Software Based Transmission Line Fault Analysis

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ABSTRACT: *Neural computing is now one of the most promising technologies in all fields of engineering, resulting in the development of a number of Artificial Neural Networks (ANN). Double circuit transmission lines are being employed in the distribution of power to consumers and have become more widespread than single transmission line, as they increase the electric power transmission capacity and the reliability of an electrical system. Losses along transmission lines occur due to faults. Possible faults on the transmission line were predicted using Artificial Neutral Network. In this work, the simulation of fault on a 132kV double circuit transmission lines using MATLAB was undertaken. Parameters considered during the simulation were the input of the network which is the fault current value at each fault location while the output of the network is the fault location. The efficiency of the neural network was tested and verified. This approach provided satisfactory results with accuracy of 95% or higher.*

KEYWORDS -*Artificial Neutral Network (ANN), 132 kV Double Transmission Line, Multi-Layer Feed-Forward Back propagation (MLFFBP), Matlab*

I. Introduction

Electrical Power system is a complex system in the world and it consists of generation, transmission and distribution. Challenging problems are usually encountered in the design of power systems to deliver amounts of electrical energy in safe, clean and economical manner. Transmission lines are used to transfer the energy from generation through distribution to the consumer. Mostly, electrical transmission line is exposed to the environment and the possibility of experiencing faults on these lines is generally higher than that on other main components of the electric power system. In Nigeria, the transmission lines covers thousands of kilometers over some difficult and impossible to access terrains. When a fault occurs on an electrical transmission line, it is very important to detect and locate it in order to make necessary repairs and to restore power as soon as possible to the consumers. This may take days and weeks in any part of Nigeria throwing the consumers into darkness with attendant health and economic losses. The time needed to determine the fault point along the line will affect the quality of the power delivery [1]. In power system stability, many different techniques can be utilized for fault analysis, however most of them are based on assumed fault equations and the parameters of the equation are estimated through curve fittings. Because of complexity of power system, the assumed equations may not capture power, frequency, current, and voltage phenomena simultaneously and accurately. To improve the power sector, the Nigerian government has undertaken long-term structural reforms (which started in 2005 but gained momentum in 2010) focused on privatizing legacy power assets and instituting regulatory reform. However, these reforms have proved insufficient and more must be done to address the challenges in the sector, which include sub-optimal utilization of generation plants (partly due to insufficient gas molecule availability), inadequate transmission infrastructure and high distribution losses (with related liquidity and viability issues).

Of the four segments of the power chain system, distribution is the aspect most visible to the consumer, and this segment in Nigeria can incur close to 46% losses due to technical, commercial and collection issues [2].

