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Detection & Classification of Electrical Power System Faults Using Artificial Neural Networks

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Abstract:
The main objective of this paper is to design two neural networks for detection & classification for electrical power system faults in transmission lines. The majority of this paper is to investigate the performance of fault detection & classification when using these developed "designed" ANN. MATLAB Simulink along with Neural Networks Toolbox were used in simulating & designing of the two networks.

I. Introduction:

There are more transmission lines being built every day, and these lines are crucial for transferring power between various networks and loads. A variety of factors can lead to transmission line faults, which have an impact on the line. Transmission line faults can be divided into the following four categories: Line to Ground (L-G), Line to Line (L-L), Three Phase (L-L-L), and Three Phase to Ground Faults (L-L-L-G) [1]. Excessive current flows when a failure or fault in the system occurs, harming the machinery and gadgets. To choose or build suitable switchgear, electromechanical relays, circuit breakers, and other protective devices, failure/fault detection and analysis are necessary.[2]. Numerous factors, including the weather, [3] defective equipment, human mistake, and smoke from fires, can cause electrical faults. There have been several methods used to find transmission line defects and classify each individual issue. In general, the last ten years saw rapid growth in artificial intelligence. A component of artificial intelligence (AI) and computer science, machine learning focuses on using data and algorithms to simulate [4] how humans learn, with the goal of continuously improving accuracy and efficiency. The rapidly expanding area of data science includes machine learning as an essential component. Using a statistical technique, the algorithm is trained to produce classifications or predictions, and it offers crucial insights for data mining projects. These insights make it easier to apply them and make business decisions with the intention of affecting important growth KPIs. [5].

The significance of data scientists will increase as big data expands and grows, demanding their assistance in determining the most pertinent business issues and, as a result, the data necessary to answer them. The almost endless amount of data, affordable data storage, and the advancement of less expensive and more effective processing have all contributed to the acceleration of machine learning. [6]. Many businesses are currently attempting to create stronger machine learning algorithms that can analyze larger and far more complex data while offering quicker, more accurate answers on large scales. One of the common intelligent control systems that may be employed in fault detection and classification is the neural network. [7]. In this paper, detection if there are faults will occur in the transmission line and to classify those faults using “Artificial Neural Networks”. First, the transmission line system was built (Supply Source, Bus & Transmission Lines) using MATLAB Simulink. After that is setting up the parameters and simulate the fault using real data. Then developing a neural network with back-propagation algorithm with a certain number of inputs, hidden layers with two activation functions (Tan sigmoid in the hidden layer & Linear in the output Layer) using Neural Network Toolbox in MATLAB. The output of the network which represent phase voltages & phase currents will be taken as the input of the neural network. Neural network will be trained with 70% of the data used & tested with 30% of the remaining data to achieve the desired output (which is the fault and the fault type). [8]. Finally, computing the error and the accuracy of the neural network in detection & classification of the fault occurred. The main target is to achieve at least 90% or above accuracy for both neural networks. Figure (1) below shows a simple transmission line system built using MATLAB Simulink.

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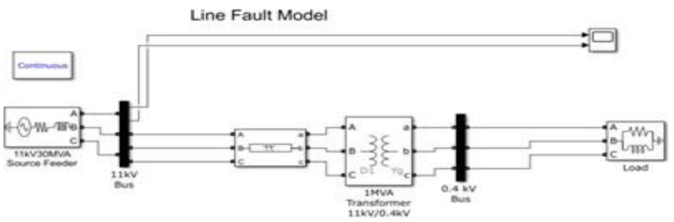

Figure (1): Transmission Line Model

II. *Artificial Neural Networks:*

A) Neural Networks & Neural Networks Layers:

The Neural Network in common is the most efficient algorithms that properly used in a Machine Learning over the recent decade for variety practical applications (For example: hand-written recognition, speech recognition, etc.). This can be defined as a computational model mimicked the way as the biological process of nervous systems where it can learn from the dataset to provide the desired outputs. The main benefit of the Neural Network algorithm is that it can address the nonlinear problems and discover the results by a very complex relation between the inputs and the outputs [9]. Every neural network consists of three layers that are represented by nodes. These nodes are connected typically based on the systems. Neural Networks construction is consisting of three main layers, input layer, hidden layer & output layers: [10].

Input Layer: this is the first layer of the Neural Network, which contains multiple nodes, received the dataset and information in various types depending on the input forms.

