

# Fault Classification in Double Circuit Transmission Lines using ANN

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**Abstract**— This paper discusses the application of ANN techniques for classification of all type of faults on double circuit transmission lines. It is very challenging task to provide distance protection a double circuit transmission line .An accurate algorithm for fault classification of single line to ground fault, double line to ground fault, three phase faults in double circuit transmission line presented using feed forward neural network (FFNN) algorithm. The algorithm used the fundamental components of voltage and current signals which is taken from the simulation diagram. This technique not requires the online data from the other communication link to retrieve the remote end data nor other sequence current compensation for healthy phases are required. This is a major advantage of the proposed technique for protection of double circuit line. Results of study on a 250 kV transmission line fed from both the ends are presented as an illustration. Simulation results indicate that algorithm is immune to the effect of mutual coupling, fault resistance and fault type.

**Keywords**- Artificial neural network, Double circuit transmission line, Fault classification, High impedance fault, Single line-to-ground fault, Double line to ground Fault, Three phase fault.

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## I. INTRODUCTION

High Voltage transmission lines utilized in modern power systems to increase reliability power transfer, and security for the transmission of electrical energy. The different configurations of double circuit transmission lines with the effect of mutual coupling make their protection a problem. The vast majority of faults (over 90%) [1] are of the single line to ground type.

The appropriate percentages of occurrences various faults are listed below: Single line to ground fault – 70-80%, Line-Line to ground fault - 10-17%, Line-Line fault – 8-10%, three phase – 2-3%.The causes of temporary faults include lightning, conductors slapping together in the wind, tree branches that fall across conductors and then fall or burn off and insulator flashovers caused by pollution. Faults that are normally temporary can turn into permanent faults.

Validation data and exciting results were noticed by the proposed Neural Network. The fault detection tested with problem being a major part of transmission and distribution system automation is selected as the topic of in this paper. In this, a method for detection of fault in high voltage transmission systems is devised. The various practical constraints, which are the unique characteristics of the transmission system are considered in the fault detection and classification problem. The work broadly covers:

“Development of a new approach for fault detection in transmission systems using Feed Forward Neural Networks and Neural Network as a detector, using the measurements available at the substation”.

The objectives of this paper is to develop the proposed 5-bus system model of transmission system for generating data sets for ANN technique under steady state and different faulty states like line to ground fault, line to line fault, double line to ground fault, and three phase fault etc and to develop an

Artificial Neural Network (ANN) model from data sets obtained by the transmission model. The algorithm used in

this paper employs the fundamental components of voltage and current signals. A model of 250KV transmission line is developed and simulated in MATLAB/SIMULINK for generating training data sets for ANN. The faults are more easily detecting using ANN in a simple and efficient way.

## II. SYSTEM CONFIGURATION

To gauge the performance of the proposed neural network-based fault detector, a 250 kV, 200 km transmission line extending between two sources has been considered in this study as shown in figure 1.

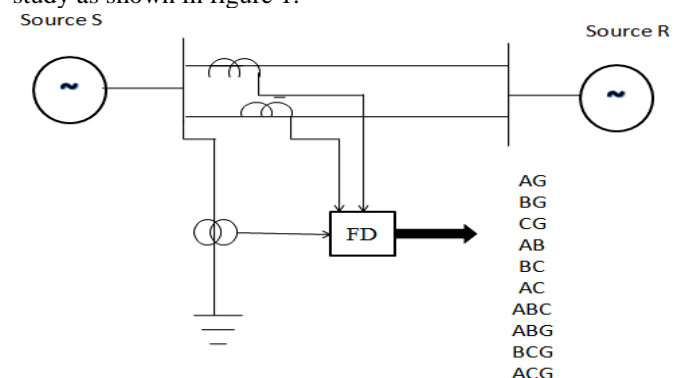


Fig. 1 The system under consideration

The transmission line is represented by distributed parameters and the sampling frequency of the line parameters is taken into account [3].The values of the three-phase voltages and currents are measured at 5 bus system and the resulting data set is ultimately fed into the neural network as inputs. A

simulink model of the transmission line model shown in figure 2 which has been used to generate the entire set of training and testing data for Neural Network. There have been 10 different fault cases simulated for the purpose of fault detection.

