Fault Detection Method based on Artificial Neural Network for 330kV Nigerian Transmission Line

Alhassan Musa Oruma[1]
[1]University of Greenwich,
London-United Kingdom

Ismaila Mahmud[2]
[2]Department of Electrical Engineering, Ahmadu Bello University, Zaria-Nigeria

Umar Alhaji Adamu[3]
[3]Department of Renewable Energy, Niger-Delta Power Holding Company, Abuja-Nigeria

Simon Yakubu Wakawa[4]
[4]Department of Electrical/Electronic Engineering Nile University, Abuja-Nigeria

Gambo Idris[5]
[5]Ministry of Industry, Trade and Investment,
Lagos-Nigeria

Mahmud Mustapha[6]
[6]Department of Electrical/Electronic Engineering, Nuhu Bamalli Polytechnic Zaria

Abstract:- This research focused on identifying various types of faults occurring on 330kV transmission lines through the use of artificial neural networks (ANN). A MATLAB model for the Gwagwalada-Katampe 330kV transmission line in Nigeria was implemented to generate fault datasets. Voltage and current fault parameters were utilized to train and simulate the ANN network architecture selected for each stage of fault detection. Four types of faults were considered, along with a fifth condition representing no fault. The results illustrated the success of the developed model in identifying various fault conditions and system parameters on the Gwagwalada-Katampe 330kV transmission line, modelled using MATLAB Simulink.

Keywords:- *Fault Detection, Transmission Line, Artificial Neural Network.*

I. INTRODUCTION

Due to the complex nature of electrical power system, transmission line networks are always prone to faults and breakdowns. The need to ensure smooth operation of the electrical power system networks require early detection of faults and prompt response especially when there is failure of the protective devices [1]. Failure in power system is usually identified through the use of protective devices that have the sole purpose of detecting and clearing such abnormal conditions. Circuit breaker, relay and transformers are among the equipment used as protective devices. A robust failure detection system will guarantee a stable operation of the transmission line network [2]. The rapid growth of the Nigerian population means that there will be a rise on the demand of electricity and in turn will have a dare consequences on the existing Nigerian transmission network. In Nigeria, the generation side and the consumer sides of power system network are connected first by the 330 kV transmission networks throughout the country. This shows the importance of the 330kV transmission line network 3. Electromechanical relays are the major distance protective device used in the Nigerian power system network. However, settings of the network, nature of the faults do affect the performance of the distance relays. With the advent of artificial intelligence (AI) that adapt to dynamic changes of the system conditions, it is possible to have a system that response to this changes effectively. Fuzzy logic systems (FLS) and artificial neural network (ANN) are among the AI techniques used in power industries [3].

In this study, ANN would be used in identifying the faults of 330kV transmission line due its characteristic of being like black box in nature which does not necessarily require prior knowledge of event to execute tasks. With this advantage, the use of ANN will ensure smooth operation of power system supply and a quick response in the case of any developed faults.

Detecting faults on transmission lines is crucial for the effective operation and control of power systems. This identification process serves a vital role in ensuring the health of the power system and contributes significantly to the safety of power system operations.

II. LITERATURE REVIEW

There have been several research studies focused on the identification and location of faults in transmission line networks. The following are summaries of some of the reviews conducted:

Various methods have been employed in identifying transmission line faults, with the prevalent use of Artificial Intelligence. High speed and great accuracy remains the outstanding feature of these methods. One prominent artificial intelligence system is the Artificial Neural Network (ANN), applied in transmission line faults identification and isolation [4].

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[5] Conducted an investigation of transmission line protective structure with distance relay as the protective element using MATLAB/SIMULINK. The study involved digitally computing impedance through symmetrical components of three-phase currents and voltages measured locally. The findings highlighted that the impedance of the faulty line [1] decreased to approximately zero, while the impedance of the remaining healthy lines (Lines B and C) maintained at 103 Ω. Specifically, the impedance of the faulty line A dropped from 91Ω to 38 Ω due to the fault, while the impedance of lines B and C remained unchanged. However, distance covered timeframe are not being considered in the study.

[6] Investigated the use of discrete wavelet and ANN in transmission line faults identification and classification. The study shows the proposed technique yielded a satisfactory results using MATLAB software. However, complex transmission line protection scenarios where not considered in the study.

[7] Employed back-propagation ANN structure in fault diagnostic system, the results show high impedance fault identified correctly as compared to other methods. However, the study did not provide information regarding the specific time interval in achieving the accuracy of the system goal.

