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Fault Identification and Classification in Transmission Line by ANN Technique Using Levenberg-Marquardt Algorithms

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Abstract— *It is very important to identify and classify the nature of transmission line fault for reliable power flow and efficient operation of power system. It is also important for relaying decision and auto reclosing requirements. The introduction of pattern recognizer has provided great progress in the power system protection. Artificial Intelligence (AI) such as artificial neural network (ANN) can be utilized for recognition and classification of fault in transmission line. The ANN method requires three phase voltage and current at fault point. These signals are applied at input of the ANN pattern recognizer. Training, validation and testing are the three essential steps employed in ANN. The back propagation learning technique is used along with Levenberg-Marquardt algorithms.*

Keywords—*ANN, BPNN, LEVENBERG-MARQUARDT,FAULT IDENTIFICATION, FAULT CLASSIFICATION*.

I. INTRODUCTION

Generation, Transmission and Distribution are the three basic function of a power system network. The component that exposed in open environment in large extent is transmission system; the likelihood of instance of fault on transmission lines is more frequent in comparison to other components. Fault in power system is defined as any huge flow of current that hinders the system [1]. Some of the fault also occurs due to natural reason which is beyond human comprehend. So it is mandatory to have reliable protection system which not only identifies the kind of fault but also correctly locate the fault. There are numerous reasons which results in disruption of power supply like lighting strokes, fall of tree branches across the line, fog and insulator failure due to salt spray on the polluted insulators. There are various kind of faults that can arise on a transmission line like phase to ground fault, phase to phase fault, three phase fault. Phase to ground fault is most regular (85%) and least severe whereas three phase fault is least occurrence (3-5%) and most severe [2]. For efficient and reliable operation of power systems, it is extremely important that the transmission line faults need to be detected and located in a reliable and accurate manner. Three phase current and voltage are taken into account at the relaying point. Based on the measurement adopted, two well-known techniques may be employed for the detection and classification of fault. This can be achieved either measuring single end measurement technique or using multi-ended measurement techniques.
As per IEEE Std. C37.114™-2004(R2009) guide the fault location technique can also be classified for decisive fault location on distribution and transmission lines [11] into subsequent categories: [3]

- Techniques based on Power frequency
- Techniques based on Differential protection
- Scheme based on Travelling wave
- Scheme based on Artificial intelligence
- Scheme based on Synchronised measurement

Now a day's artificial intelligence related method such as ANN, Fuzzy logic and expert related technique [4] are used in power system fault identification and classification. With artificial techniques the discrimination between various fault cases becomes easier.

In this paper for fault identification and classification in long transmission line ANN method is comprehensively employed.
ANN defined as interrelated set of nodes, like the neurons in brain [5]. An ANN consists of simple processing unit, neuron and a weight which is connected with these neurons. The different kind of transmission line faults is modelled, simulated in MATLAB and Artificial Neural Network with back propagation algorithm is used for identification of these faulty patterns [6].

II. ARTIFICIAL NEURAL NETWORK

An Artificial Neural Network (ANN) can be treated simple neurons in the brain that are usually linked in parallel distributed manner and arranged in multiple layers [7]. ANN architecture has basically three layers. The very first layer is input layer, next layer is hidden layer and the last layer is output layer. Hidden layers can have more than one layer.

Each hidden layer has number of neuron in it. Feed-forward ANN model also described as the perceptron is shown in Fig 1. Each and every neuron is attached with a weight and adjustment of different weight is known as training set of artificial neural network [8], [14], [15].

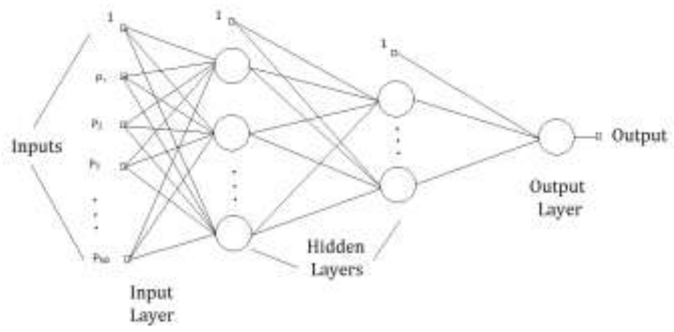

Figure 1. Architecture of a feed-forward ANN with three layers.

2.1. Model of Neuron

A layer is composed of number of interconnected nodes. Each node contains an activation function. An activation function decides the faithfulness of the neurons towards the output [9].