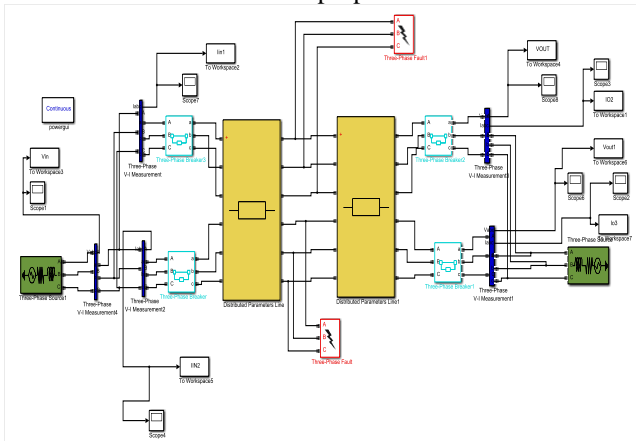


Fig. 2 System model simulated in MATLAB/Simulink  
 The first step in the process is fault detection.

**(a). Network Simulation**

The network is trained using “znntrain”. This function calls ANN functions included in the MATLAB NN toolbox. The functions called are “newff” and “nftool”. The “newff” function creates feedforward network and returns a network object. The “train” function trains the network created. The syntax of “newff” function can be read from MATLAB help. The one used in this work only uses some of its parameters namely “newff” (input, [N1, N2, ... Nj], {F1, F2, ... Fj}, training algorithm). The above function creates a feedforward network with j layers (input layer not involved). The Total numbers of nodes with every layer are N1, N2, and Nj with each layer having activation functions F1, F2, and Fj respectively.[10]

**Feed Forward Neural Networks**

A layered neural network is network of neurons organized in the form of layers. The information is transmit from the input layer towards the output layer but not vice versa, i.e. the network is a Feed forward type. A single layer neural network where only the output layer has neurons is an example of Feed forward layered networks. Figure 4 gives the Single Layer Feed forward Neural Network model. A single-layer network cannot solve any problem that is linearly inseparable. In this respect, multilayer Feed forward networks have been proposed. , In the multilayer Feed forward networks consist of one or more hidden layers, whose computation nodes are correspondingly called hidden neurons. Figure 5 gives a sample multi-layered Feed forward neural network. The function of the hidden neurons is to intervene between the external input and the network output .Extract higher nonlinear relationships exacted by adding one or more hidden layers the network. The network can be fully connected in the sense that every neuron in each layer of the network is connected to every other neuron in the adjacent forward layer.

**Recurrent Networks**

A recurrent network uses its outputs as its inputs. We show the modular design for training recurrent network in Figure 6. The training procedure starts by feeding an input

vector x into the modular network. The desired responses set to a target sequence. The output of the network is feedback to itself as the next input in each iteration. The procedure will be continued until the error reduced to a satisfiable range. We treat recurrent network as a normal feed forward network, where we connect its output destination back to itself. The modular design is particularly useful for the data flow machine. It is believed to achieve high degree of parallel computation. The main achievement is that we can decompose neural networks into small modules which enable us to feed each module into multi-speed processors that can conform the spirit of data flow machine. The self-organization neural network can cope with the data flow machine structure with less modifications and we omit its discussion. [3]

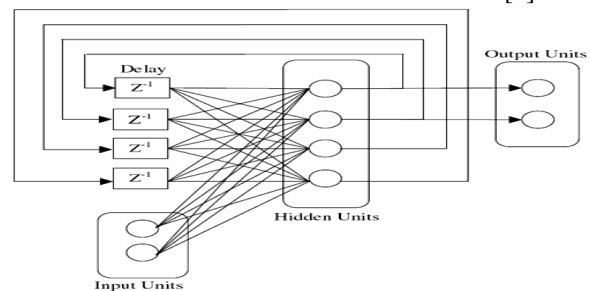


Figure 3:Recurrent Network

**3.3.3 Network Layers**

The commons type of ANN consist of three groups, or layers, of units; a layer of “input” units are connected to a layer of “hidden” units, which is connected to a layer of “output” units.