Hidden Layer: it can be represented in hidden layers as well as a single layer. These layers received the data from the input layer and implement some mathematical formulation those results are sent to the output layer in a form of pattern.

Output Layer: those nodes will receive the result compared with the desired output for checking the performance. The programmer will do and repeat these steps unless the closely desired outputs have been achieved.

B) Neural Network Structure:

Neural Network structure consists of neurons in input layers, first activation function in input layer, weights and biases, hidden neurons in hidden layer, second activation function in output layer & the desired output. Figure (2) shows general structure of a neural network. [11].

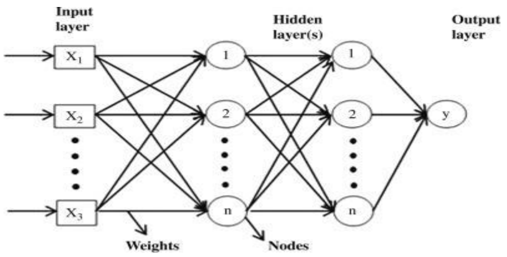

Figure (2): NN Structure

III. *Detection & Classifications of Electrical Faults Using Neural Networks:*

A) Fault Detection Neural Network:

The planned design of the neural network was to take the phase voltages & the phase currents as inputs to the neural network. The neural network structure is as following:

Input Layer with 8 Inputs, Tan-sigmoid Activation function in the input layer, Hidden Layer with varies numbers of hidden neurons, Linear Activation function in the output layer, Output Layer with one output, Back propagation Algorithm, Training with Levenberg-Marquardt Algorithm with 70% of the data, Validation of 15% of the data, Testing of 15% of the remaining data. Figure (3) below shows the structure of the neural network developed. [12].

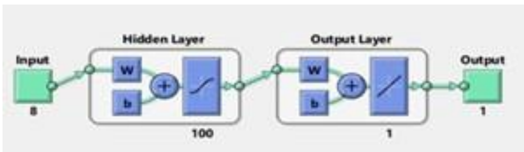

Figure (3): Fault Detecting Neural Network

B) Fault Classification Neural Network:

The planned design of the neural network was to take the phase voltages & the phase currents as inputs to the neural network. The neural network structure is as following:

Input Layer with 8 Inputs, Tan-sigmoid Activation function in the input layer, Hidden Layer with varies numbers of hidden neurons, Linear Activation function in the output layer, Output Layer with four outputs, Back propagation Algorithm, Training with Levenberg-Marquardt Algorithm with 70% of the data, Validation of 15% of the data, Testing of 15% of the remaining data. Figure (4) below shows the structure of the neural network developed. [13].

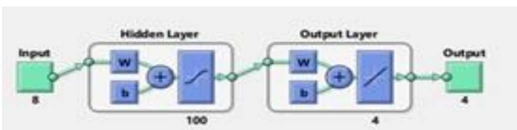

Figure (4): Fault Classifier Neural Network

IV. Fault Detection System Using Artificial Neural Network:

To start creating the desired neural network, first is to identify the inputs for the neural network and the target outputs as per table (1) below:

Inputs (Fault Type)	Network Output
A-G	1
B-G	1
C-G	1
AB	1
AC	1
BC	1
ABCG	1
No Fault	0

Table (1): Fault Detecting Inputs & Outputs

After identifying all inputs and outputs needed, the neural network was trained using MATLAB tool for neural network (nftool). Considering 70% of the data for training, the other 30% was divided into 15% validation & 15% testing. The training process is shown in figure (5) below.