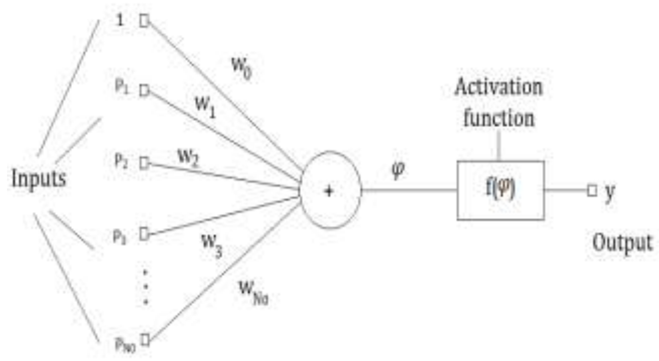

Figure 2. Neuron Model Representation

The output of the neuron is given by

$$y = f(\varphi) = f\left(\sum_{m=0}^{N_0} w_m a_n\right)$$

Where threshold value is $w_0 a_0$, activation function of neuron is f (φ), Φ represents output summation signal and output is represented by Y

$\Phi = [W]^T A$

Where $[w_0, w_1, \ldots\ldots w_{k0}]$ $A = [p_0, p_1 \ldots\ldots pN_0]^T$

There are various type of activation function which are employed in artificial neural network is step function, piece wise linear function, sigmoid unipolar function and sigmoid bipolar function.
Perceptron can be of single layer or multilayer. Connection of two or more variable weights is described as Multilayer perceptron (MLP). Multilayer perceptron is more powerful than single layer perceptron (SLP). For n number of layer or stage perceptron has exactly n variable weight layers and n+1 neurons layer with neuron layer 1 is input layer.

In each i^{th} layer, the no. of neuron is N_i and all these neurons are bonded to their foregoing layer. Excitation signals are applied at input layer [10]. The neurons act like a processing units aligned in a specific way to accomplish a desired output by solving a non-linear process on its inputs. A weight is put to every neuron and training of an ANN is the process of adjusting the weights adapted to the training set. In order to obtain required output synaptic weight of neural network is adjusted. Hence we require training data set used to train neural network.

In Fig 3.1, P1, P2 … PN0 is the input values to ANN. With their exceptional pattern determining abilities ANNs are used in vast field including signal processing and decision making.
One of the biggest challenges of neural network applications there is no set rule to decide the no of hidden layer and number of neurons in each hidden layers.
According to the connection of neuron in a model, neural network can be of two types, one is feed-forward and other is feed-backward.

2.2. Feed forward Network

In feed-forward network the information flows in one direction i.e. unidirectional flow due to no feedback connection [9].The assumed network has N0 input and K_R output signals. Calculation for the i^{th} layer can be described by the following equation.

$$p^{(i)} = f^i(W^i g^{i-1})$$

$p^i = [p_1^i \, p_2^i \, \ldots \, p_{N_i}^i]^T$ is the output signal of the i^{th} layer.

And $w^i = \begin{pmatrix} w_{10}^i w_{11}^i & \cdots & w_{1N_{i-1}}^i \\ \vdots & \ddots & \vdots \\ w_{N_i0}^i w_{N_i}^i & \cdots & w_{N_iN_{i-1}} \end{pmatrix}$ is weighting

matrix involving $(i-1)^{ih}$ layer and i^{th} layer.

$$g^{i-1} = \begin{cases} A & for\ i = 1 \\ \begin{bmatrix} 1 \\ p^{i-1} \end{bmatrix} & for\ i = 2,3,..R \end{cases}$$

Where A is input signal matrix, f^i is the activation function in the i^{th} layer.
The output vector is given by

$$y = p^R = [y_1 \, y_2 \, \ldots \, y_{NR}]^T$$

2.3. Learning Techniques

Learning or training is basically adjustment of weight in order to get required target. Learning of neural network could be done by

i. Forming new connection
ii. Deleting existing connection
iii. Adjusting connecting weights
iv. Adjusting the neuron's threshold values
v. Developing new neurons
vi. Removing existing neurons

Among above given methods changing the weight is most used method. Three important method of learning is [7]

- Unsupervised learning (provides input pattern)
- Reinforcement learning method (provides feedback to the network)
- Supervised learning methods (provides training patterns with desired value)

In supervised learning both input and desired goal is known prior to training of neural network where as in unsupervised learning we do not know the exact association between the inputs and outputs, we train the ANN with known input values. So it is very important to select the suitable values for better training [8]. Two well-known unsupervised learning algorithms are adaptive resonance theory (ART) and self-organised map (SOM). Because of the nonlinear behaviour of activation function, a numerical method is required to solve these nonlinearities. The back propagation method is based on steepest descent approach and is extensively used for training known as Levenberg-Marquardt algorithm with *trainlm* command [12].

