs when new data is presented to it. There are several techniques used to test the performance of a trained network, a few of which are discussed in this section. One such technique is to plot the best linear regression fit between the actual neural network's outputs and the desired targets. Analyzing the slope of this line gives us an idea on the training process. Ideally the slope should be 1.Also, the correlation coefficient (r), of the outputs and the targets measures how well the ANN's outputs track the desired targets. The closer the value of 'r' is, to 1,the better the performance of the neural network. Another technique employed to test the neural network is to plot the confusion matrix and look at the actual number of cases that have been classified positively by the neural network . Ideally this percentage is a 100 which means there has been no confusion in the classification process. Hence if the confusion matrix indicates very low positive classification rates, it indicates that the neural network might not perform well. The last and a very obvious means of testing the neural network is to present it with a whole new set of data with known inputs and targets and calculate the percentage error in the neural networks output. If the average percentage error in the ANN's output is acceptable, the neural network has passed the test and can be readily applied for future use. The Neural Network toolbox in Simulink by The Math Works divides the entire set of data provided to it into three different sets namely the training set, validation set and the testing set. The training data set as indicated above is used to train the network by computing the gradient and updating the network weights. The validation set is provided during to the network during the training process (just the inputs without the outputs) and the error in validation data set is monitored throughout the training process. When the network starts over fitting the data, the validation errors increase and when the number of validation fails increase beyond a particular value, the training process stops to avoid further over fitting the data and the network is returned at the minimum number of validation errors .The test set is not used during the training process but is used to test the performance of the trained network. If the test set reaches the minimum value of MSE at a significantly different iteration than the validation set, then the neural network will not be able to provide satisfactory performance.

VIII. FAULT DETECTION

For the fault detection process, Six inputs has been provided to the neural network. The inputs are values of three phase voltages and three current phases respectively. The value of three phase voltages and currents are normalized with respect to the pre fault values of the voltage and current respectively. All ten different type of faults and no fault cases have been considered in developing data set. Hence the training set consisted of about 1100 input output sets (100 for each of the ten faults and 100 for no fault case) with a set of six inputs and one output in each input-output pair. The output of the neural network is just yes or no (1 or 0) depending on whether or not a fault has been detected. Fig. 5 shows a snapshot of the trained ANN with the 6-10-5-3-1 configuration and number of iterations required for the training process was 55. It can be seen that the mean square error in fault detection achieved by the end of the training process was 9.43e-5 and the number of validation check was zero.

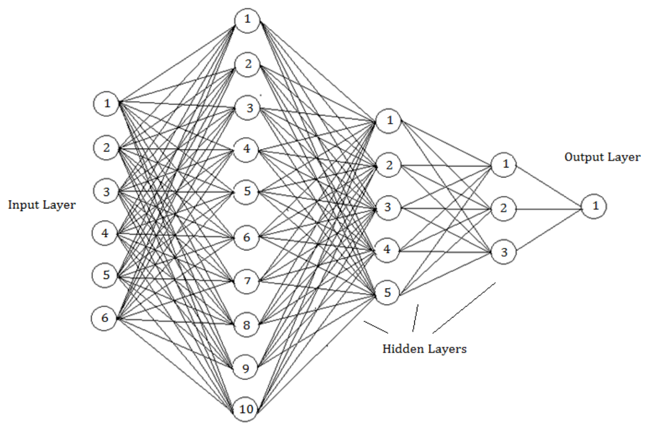

Fig.5 Chosen ANN for fault detection (6-10-5-3-1)

Fig.6 presents the structure of the choosen ANN for the purpose of fault detection. It has three hidden layers with 10,5 and 6 neurons respectively while 6 neurons in input layers and 1 neuron in output layer. If fault is occurs on transmission line then output would be 1 and if there is no fault then output would be 0.

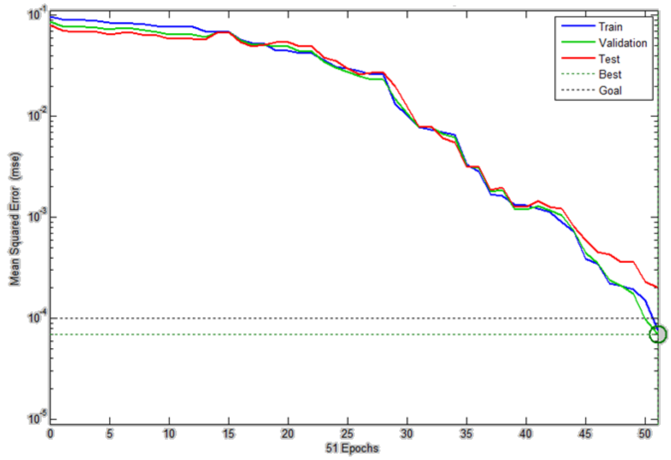

Fig.6 Mean error square performance of the network(6-10-5-3-1)