[8] Proposed an intelligent system that will identified fault for a 33-kV Nigerian transmission line, utilizing an ANN. The simulation results showed the developed system effectively identified and classified faults on the lines. Mean square error (MSE) and confusion matrix were used as the evaluation matrix, with the result indicating great accuracy of 95.7% and 0.00004279 as the MSE. Though, the results show the developed technique to have a satisfactory performance on the Nigerian transmission line, it did not include information about the time of occurrence for fault classification.

[9] Used the hybrid form of adaptive neuro-fuzzy inference system (ANFIS) with discrete wavelet transform (DWF) in detecting, classifying and locating faults on a 132kV transmission line. The simulation results of the employed system was able to successfully differentiated normal condition from the faults within the timeframe stipulated after the faults inception. However, the study did not provide information about the faults at different phases of the fault condition.

[4] Examined faults on 132kV transmission line from Enugu - Otukpo – Yandev in the southeast part of Nigeria using ANN as the fault intelligent system. Three line – ground, three lines – lines, three double lines – ground and one three phase fault were the faults considered in the study. Regression analysis was used as the performance index and the graphs indicate the convergence of the expected result to the target output. However, the time at which the fault occur was not included in the study.

[10] Proposed a hybrid system of S-transform (ST) and ANN to conduct identifying, classifying, and locating a fault on an overhead transmission line. ST perform the extraction of features used in training the ANN. The results show effective faults classification and noise effect on voltage and current parameters were taken into consideration. However, other fault conditions were not considered in the study.

III. METHODOLOGY

The Gwagwalada-Katampe 330kV transmission line is considered in this study due to availability of data. The system consists of one generator output 16kV, step up transformer output 330KV. Other parameters are: frequency of 50Hz, real power of 171.48MW, reactive power of 41.84MVAR, apparent power of 176.5MVA, line voltage of 330kV, and line distance of 280km. MATLAB/Simulink was used to model the transmission line as shown in Fig. 1.