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III. MODELING OF TRANSMISSION LINE FOR FAULT IDENTIFICATION

The proposed artificial neural network technique has been used on a transmission line. The Figure 3 shows the simulated model. In this model, two generators are connected with transmission line having distributed parameter at each end. Resistance, inductance and capacitance of the transmission line are taken into account. The length of transmission line is taken as 300Km and base voltage of 220KV. Three phase short circuit level at base voltage is 10^9VA and X/R ratio is taken as 10.

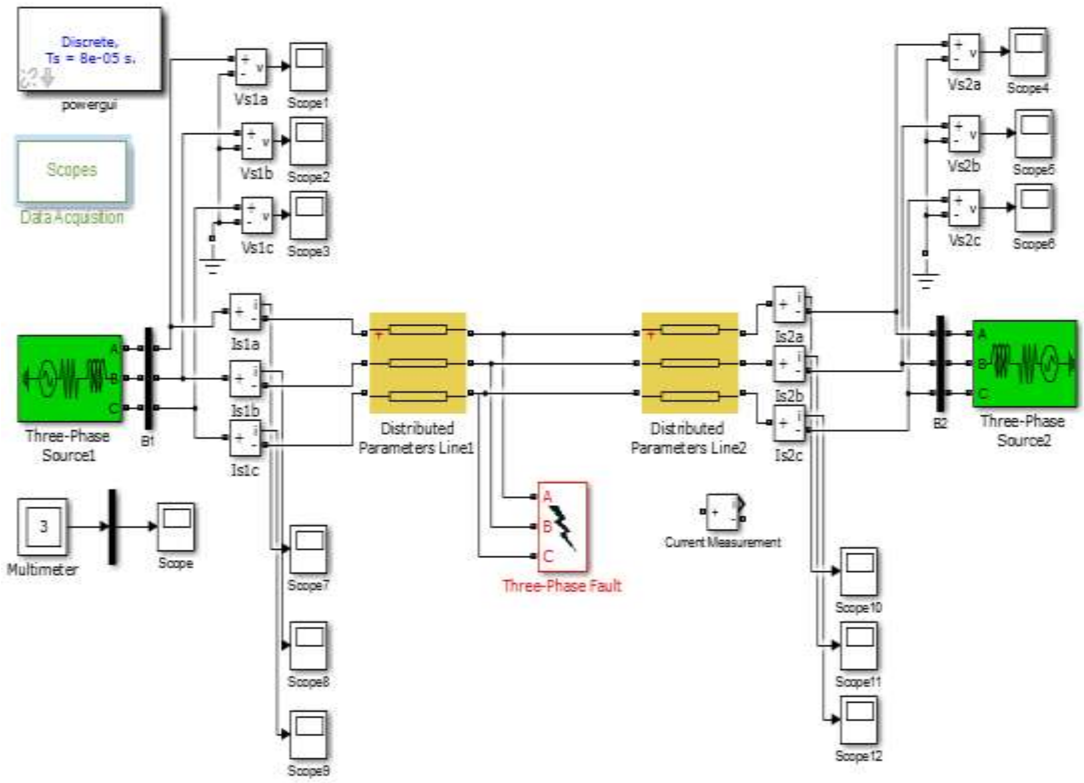

Figure 3. Proposed Transmission Line Model Simulated in MATLAB@/Simulink Software.

IV. DATA PRE-PROCESSING, TRAINING AND TESTING

Extraction of feature with sampled signal is called pre-processing stage. During the fault condition voltage and current experiences transient. The change of energy in voltage and current waveform can be seen during transient period. By using some tool, the change in voltage and current is calculated and normalisation of these voltage and current is done with their pre fault values.These waveforms of three phase Voltage and current were sampled at a sampling frequency of $1x10^3$ Hz. therefore 20 samples in each cycle as shown in Figure 4. To make easy learn for the network, per-processing of data is used for training purpose. The ratio of pre-fault and post fault current and voltages in each phase are used at the input of artificial neural network.