The training performance plot is shown in fig.6 which represents that training performance shown by NN is enough well. The overall mean square error of the trained neural network is less than the pre defined value of 0.0001. The value of mean square error is 9.43e-5 delivered in the end of the training of the NN. This data set is used for the training purpose the ANN. After the training of the NN, its performance is checked by plotting the linear regression plot that co-relates the targets to the output as shown in fig.7.

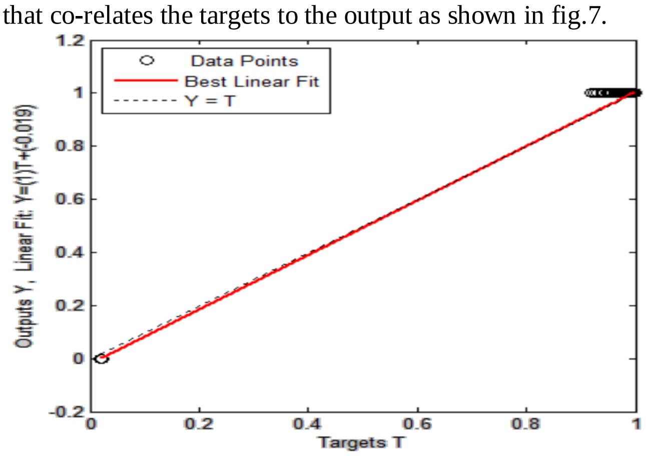

Fig.7 Regression FIT of the outputs vs. targets for the network(6-10-5-3-1)

The correlation coefficient (r) is a measure of how well the neural network's targets can track the variations in the outputs (0 being no correlation at all and 1 being complete correlation). The correlation coefficient in this case has been found to be 0.99967 in this case which indicates excellent correlation.

IX. FAULT CLASSIFICATION

The same process which has done for fault detection is also followed here in terms of the design and development of the classifier neural network. The designed network takes six inputs (three phase voltage value and three current phase values normalize to their corresponding pre-fault values) as explained earlier. Here, the various possible permutations can represent each of the various faults accordingly. The proposed neural network should be capable to accurately distinguish between the ten type os faults. The truth table shows the faults and the ideal output for each of the faults is illustrated in Table 2.

Type of faults	Network Outputs			
	A	B	C	G
A-G fault	1	0	0	1
B-G fault	0	1	0	1
C-G fault	0	0	1	1
A-B fault	1	1	0	0
B-C fault	0	1	1	0
C-A fault	1	0	1	0
A-B-G fault	1	1	0	1
B-C-G fault	0	1	1	1
C-A-G fault	1	0	1	1
A-B-C fault	1	1	1	0

After tried various NN, the chosen neural network for fault classification is shown in below figure 8.

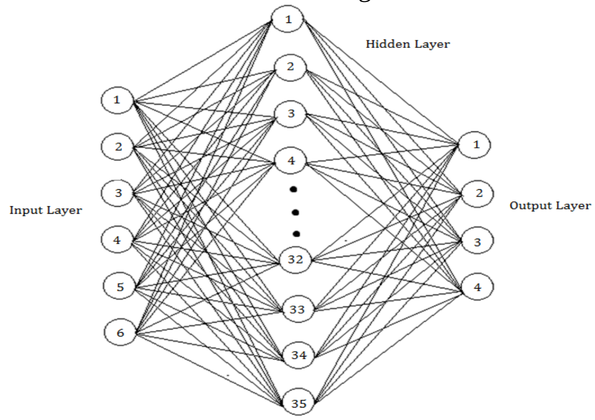

Fig.8 Chosen ANN for fault classification(6-35-4)

Figure 8 represents the structure of the chosen ANN for the purpose of fault classification. This neural network has 6 neurons in input layers, 35 neurons in hidden layer and 4 neurons in output layers. Each of the neurons in the output layer would indicate the fault condition on each of 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 failed. The training set contains total 1100 input output sets (100 for each ten faults and 100 for the no fault case) with a set of six inputs and one output in each input output pair. Back-propagation networks with a variety of combinations of hidden layers and the number of neurons per hidden layer have been analyzed. Among those, the one that achieved satisfactory performance was the neural network 6-35-4. The overall mean square error of the trained neural network is 0.00359 and it can be seen from figure 9 that the testing and validation curves have similar characteristics which is an indication of efficient training.