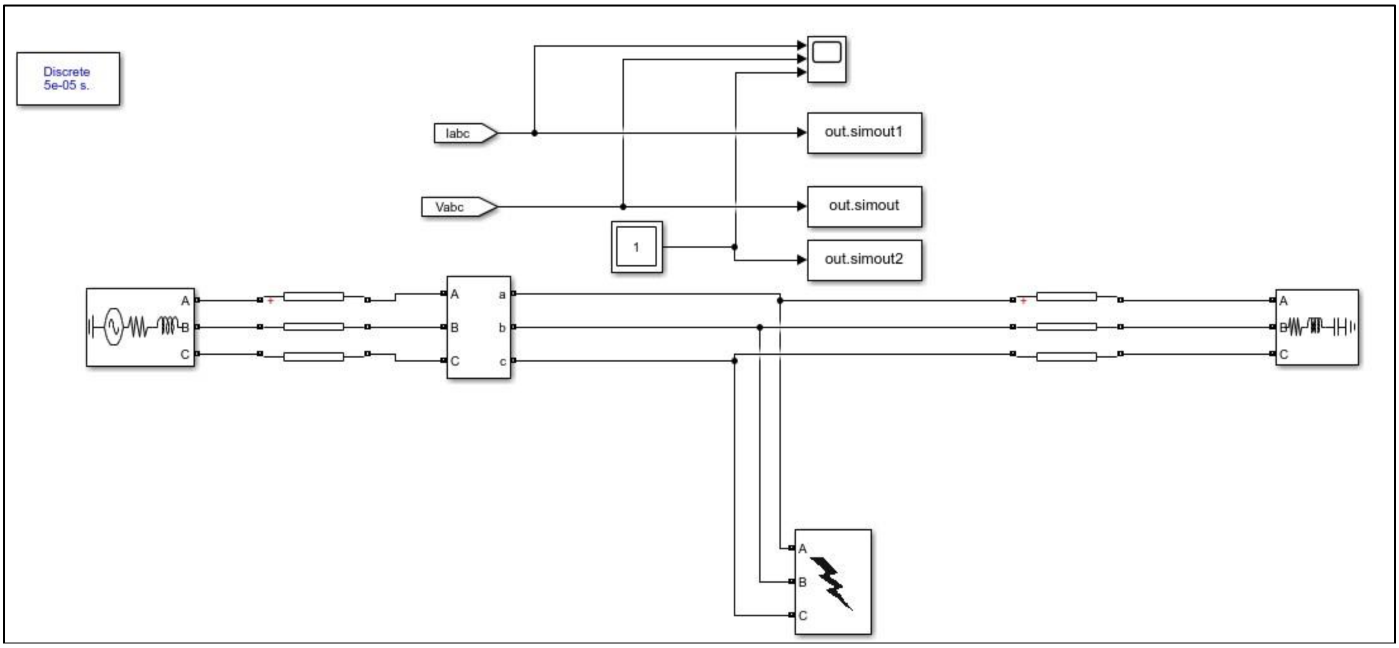

Fig 1 Gwagwalada – Katampe 330kV Transmission Line Matlab/Simulink Model

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Four fault scenarios where generated from the Matlab/Simulink model with the addition of no fault condition. The four fault conditions are single line – ground (SLG) fault, double line – ground (DGL) fault, line – line fault and three phase fault. For each condition, 800 data ponits of three phase voltages and currents making overall of 5 x 4,000 datasets.

➢ *Artificial Neural Network*

An Artificial Neural Network (ANN) is a highly parallel distributed processor composed of processing units capable of storing experiential knowledge and making it accessible for use. Similar to the functional behavior of the human brain, the network receives input signals, and internal processing occurs through the activation of neurons, resulting in output signals [11]. An ANN consists of a massively parallel distributed processing system comprising interconnected neural computing elements known as "Neurons," which possess the ability to learn and acquire knowledge.

The basic processing unit of an ANN is the neuron, and neurons are interconnected by links. Each neuron receives inputs, which are modified by 'weights.' The synaptic weights either strengthen or weaken the processed signal, and to generate the final output, the sum of the weighted outputs is passed through a non-linear filter known as the "activation function." This process includes a threshold value called 'bias,' which influences the release of the output. Figure 2 illustrates the structural nature of an artificial neural network, incorporating input signals, input layers, hidden layers, and the output layer.