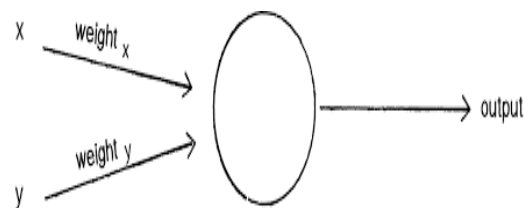


Figure 4: Single Layer Feedforward Network

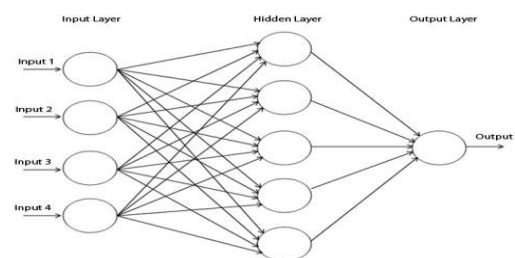


Figure 5: Multi Layered Feedforward Network

The activity of the input units represents the raw information that is fed into the network. The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the inputs and the hidden units. The behavior of the output units depend on the activities of the hidden units and the weights between the hidden and the output units.

This simple type of network is interesting because the hidden units are free to construct their own representations of the input. The weights between the input and the hidden units

determine when each hidden unit is active and so by modifying these weights, a hidden unit can choose what it represents.

The single-layer organization is one in which all units are connected to one another. It constitutes the most general case and is of more potential computational power than hierarchically structured multi layer organizations. In multi layer networks, units are often numbered by layers, instead of following a global numbering.

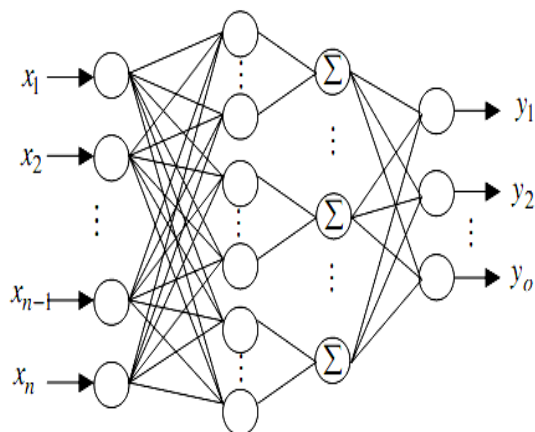


Figure 6: A Simple ANN model

**Backpropagation Algorithm**

We have already seen the benefit of the multi-hidden layer in an artificial neural network. We understood that the hidden layer allows ANN to develop its own internal out of this mapping. Such a rich and complex internal representation capability allows the hierarchical network to learn any mapping and not just linearly separable ones. Let us consider the three-layer network with input layer having ‘1’ nodes, hidden layer having ‘m’ nodes, and an output layer with ‘n’ nodes. We consider sigmoidal functions for activations of the hidden and output layers and linear activation function for input layer.[10]