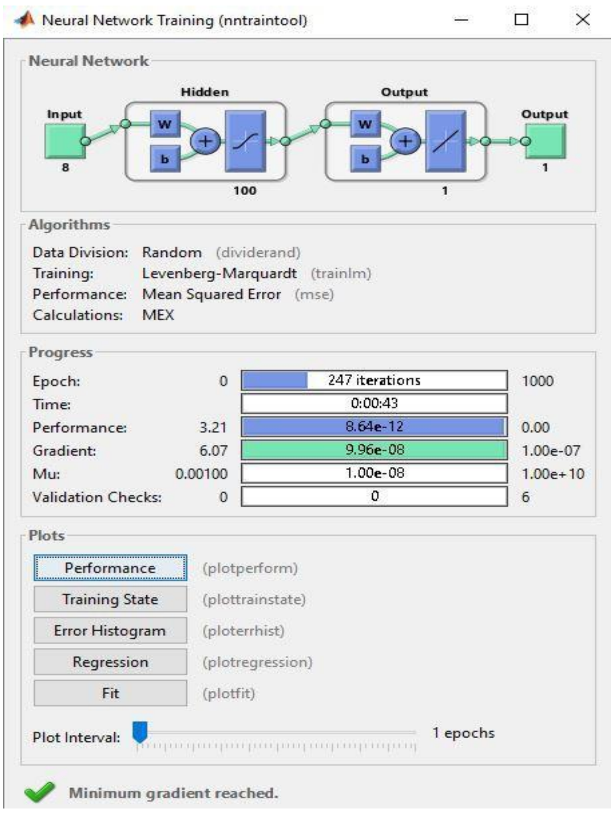

Figure (5): Fault Detection Training

After Training, the graphs for neural network performance and the regression model in order to see the behavior of the designed network. figure (6) below shows the performance of the neural network. [14].

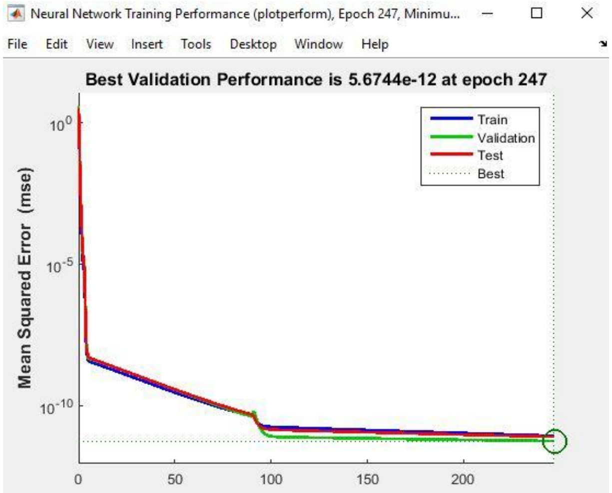

Figure (6): Detection Network Performance

The regression graph for the developed neural network for fault detection is shown in below figure (7)

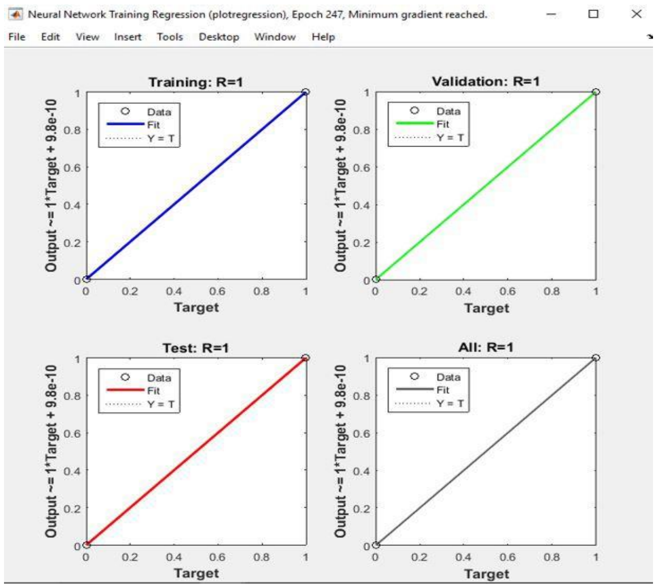

Figure (7): Regression Fit for Detection ANN

From the performance graph and the regression graph, the developed neural network is stable. The aim was to get the best performance of the neural network by adjusting the number of hidden neurons in the hidden layer, it is found that when the number of hidden neurons in the hidden layer is 100, receiving the best performance of the neural network with mean square error of 9.96e-08 in 247 iterations with performance of 99.9%. when the inputs of table (1) given to the network, 99.9% output received

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V. Fault Classification System Using Artificial Neural Network:

To start creating the desired neural network, the inputs which are represented by the phase voltages (Va, Vb & Vc) and the phase currents (Ia, Ib & Ic) as shown in table (2) below: [15].