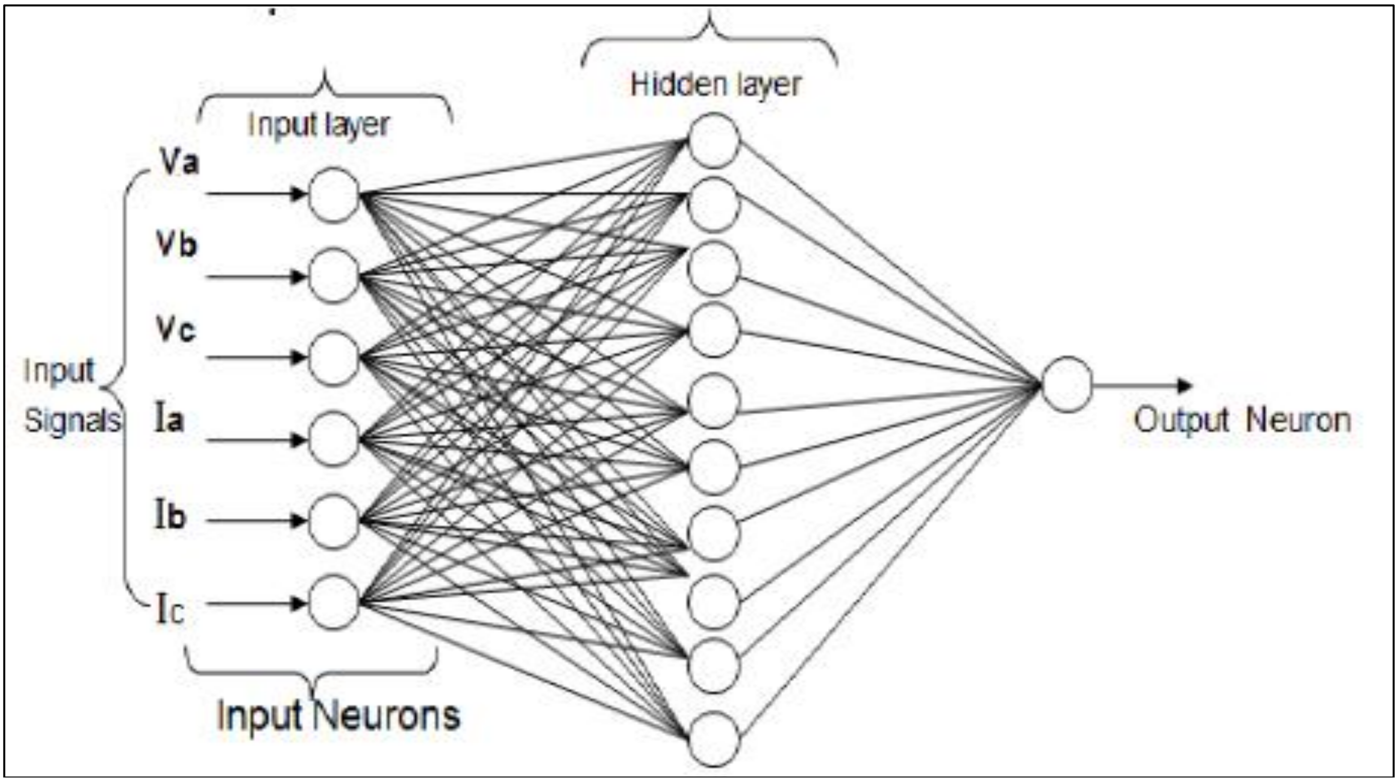

Fig 2 Structure of Artificial Neural Network

In this study, we adopted the train/test/validation split model evaluation procedure to assess the model's generalization to out-of-sample data. Evaluation metrics commonly used in the literature, such as the correlation coefficient (R) and mean square error (MSE), were employed to quantify the performance of the regression model. For the classification model, accuracy and the confusion matrix were utilized as evaluation metrics. The experiment involved a split of 70% for the training set, 15% for the test set, and 15% for the validation set.