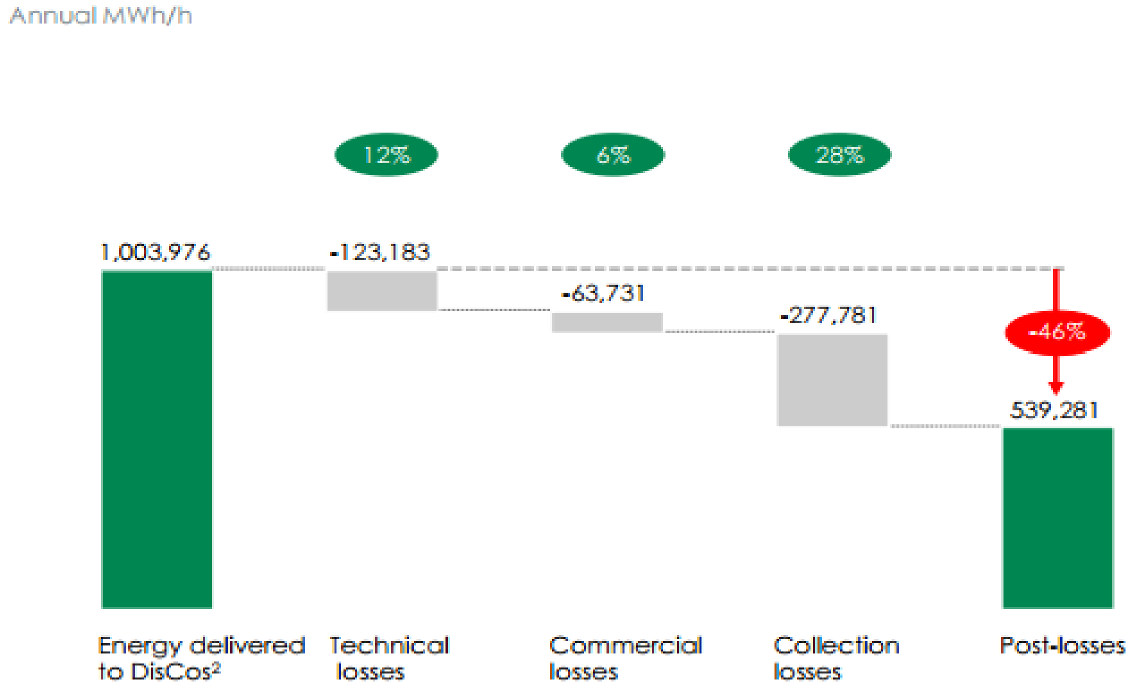

Figure 1: Overview of distribution performance in 2014, adapted from [2]

In attempt to solve its distribution problems, the government sold its principal shares in the power sector to private investors. This process started in 2005, went through a change of government and then picked up again in 2010. The investors that took over were called DISCOs with the promise of grid expansion, and the increase in the number of new connections and capex to be spent on meters.However, the DISCOs face significant financial pressures largely due to low energy tariffs, outages and the unwillingness of the customers to pay for non-existent power. In March 2015, the regulator ruled that collection losses could not be passed on to consumers via retail tariffs. With collection losses set at zero, distribution companies would have needed to achieve dramatically lower loss levels to meet their loss commitments. Faced with this situation, several distribution companies declared force majeure, triggering a regulatory crisis and a temporary loss of investor confidence [2]. Most of the losses shown in Fig. 1 are due to one form of fault or the other on the transmission line before the power arrive at the consumer. It therefore becomes extremely necessary to investigate cheap and fast new fault modeling techniques for power system stability analysis in Nigeria since most operators are weary of new heavy financial investment in the power sector.

Fault (which in Nigeria may occur as a result of lightning strikes on bus bar, collapse of transmission line, accidental short circuit by snake, kite and bird,tree or bamboo touching line, human mistake) is an unwanted condition that occurs in power system. Fault occurs due to insulation breakdown at one or more point on a conductor or a conducting object coming in contact with live point as indicated above. These conditions will affect voltage and current value on power system. Transmission line is the part of power system in which fault most likely occur. Researches on fault analysis are very important for protection purposes to enhance reliability of electricity supply. Double-circuit lines are now widely used in transmission systems due to their significant economic and environmental advantages over single-circuit lines. Double circuit transmission lines are defined as lines that share the same structure or a portion of their length. These lines have been extensively utilized in modern power systems to enhance the power transfer, reliability and security for the transmission of electrical energy.

Accurate detection and location of faults for an inspection-repair purpose is very important for accelerating service restoration, thus reducing outage time, operating costs and consumers' complaints. However, the fault analysis for double-circuit lines is much more complicated than single circuit lines because of mutual couplings between two circuits and the existence of more complex fault types.

There are many research work on fault detection through which different approaches have been proposed to detect faults. The study in [1] used an offline detector method to detect faulty line by injecting special frequency signals to the line. This method was neither safe nor convenient. Other methods identify the phase to ground fault according to the changes of the three phase voltages and currents but cannot properly distinguish between faulty line and healthy lines. Recently, with the advent of the microprocessors, various analytical methods have been developed and tested to detect faults. Unfortunately, these methods use digital signal processing which take time and do not have the ability to adapt dynamically to the system operating condition. They are likely to make incorrect decision if the signals are noisy [3]. Artificial neural network on the other hand, provide a promising alternative, because they can handle most situations which cannot be defined sufficiently for finding a deterministic solution. The ANNs takes into account their noise immunity, robustness, fault tolerance and generalization capabilities. The ANN networks have ability to learn the desired input-output mapping based on training example, without looking for an exact mathematical model. The intent of this paper is to analyze symmetrical faults on 132kV transmission line by modeling and simulating a double circuit 132kV transmission line using MATLAB toolbox and Simulink. The detection of potential faults on the model line was done using Artificial Neural Network (ANN) and validation of the ANN in fault prediction along transmission lines. This approach is simple and cost effective and have a fast response time.