SN	Va	Vb	Vc	Ia	Ib	Ic	Fault
1	0.000	1.020	1.070	3.800	0.000	0.000	**A-G**
2	1.020	0.000	1.070	0.000	3.800	0.000	**B-G**
3	1.020	1.070	0.000	0.000	0.000	3.800	**C-G**
4	0.500	0.500	1.000	3.500	3.500	0.000	**AB**
5	0.500	1.000	0.500	3.500	0.000	3.500	**AC**
6	1.000	0.500	0.500	0.000	3.500	3.500	**BC**
7	0.000	0.000	0.000	3.850	4.100	3.500	**ABCG**
8	1.000	1.000	1.000	1.000	1.000	1.000	**No Fault**

Table (2): Input Phase Voltages & Phase

Then, the input to the neural network is defined as fault type in coded form (4 bits) as shown in table (3) below:

Fault Type	**Network Target Output**			
	A	**B**	**C**	**G**
A-G	1	0	0	1
B-G	0	1	0	1
C-G	0	0	1	1
AB	1	1	0	0
AC	1	0	1	0
BC	0	1	1	0
ABCG	1	1	1	1
No Fault	0	0	0	0

Table (3): Input & Target Output for Classification Neural Network

The outputs were classified as per fault type, 4-bits were used to represent each type of fault so the neural network can remember it easily. Once identifying the inputs and target outputs finished, the next phase which is training the neural network and find out the performance and the corresponding mean square error along with the network accuracy. Figure (8) shows the training process of the network. 70% of the data used for training, 15% for validation and 15% for testing. [16].

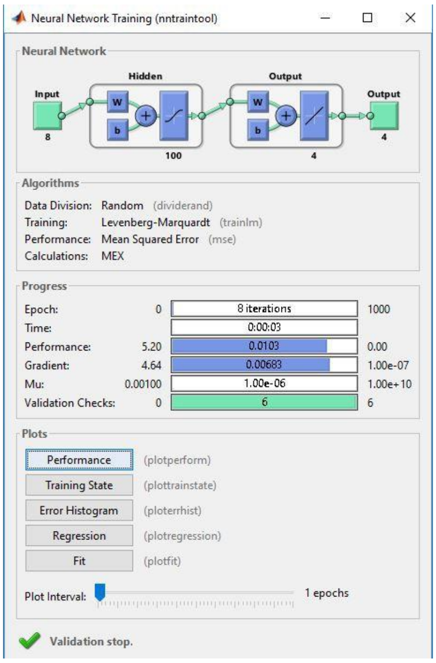

Figure (8): Training Process for Classification ANN

After Training, the graphs were obtained for neural network showing the performance and the regression model to see the behavior of the designed network. figure (9) below shows the performance of the neural network. [17].

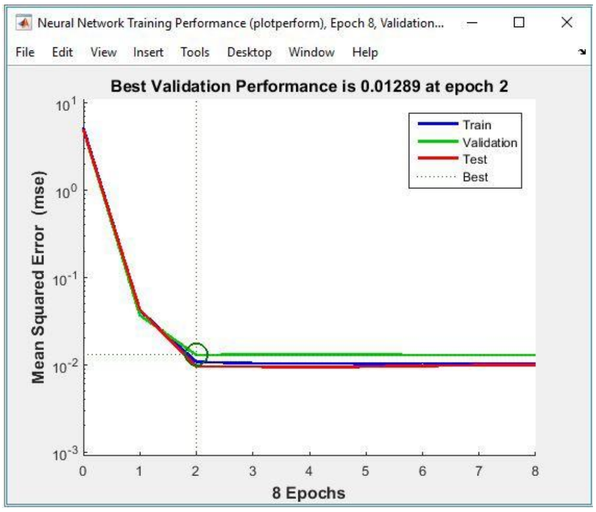

Figure (9): Classification Network Performance

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The regression graph for the developed neural network for fault classification is shown in below figure (10):

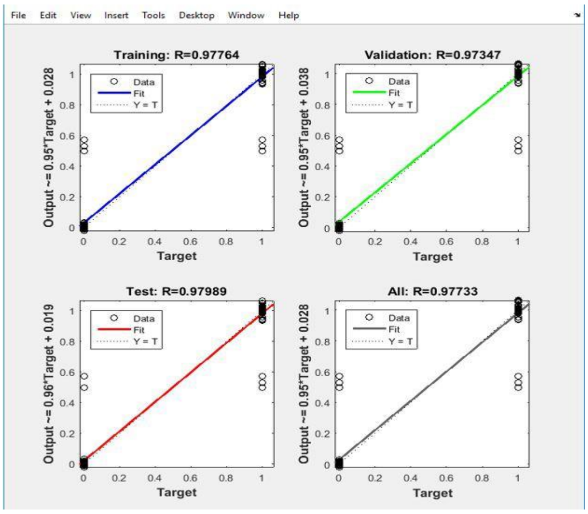

Figure (10): Regression Fit for Classification ANN

The neural network was tested to ensure getting the target output. The graphs for some faults were obtained to make sure that the performance of the designed neural network is fine. Figure (11, 12 & 13) show the graphs of some faults detected by using artificial neural network. [18].