Figure 5 shows the snapshot of the configured ANN model in MATLAB/Simulink environment [13]. The Neural Network toolbox in Simulink of MATLAB divides the entire set of data into three forms. First is Training data set, second is Validation data set, and the last is Testing data set. The neural network is trained for given data set by finding the gradient and updating the weights. During the training process, validation data set is provided and fluctuation(error), in the validation data set is governed through-out training process. When neural network starts over-fitting the data, error increases in validation set. To evade the over-fitting of the data, neural network is set where the validation error is minimum [15]. To check the performance of the neural network, test data is used.

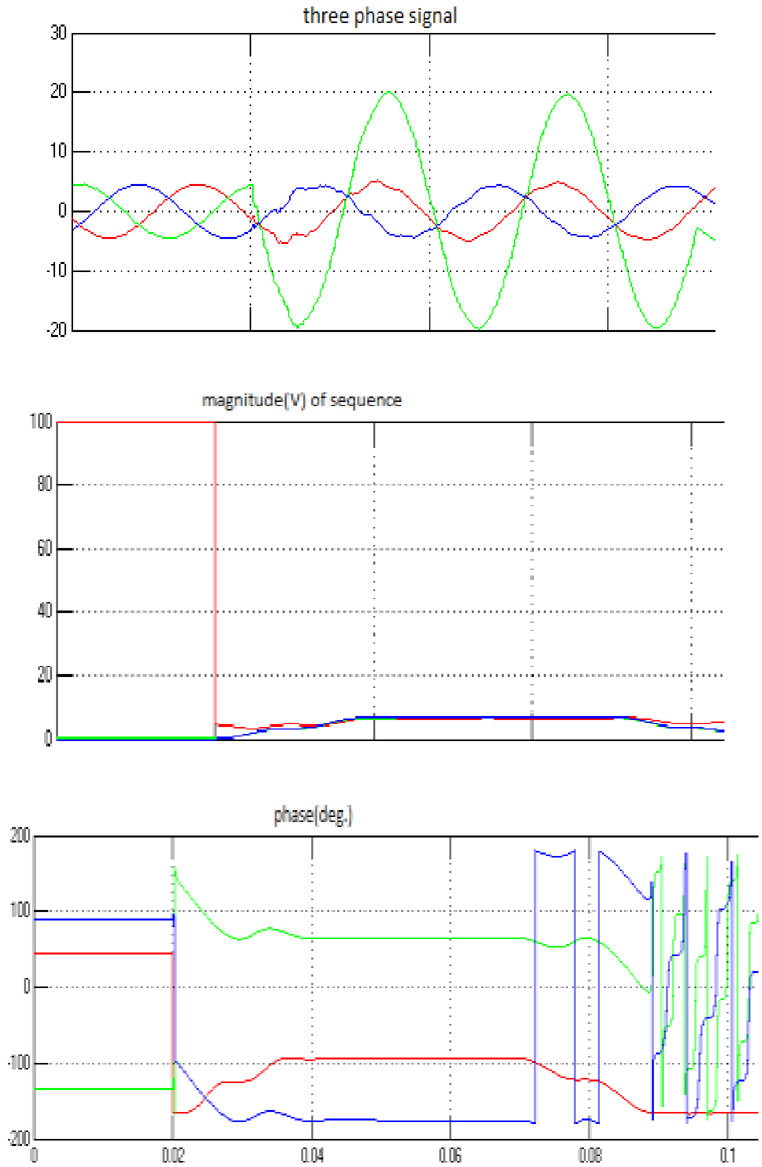

Figure 4. Pre-Processing of Data

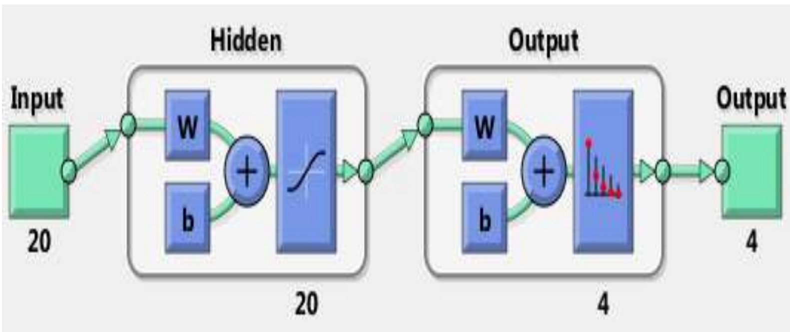

Figure 5. Configured ANN Model in Matlab/Simulink Environment

Due to induction of non-linear behaviour of transfer function or nonlinear mapping function, the networks ability to configure complex functions enhances. This also makes an impact on decision boundary shape. A sigmoid function such as *logsig*, *tansig* can produce decision boundary having smooth curve and edges. In the above modelled architecture for hidden layer *tansig* function is used as transfer function where as for *purelin* is selected for output layer.