II. Artificial Neural Network Development

Neural network technology is an emerging technology in electrical engineering for power system modeling, simulation, optimization and design. Multilayer Perceptron (MLP), Radial Basis Function (RBF), Knowledge Based Neural Network (KBNN), Wavelet network and Recurrent Neural Network (RNN) are commonly used NN structures. Selection of NN structure and training algorithm are two major issues in developing NN model. The most important and time consuming step in model development is NN training. The NN model uses the measured or simulated data for training. Training is an optimization process in the weight space and is often done using optimization–based training algorithm such as backpropagation (BP). Training algorithms are an internal part of neural model development. Any alternative structure may still fail to give a desired model, unless trained by a suitable training algorithm [3]. The proper training algorithm manages to reduce the training time by achieving better accuracy. A distinct advantage of neural computation is that, after proper training, it completely bypasses the repeated use of complex iterative processes for new design presented to it.

2.2 Structure of Multi-Layer Feed-Forward Network

The standard multilayer feed-forward network (Fig. 2) is employed as the network architecture in this study. The multi-layer feed-forward network is a network of neurons and synapses organized in the form of layers. There are three kinds of layers in an ANN: the input layer, hidden layer and output layer. The function of the input layer is simply to buffer the external inputs to the network. The hidden neurons have no connections to the inputs or outputs. By including hidden layers, the network is empowered to extract higher-order statistics as the network acquires a global perspective despite its local connectivity by virtue of the extra set of synaptic connections and the extra dimension of neural interactions [4].

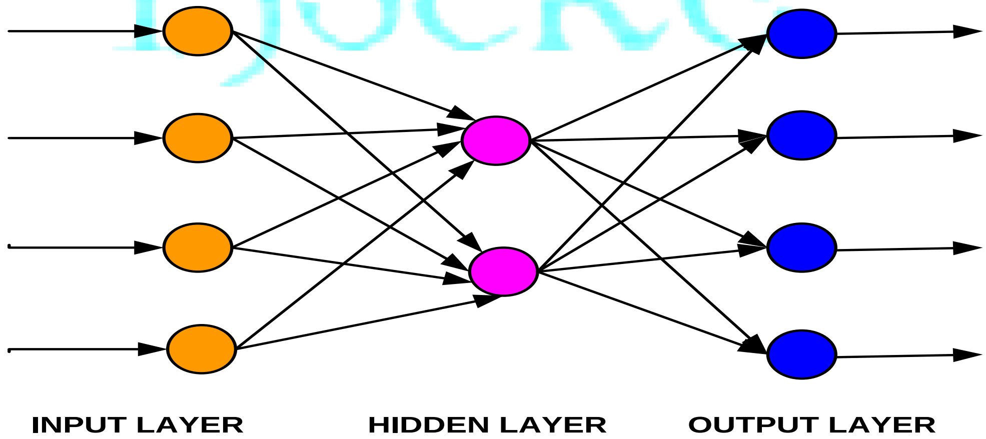

Figure 2: Structure of Multi-Layer Feed-forward Network.

Basically, ANNs consist of a network of neurons and synapses arranged in layers, the source nodes in the input layer of the network supply respective elements of the activation pattern, which constitute the input signals applied to the neurons (computation nodes) in the second layer. The output signals of the second layer are used as inputs to the third layer, and so on, for the rest of the network

2.3 Transmission Line Model

To determine the performance of the proposed neural network-based fault prediction, a 132 kV, 100km double circuit transmission line extending between two sources as shown in Fig. 3 was developed for this study.