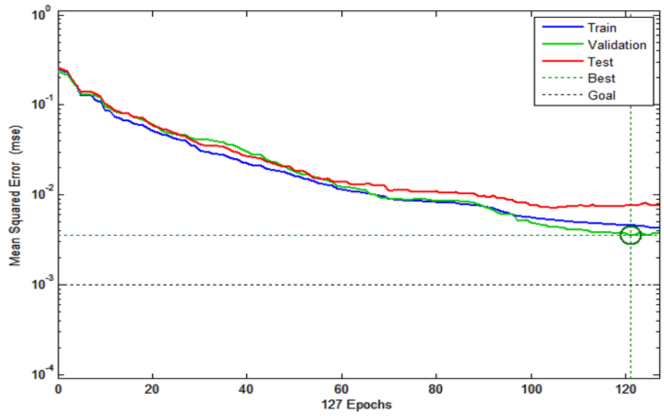

Fig.9 Mean square error performance of the network

The performance of the trained neural network is tested by plotting the linear regression that relates the targets to the outputs as shown in fig.10.

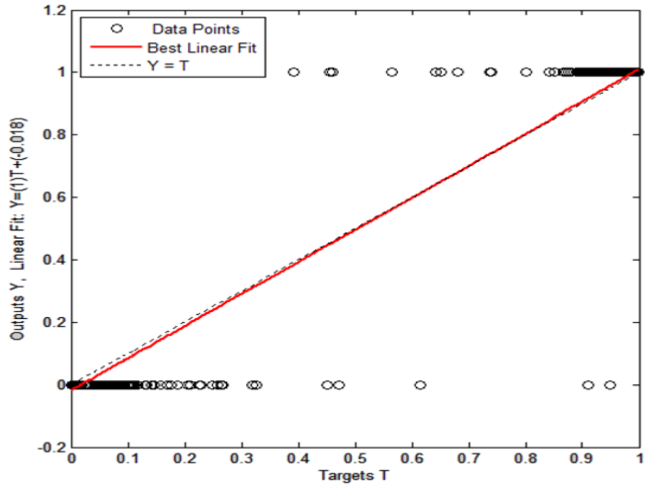

Fig.10 Regression fit of the output vs. targets of ANN with configuration.

The correlation coefficient found in this case was 0.98108 which indicates satisfactory correlation between the targets and outputs. The dotted line in the figure indicates the ideal regression fit and the red solid line indicates the actual fit of the neural network. It can be seen that both these line track each other very closely which is an indication of very good performance by neural network.

X. CONCLUSION

We have studied the usage of Neural Network as an alternative method for the Fault location on Transmission Line in this paper. Three common Faults were discussed here which are single line to ground fault, Double line to ground fault and Line to Line fault. By simulation of these Faults, We got the value of phase voltage and phase current for various faults .By using these values; we trained the Neural Network for fault detection and fault classification on transmission line. So, we can detect fault on given transmission line and recognize type of fault (Line-Line fault, double line-Ground fault, Line-ground fault) as well. There is huge scope to be explored artificial neural network. The fault detection and classification can be made intelligent by nature by developing suitable intelligent techniques. This can be achieved if we can have large amount of data set and least time for calculation.

REFERENCES

[1] Rajveer Singh, "Fault Detection of Electric Power Transmission Line by Using Neural Network" ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 2, Issue 12, December 2012.
[2] Sanjay Kumar K *, Mr.Shivakumara Swamy.R **, Dr. V. Venkatesh, " artificial neural network Based method for location and classification of faults on a transmission line", International Journal of Scientific and Research Publications, Volume 4, Issue 6, June 2014.
[3] Dr. S. M. El Safty Prof. Dr. H. El Dessouki Eng. M. El Sawaf, "Artificial Neural Network Fault Detection For Transmission Line Protection"sept,2004.
[4] Seema Singh1, Mamatha K R2,Thejaswini S3, " Intelligence fault identification system for transmission line using artificial neural network", e-ISSN: 2278-0661, p- ISSN: 2278-8727Volume 16, Issue 1, Ver. I (Jan. 2014).
[5] Suhaas Bhargava Ayyagari," Fault location on transmission line by using Artificial intelligence" http://uknowledge.uky.edu/gradschool_paper/657
[6] Surender Kumar Yellagoud, Munjuluri Sree Harsha, Bhamidipati Sridhar, "More Accurate and Fast Fault Identification on Power Networks Using Artificial Neural Networks", ISSN: 2249 – 8958, Volume-2, Issue-5, June 2013.