For the training purpose the artificial neural networks for various stages, chronological feeding has been selected for input/ output pair. All the ten type of fault has been simulated in MATLAB Simulink at various points along proposed transmission line system. In all these problems, a different fault case for each of the ten types of faults has been simulated. While performing fault test along with phase fault, fault distance from the source fault resistance and inception angle also varied in order to get real time picture. The variation in fault resistance has been done in following sequence: 1Ω, 5 Ω, 10 Ω, 25 Ω, 50 Ω.

V. FAULT IDENTIFICATION

For identification of fault, BPNN is employed. To make the learning process faster, an optimization technique Levenberg-Marquadt has been exploited extensively. Very first stage of fault detection through ANN is the selection of size of neural network. After the selection of proper size six inputs with three voltages V_{abc} three currents I_{abc} of each line) are provided at neural network (NN) input. These voltages and currents Normalization is done with pre-fault values. The data set is prepared for all ten type of fault and no fault case is also considered. Total 330 input output samples in which 30 for individual ten faults and another 30 samples for nofault. The neural network responds in simple way i.e. whether the fault occurred or not. If there is fault in the system, then it will show digitally 1 and 0 in case of no fault condition. After very sincere effort the NN with three layers has been structured. The first layer is the input layer having liner transfer function, 2^{nd} layer is hidden layer having tansig transfer function and the last layer is output layer with logsig transfer function. The network is selected with 6-20-10-1(number of input layer is six, twenty neurons in 1^{st}hidden layer and ten neurons in 2^{nd} hidden layer and 1 neuron in the output layer). Figure 6, shows the closeness of the training validation and testing lines. The overall MSE obtained with adopted layers is 6.9667e-5 is achieved which is very less than pre-set value. So, this network has been adopted for ANN fault detection.

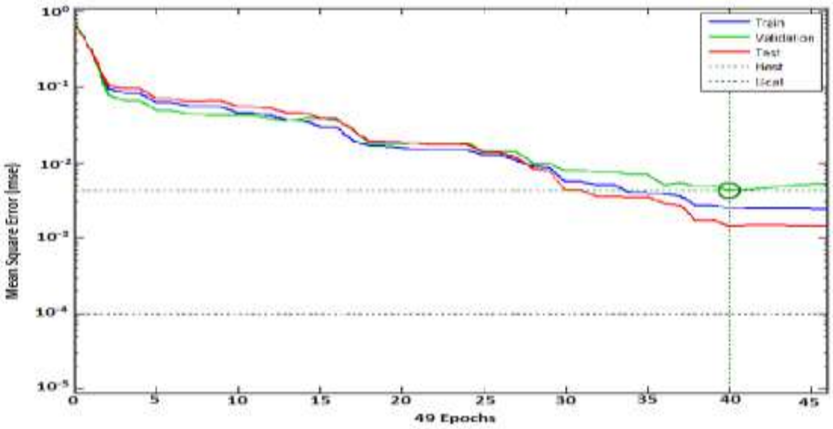

Figure 6. MSE Performances with Layers (6-20-10-1)

After training of the network, testing is performed on the network for fault detection with ANN. This testing is done with the help of linear regression plot. In linear regression plot target relates with output in a specific manner as shown in Figure7.

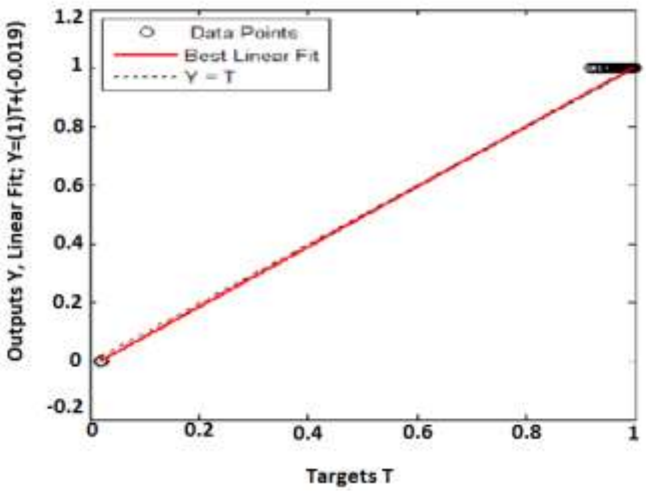

Figure 7. Regression Fit for Layers (6-20-10-1)

Confusion matrix is another method available for testing performance. Figure.8 shows the confusion matrix regarding adopted neural network.