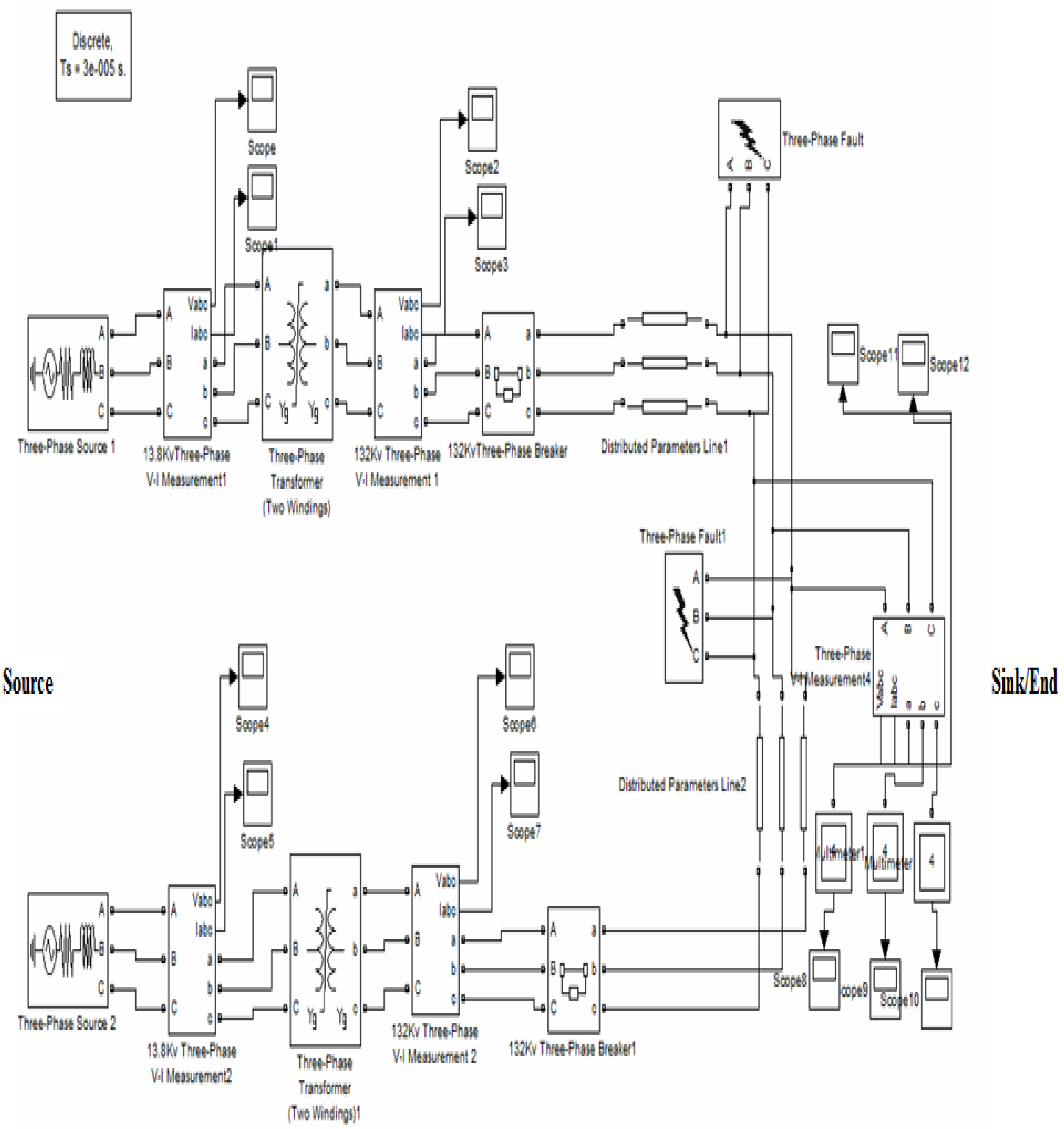

Figure 3: 132 kV Double Circuit Transmission Line Model

.All components were modeled by the MATLAB Simulink and Sim-Power System toolbox. The input and output data used for training and testing the neural fault detector were obtained from the Sink/End of the power system model. A highly accurate transmission line simulation technique (Fig. 4) was utilized to produce voltage and current waveforms for phase to ground fault.