IV. RESULTS AND DISCUSSIONS

The fault detection was implemented using the Levenberg-Marquardt method for the neural network architecture. The output of the neural network corresponds to the five classes of faults mentioned earlier. Specifically, single line-to-ground fault, double line–ground fault, line–line fault, three-phase fault, and no fault are labeled as 1, 2, 3, 4, and 5, respectively. Figure 3 illustrates the neural network architecture for both the regression model and the classification model.

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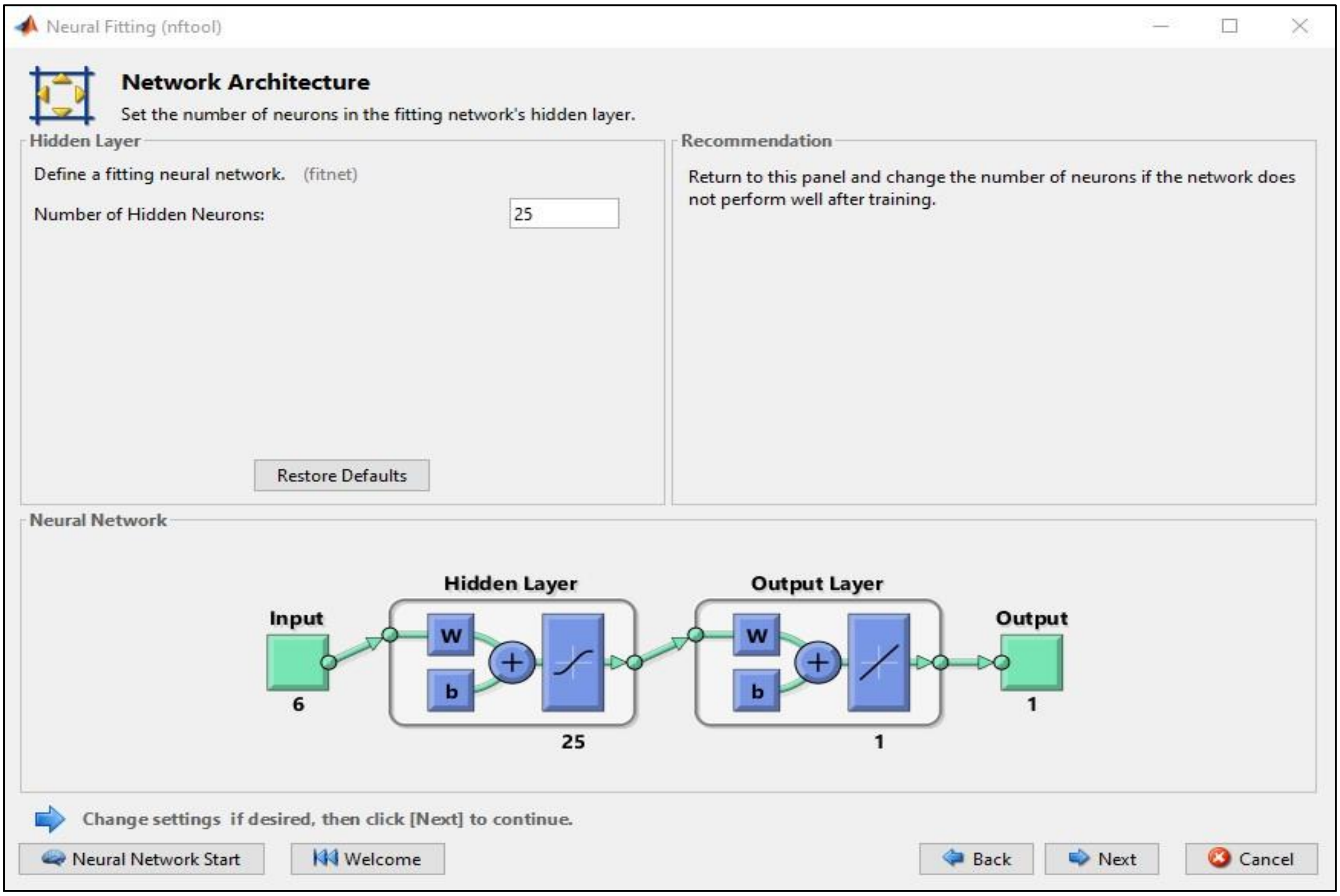