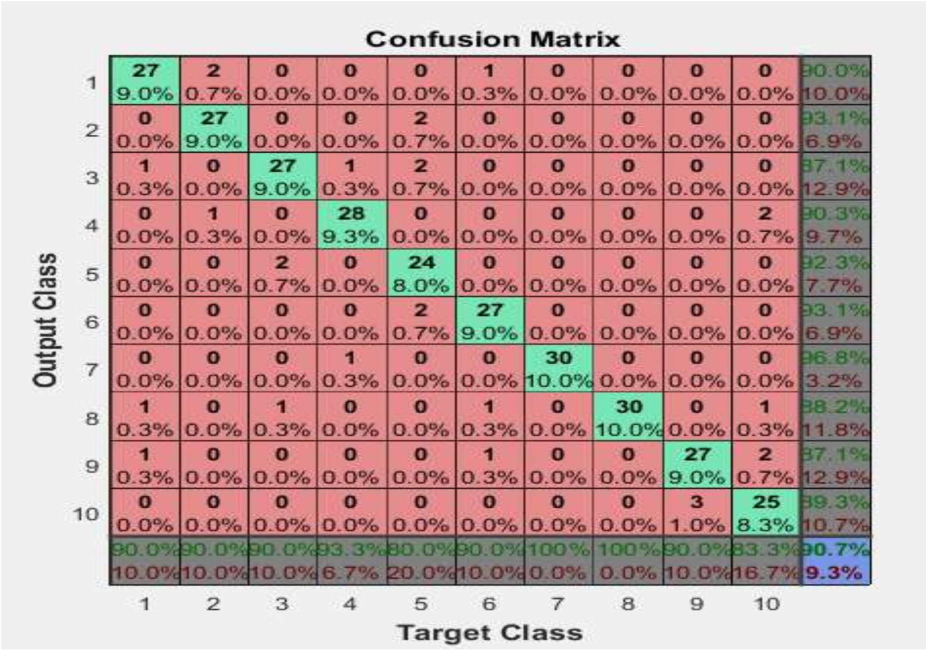

Figure 8. Confusion Matrix Adopted Neural Network

VI. FAULT CLASSIFICATION

Fault classification is also done in the same way as it was done for fault detection in terms of development and design of the ANN. The neural network is fed with six inputs having three voltages and three current of each phase. These voltage and current are normalized with their pre-fault values of voltage and current. Four outputs are obtained from neural network in which three values gives an indication to phase fault and fourth one gives information about ground fault. The output of neural network is in the digital term; 0 or 1 indicating 'no fault' and 'fault' condition in the transmission line.SE Hence all ten type of fault combination has been illustrated in the truth Table 1 where A,B,C represents phase values and G represent ground. The proposed method must be capable to distinguish among all the ten fault cases accurately training data contains whole 300 inputs- output pattern (30 for individual type of fault) with six inputs of voltage and current and one output in each input–output arrangement. BPNN having various combinations of hidden layer and variable neuron in each hidden layer were studied. BPNN with 6-36-4(i.e. input layer having 6 neurons, 36 neurons in one hidden layer and one output with 4 neuron) gives quite satisfactory result. With proposed neural network the overall M (mean square error) of 0.036807 is obtained. The comparable characteristic of testing curve and validation in the fig shows the competence accuracy.

Table 1. ANN Fault Classifier Output

Fault Type	Outputs of the network			
	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-G	1	1	0	1
B-C-G	0	1	1	1
C-A-G	1	0	1	1
A-B-C	1	1	1	0

VII. CONCLUSION

An artificial intelligence based method artificial neural network has been adopted for fault Identification and fault classification. A feed-forward network with Levenberg-Marquardt algorithm is successfully used. The proposed techniques clearly identify and classify all ten types of fault in a long electric power transmission line. The selected network with suitable number of input layer, hidden layer and output layer ensures minimum mean square error. For simulation of long power transmission line model and to obtain the training data set Matlab@/ Simulink software R2011b version 7.13 has been used.

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AUTHOR'S DETAIL

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