III. Methodology

For the design of a neural network system for the prediction of double circuit transmission line fault, a FFBP algorithm was used which consists of three layers: input, hidden and output. The input and output layers were selected to be the best that suits the requirement of the design. Sufficient amount of data were generated for the training from the simulation of a model transmission line and the execution of algorithm starts with the training process of ANN model (Fig. 2).Fortescu's theorem was utilized to obtain the power system component as shown in Fig. 4. After executing the algorithm the output was compared with the required target. When the outcome of algorithm gave better result, then the ANN model was tested with new data to determine the accuracy of the ANN model. The selection of number of neurons used for hidden layers and value of moment count (mc) in algorithm plays very important role in providing higher accuracy for the developed ANN model. When the accuracy was not achieved, the by number of neurons for hidden layers were changed along with the number of epochs, so as to develop appropriate ANN model for the fault prediction.

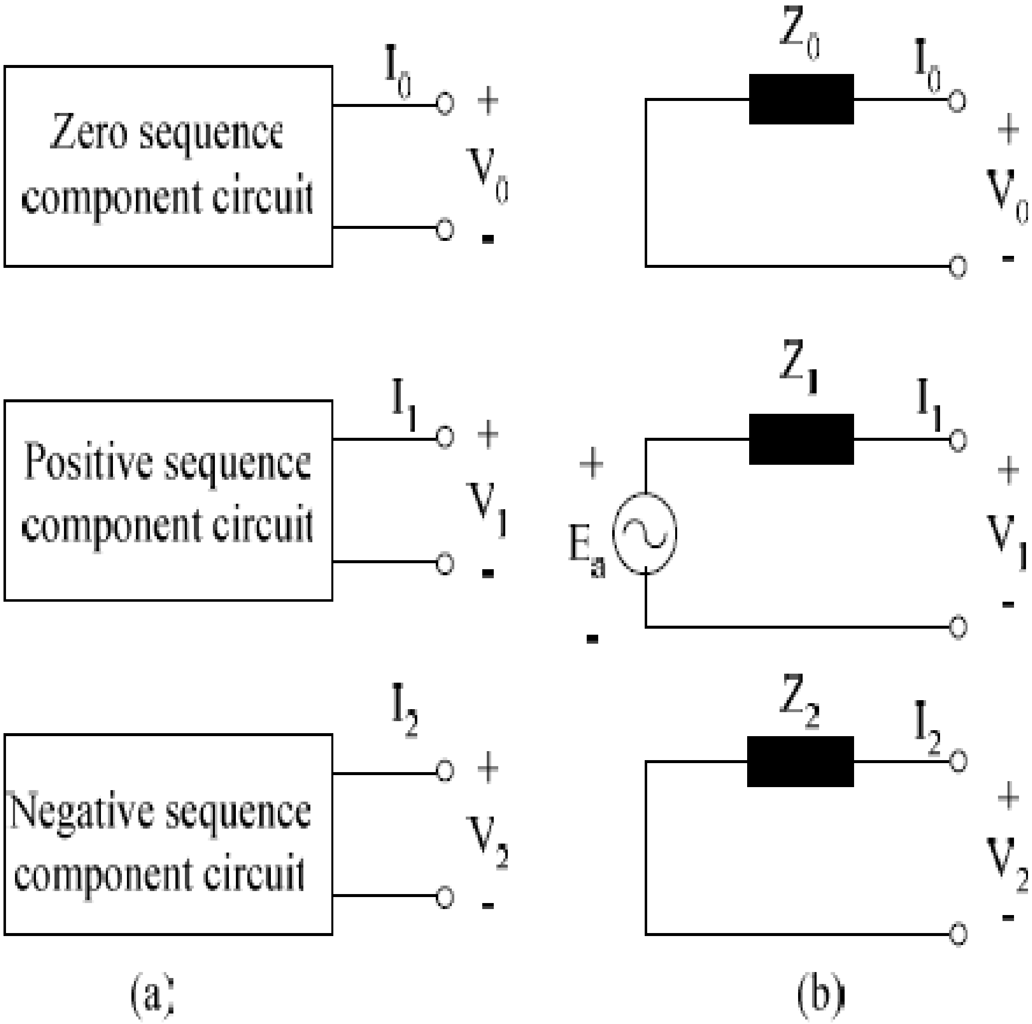

Figure 4: Symmetrical component circuits in three phase balanced system

IV. Results and Discussion

In order to evaluate the performance of proposed FFBP-ANN based model for fault prediction on the designed transmission line [5], simulated results were obtained from the modeled 132 KV double transmission line. 81 input-output training patterns were used for training the proposed 3-20-3 ANN structure with the following learning parameters: performance goal (Mean Square Error (MSE)) = 0.00771454, learning rate = 0.05 and maximum number of epochs = 21. The learning characteristic of proposed MLFFBP-ANN based model is shown in Fig. 5.