Fig 3 Neural Network Architecture for the Regression Model

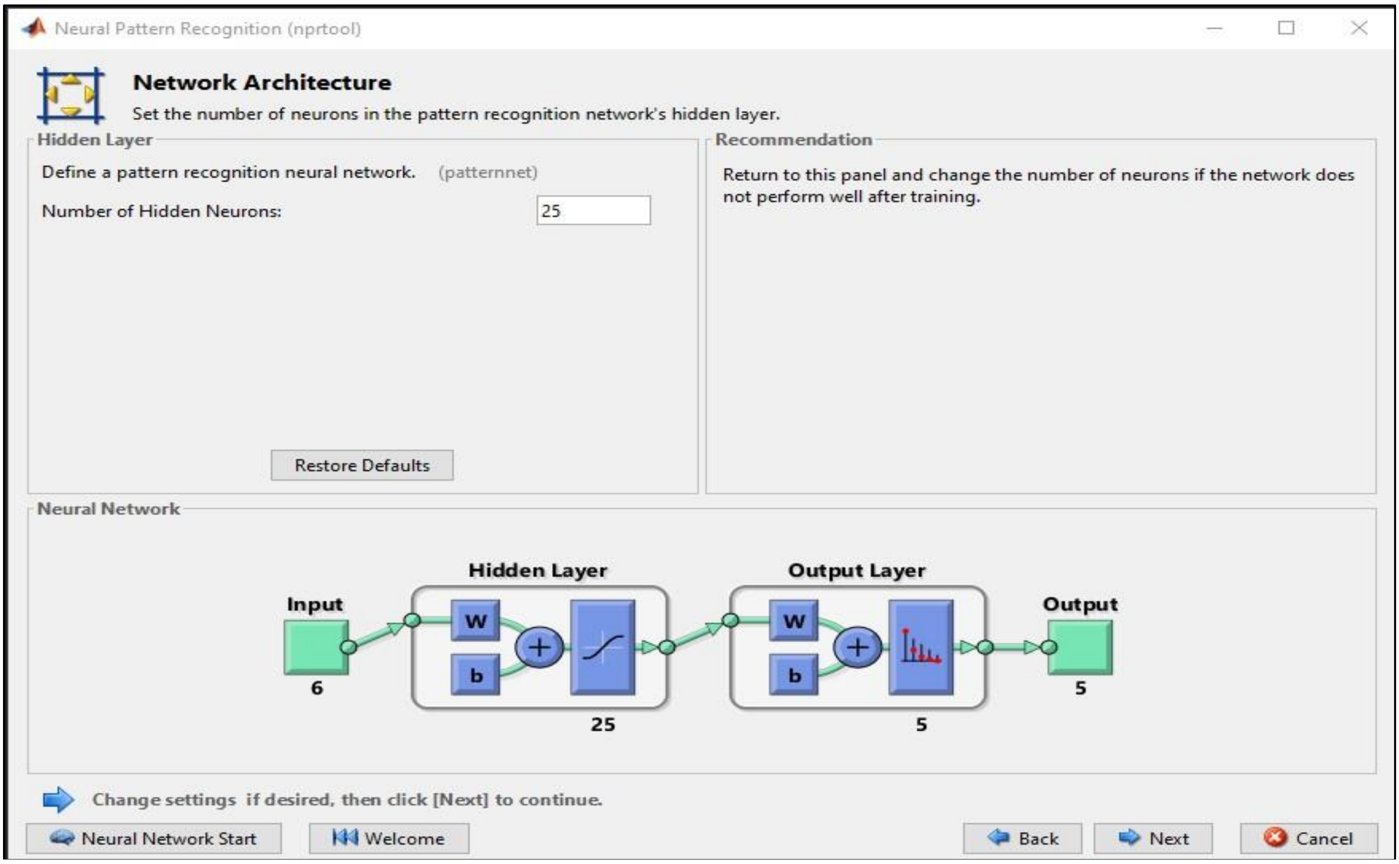

Fig 4 Neural Network Architecture for the Classification Model

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The performance graphs illustrate the effectiveness of the neural network during the training process. Figure 5 represents the performance graph for the regression model, and Figure 6 corresponds to the classification model. As depicted in the figures, the best validation was achieved with a mean square error value of 0.058158 at 183 epochs for the regression model. Similarly, for the classification model, the best validation occurred at 0.011201 cross-entropy error value at 155 epochs.

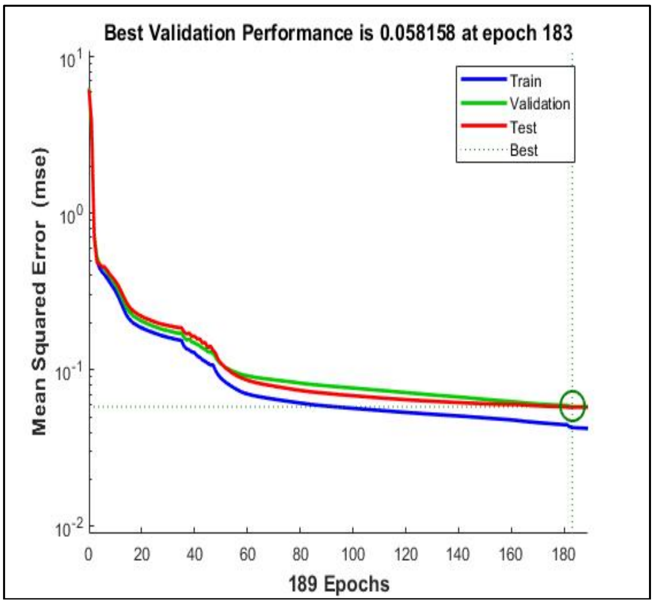

Fig 5 Performance Graph for the Regression

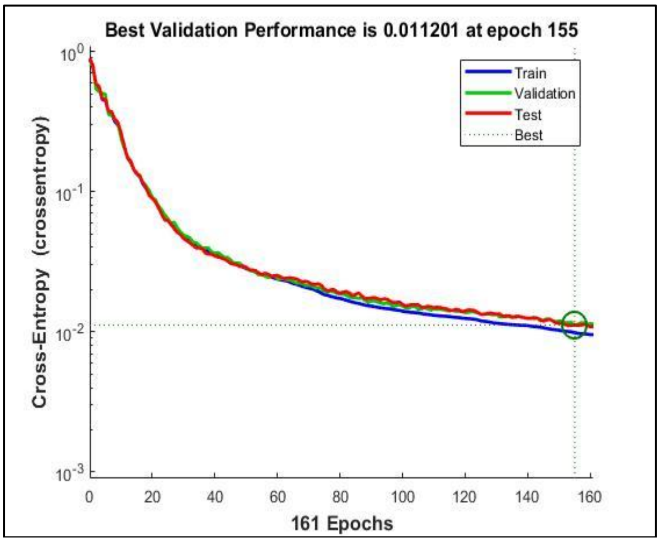

Fig 6 Performance Graph for the Classification

The correlation coefficient (r) serves as a metric to assess how effectively the neural network's objectives can track variations in outputs, with 0 indicating no correlation and 1 indicating total correlation. In this study, the correlation coefficient was found to be 0.98811, signifying a strong connection between the targets and the outputs. This is further illustrated by Figure 7. Additionally, for the classification model, the correctness of the classes for the trained neural network was evaluated using the plot of confusion matrices, providing insights into the model's performance in classifying different fault categories.