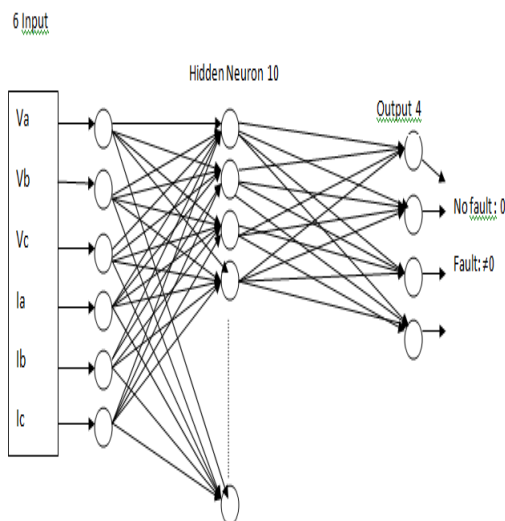


Figure 7. A (6-10-4) Neural Network

**Flowchart for Back Propagation Algorithm**

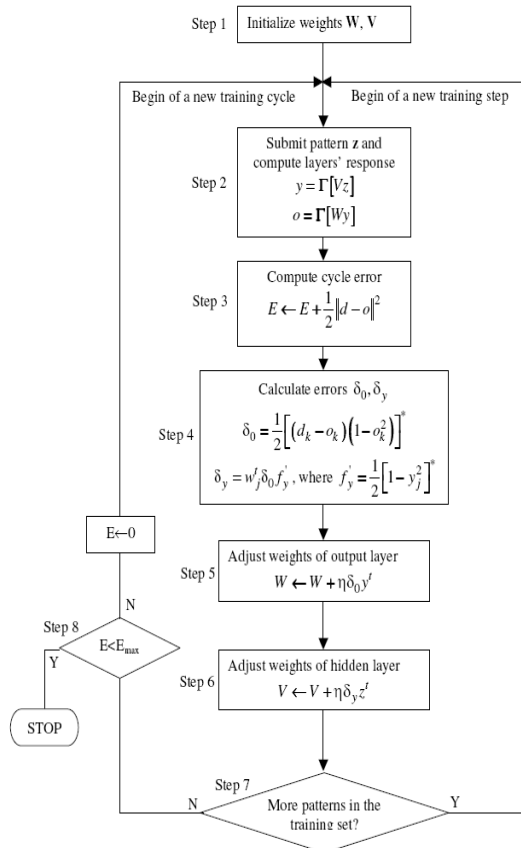


Figure 8. Flowchart for Back Propagation Algorithm

**Proposed ANN for Fault Classification**

Multilayer feed forward networks used to process the prepared input data. A network was selected initially. Different networks with three inputs and a single output were considered for designing the fault classifier based neural network. [9]

The networks’ architecture which involved training and testing different number of networks. Three layer networks were found to be appropriate for the fault selector application. For all the networks, trans-sigmoidal function used as the activation function of the hidden layer neurons and same was used for the output layer.

Once trained, the networks performance generally tested using a validation data set. The suitable network, which showed satisfactory results were finally selected. The selected network has 6 inputs and 4 outputs. The number of neurons for the hidden layer is chosen to be 10 neurons. Based on the fault type, which occurs on the system, output neurons should be between 0 and 1. The fault classification of ANN outputs for various faults are shown in table 1.

Type of fault	Network Output			
	A	B	C	G
A-G fault	1	0	0	1
B-G fault	0	1	0	1
C-G	0	0	1	1

<b>fault</b>				
<b>A-B fault</b>	1	1	0	0
<b>B-C fault</b>	0	1	1	0
<b>A-C fault</b>	1	0	1	0
<b>A-B-G fault</b>	1	1	0	1
<b>B-C-G fault</b>	0	1	1	1
<b>C-A-G fault</b>	1	0	1	1
<b>A-B-C fault</b>	1	1	1	0

**Table 1 Fault Classification ANN outputs for various Faults.**

**Overview of the training process**

Two important steps are training and testing in the application of neural networks for any purpose are. The first of the two steps namely training the neural network is discussed in this section. Neural network learns from the inputs and updates its weights accordingly by the training process.

In order to train the neural network we need a large set of data 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. It will eventually be able to produce an output when a new data is provided to it, ANN slowly learns the training set and slowly develops an ability to generalize upon this data. During the training process, the neural

network's weights are updated time to time with the prime goal of minimizing the performance function.

But usually feed forward networks employ Mean Square Error as the performance function and the same is adopted throughout this work, This performance function can be user defined. 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 on the transmission line.

Sequential feeding of input and output pair has been adopted for the task of training the neural networks for different stages. In view of all these issues, about 3000-4000 data sets for each of the 10 kinds of faults have been simulated.

**Overview of the 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 essential in order to make sure the trained network can produce desired outputs and generalize well when new data is feeding into 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.