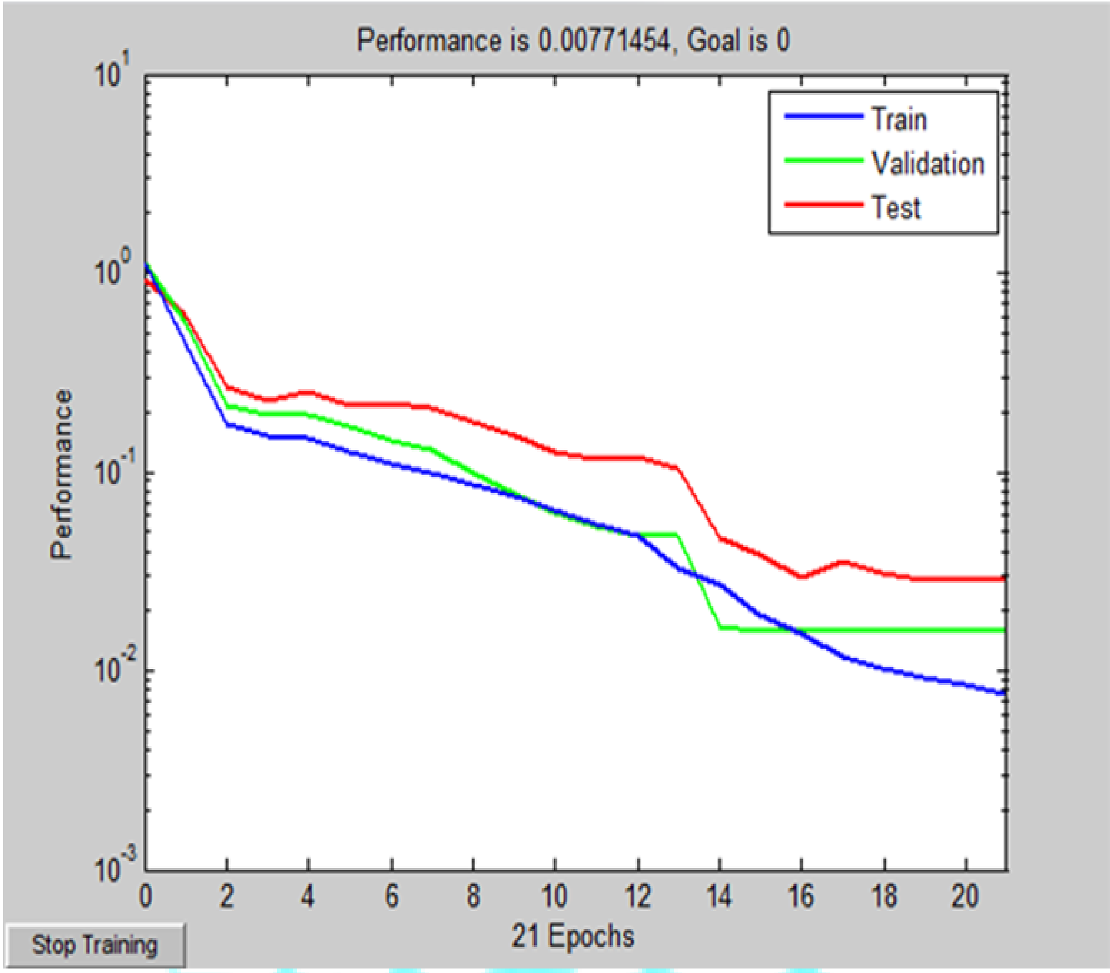

Figure 5: Learning Characteristic of FFBP-ANN

It has been observed that total number of 21 epochs was needed to reduce MSE level to as low a value as 0.00771454. Achievement of such a low value of performance goal (MSE) indicates that trained ANN model is an accurate model for predicting three phases to ground fault on the transmission line.