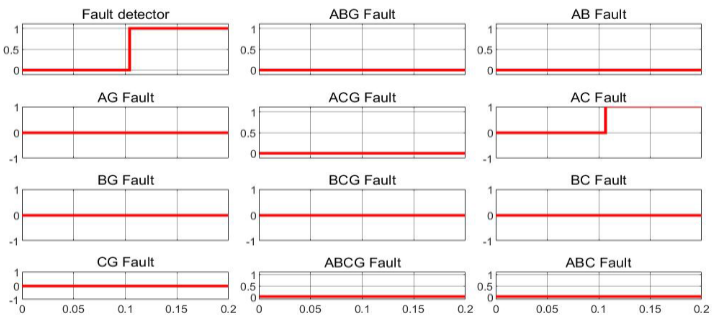

Figure (11): A-C Fault

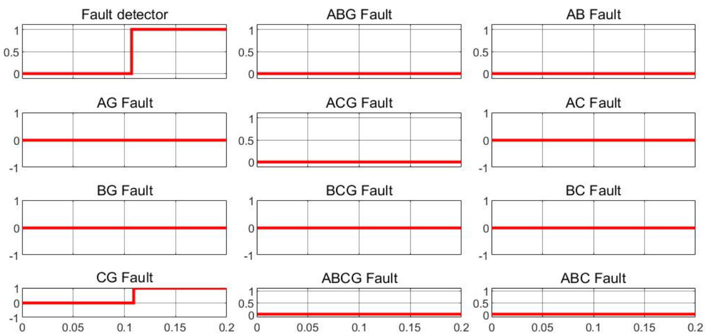

Figure (12): C-G Fault

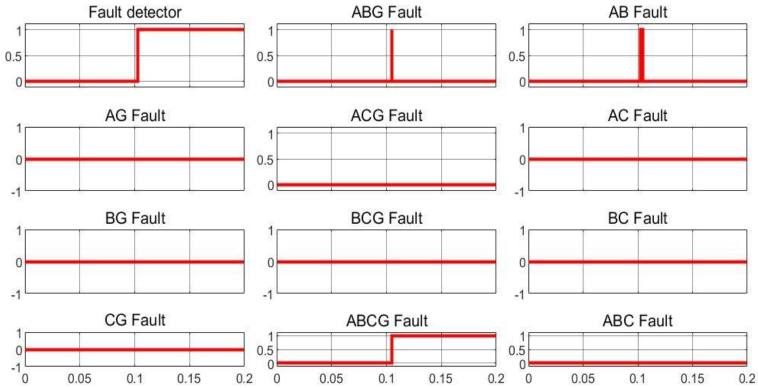

Figure (13): A-B-C-G Fault

The performance of the neural network was excellent with mean square error of 0.00683 with 8 iterations. The Accuracy of the neural network was almost near 97%. The aim was to obtain the best performance of the neural network by adjusting the number of hidden neurons in the hidden layer. The results were that with 100 number of hidden neurons in the hidden layer, the best performance of the designed artificial neural network with almost 97% output accuracy was obtained. [19].

VI. *Conclusion & Future Work:*

The main objective of this paper is to use the artificial intelligence in detecting and classification of electrical faults in electrical power systems. The two developed neural networks were to do the required functions. The first neural network was for fault detection by arranging the fault types happening into "0" and "1". The second neural network is for fault classifications by using phase voltages and phase currents as an input with target output of 4 digits classifying the fault type. The overall performance of the two artificial neural networks was excellent with accuracy of almost 100% for fault detection neural network and 97% for fault classification neural network. As a future work, a third neural network may be developed to be used for determining fault occurring location. By developing the third neural network, a complete system to be used in detecting, locating and classification of electrical faults in any power system network will be created. All work was done using MATLAB software with Neural network built-in tool (nftool).

VIII. Acknowledgment:

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