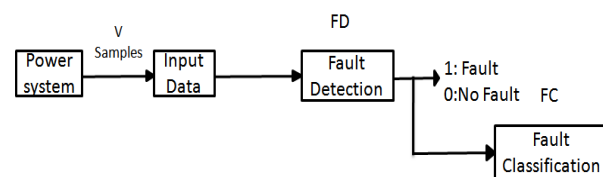
Ideally the slope should be 1, Analyzing the slope of this line gives us an idea on the training process. Also, the correlation coefficient (r), of the outputs and the targets measures how well the ANN outputs track the desired targets. The closer the value of 'r' to 1, the better the performance of the neural network. Hence if the correlation coefficient indicates very low positive classification rates, it shows 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 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 overfitting 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 be able to provide satisfactory performance.

**Proposed ANN for fault classification**

To process the prepared input data a Multilayer feed forward networks were chosen. A network was selected initially. For designing the fault classifier based neural network, different networks with six input and a four output were considered.



**Figure 3.23: Major Blocks constituting Fault Classifier**

The networks' architecture was decided empirically which involved training and testing different number of networks. Three layer networks were found to be appropriate for the fault selector application. For all the networks, trans-sigmoidal function was used as the activation function of the hidden layer neurons and same was used for the output layer. [9]

**Results and Discussion**

Training the Fault Classifier Neural Network

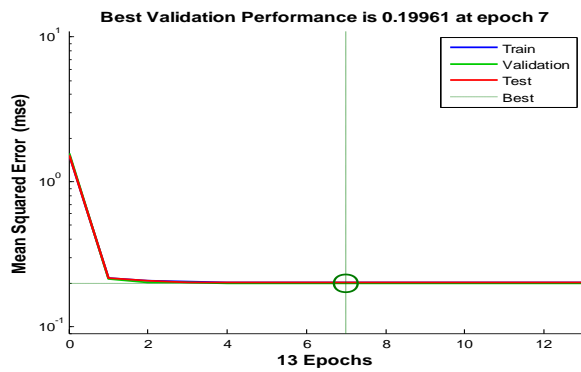


Figure 7 Mean-square error performance of the network (6-20-4)

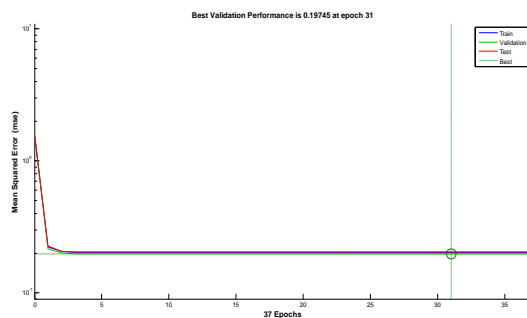


Figure 8 Mean-square error performance of the network (6-25-4)

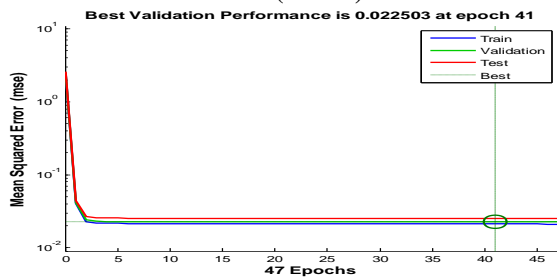


Figure 9 Mean-square error performance of the network (6-35-4)

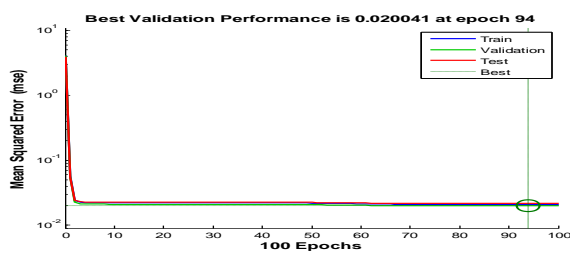


Figure 10 Mean-square error performance of the network (6-45-4)