4.1 Regression Analysis of output and Targets

The regression analysis of ANN is shown in Fig. 6 for the training output versus target, validation output versus target and test output versus target in which their regression data were expected to be less than one or equal to one for accurate fault current input. In this study, the regression analysis is equal to 0.9627 (96.27%) for Training outputs versus Targets, 0.89988 (89.99%) for Validation outputs versus Targets, 0.9823 (98.23%) for Test outputs versus Targets which indicate the accurate results for the proposed ANN network.

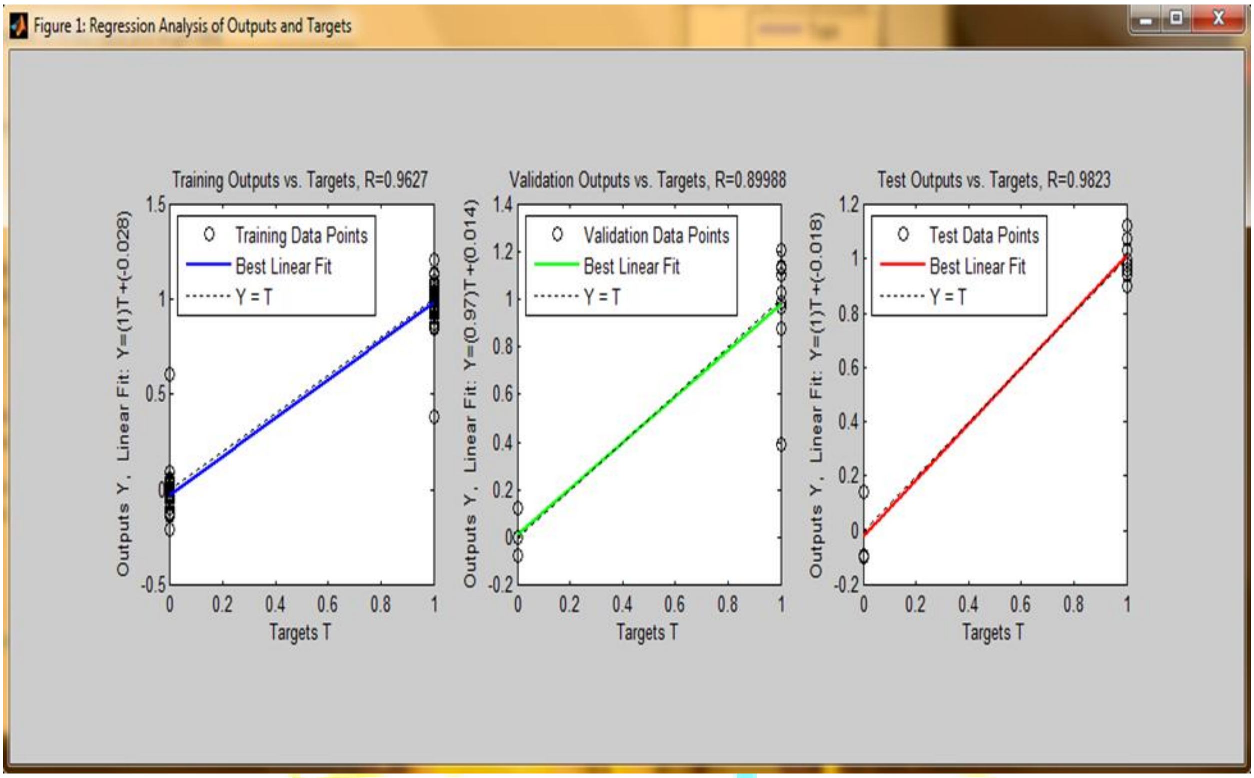

Figure 6: Training State of ANN

V. Conclusion

This study was conducted to analyze three-phase to ground fault on 132 kV double transmission lines span across 100km range. The fault was simulated at different distances from the proposed transmission line model and data were obtained for the Artificial Neural Network. The result of the analysis shows that the ANN has low mean square error of 0.00771454, learning rate=0.05 and maximum number of epochs = 21. The regression result indicated for the proposed ANN network shows the level accuracy of 95% higher. The design and simulation of the faults was done successfully using Sim Power Systems Toolbox in MATLAB Software. This technique is fast, cheap and reliable and can help the Nigerian power sector in quickly predicting faults thereby lowering the down time in the power sector

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