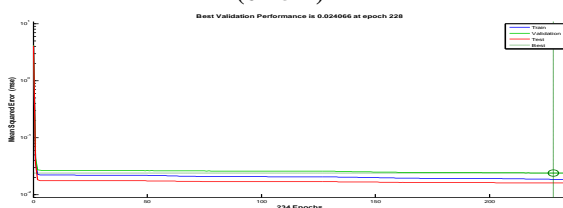


Figure 11 Mean-square error performance of the network (6-60-4)

## Discussion

Back-propagation networks with a variety of combinations of hidden layers and the number of neurons per hidden layer have been analysed. Of these, the ones that achieved satisfactory performance are shown followed by the best neural network which has been described further in detail. Figures 7-11 show the error performance plots of neural networks with hidden layers respectively. The various error performance plots have been shown in Figures 7-11.

After extensive simulations it has been decided that the desired network has one hidden layer with 10 neurons in the hidden layer. For illustration purposes, several neural networks (with varying number of hidden layers and neurons per hidden layer) that achieved satisfactory performance are shown and the best neural network has been described further in detail.

Figures 7 – 8 show the error performance plots of neural networks with 20 and 25 hidden layers respectively. The various error performance plots have been shown in Figures 7 – 11. Fig 7 shows the training performance plot of the neural network 6-20-4, 6 neurons in the input layer, hidden layer with 20 neurons in it and 4 neuron in the output layer). It can be seen that the network did not achieve the desired Mean Square Error (MSE) goal by the end of the training process.

Figures 10-11 shows the training performance plot of the neural network with varying the hidden layer neuron. It is to be noted that the neural network could not achieve the MSE goal of 0.0001 by the end of the training process.

The figure 10 training performance plots, it is to be noted that very satisfactory training performance has been achieved by the neural network with the 6-45-4 configuration (6 neurons in the input layer, 45 hidden layers and 4 neuron in the output layer). The overall MSE of the trained neural network is near about the value of 0.0001 and is actually performance value 0.020041 by the end of the training process. Hence this has been chosen as the ideal ANN for the purpose of fault detection.

## Testing the Fault Classifier

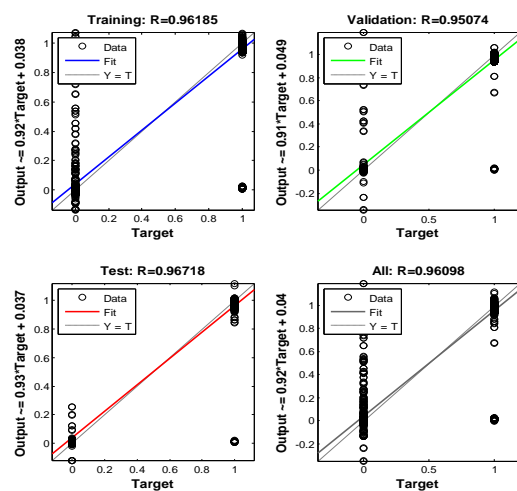


Figure 12 Regression fit of the Outputs vs. Targets of ANN with configuration (6-60-4)

## Discussion

Once the neural network has been trained, its performance has been tested by taking three different factors into consideration. The first of these is by plotting the best linear regression that relates the targets to the outputs as shown in Figure 12. The correlation coefficient in this case was found to be 0.96098 which indicates satisfactory correlation between the targets and the outputs.

The dotted line in the figure indicates the ideal regression fit and the blue solid line indicates the actual fit of the neural network. It can be seen that both these lines track each other very closely which is an indication of good performance by the neural network.

### Conclusion

The aim of this paper is to present a novel approach for classifying faults in High Voltage Transmission Line systems using Matlab using ANN technique considering various practical constraints. Power system High Voltage Transmission Line model was simulated in MATLAB/SIMULINK platform. The proposed Neural Network can be used for a real time approach in the power system analysis. From the results obtained, it can be concluded that the measurements made during fault in a high voltage transmission system contain information about the classification of faults. The data obtained at the substation are used in ANN tool to classify the fault in Transmission systems. The studies carried out in this work show that, for different network configurations in power system, the similar structure of the neural network can be used, and only the weights of the neural networks are updated for different configurations and different and more accurate results can be obtained.

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