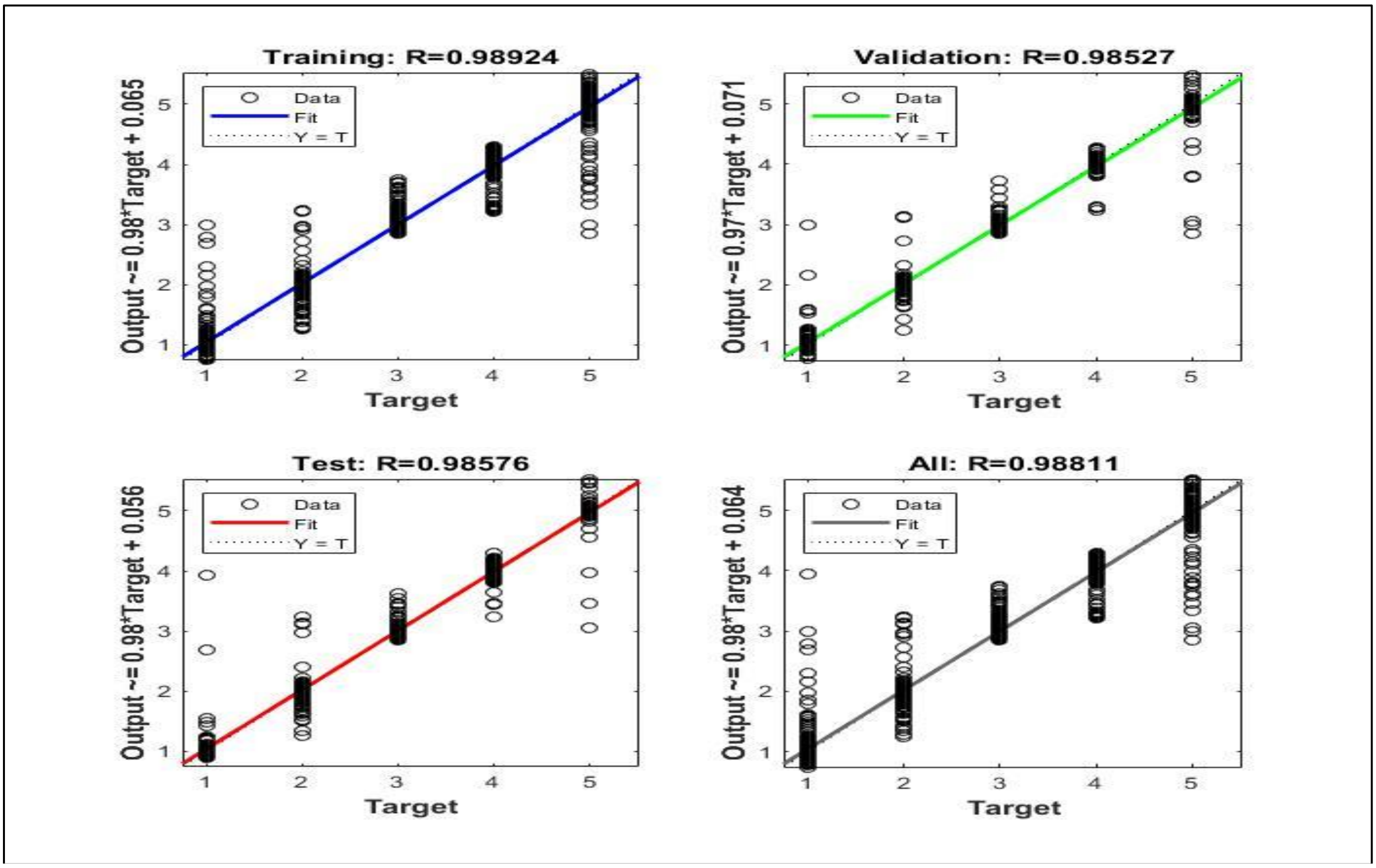

Fig 7 Regression Plots for ANN

Figure 8 illustrates the efficiency of the trained neural network in determining the type of fault, achieving an accuracy of 98.5%. This conclusion indicates that the neural network demonstrates a high level of proficiency in distinguishing between all four types of transmission line defects and recognizing a fault-free condition.

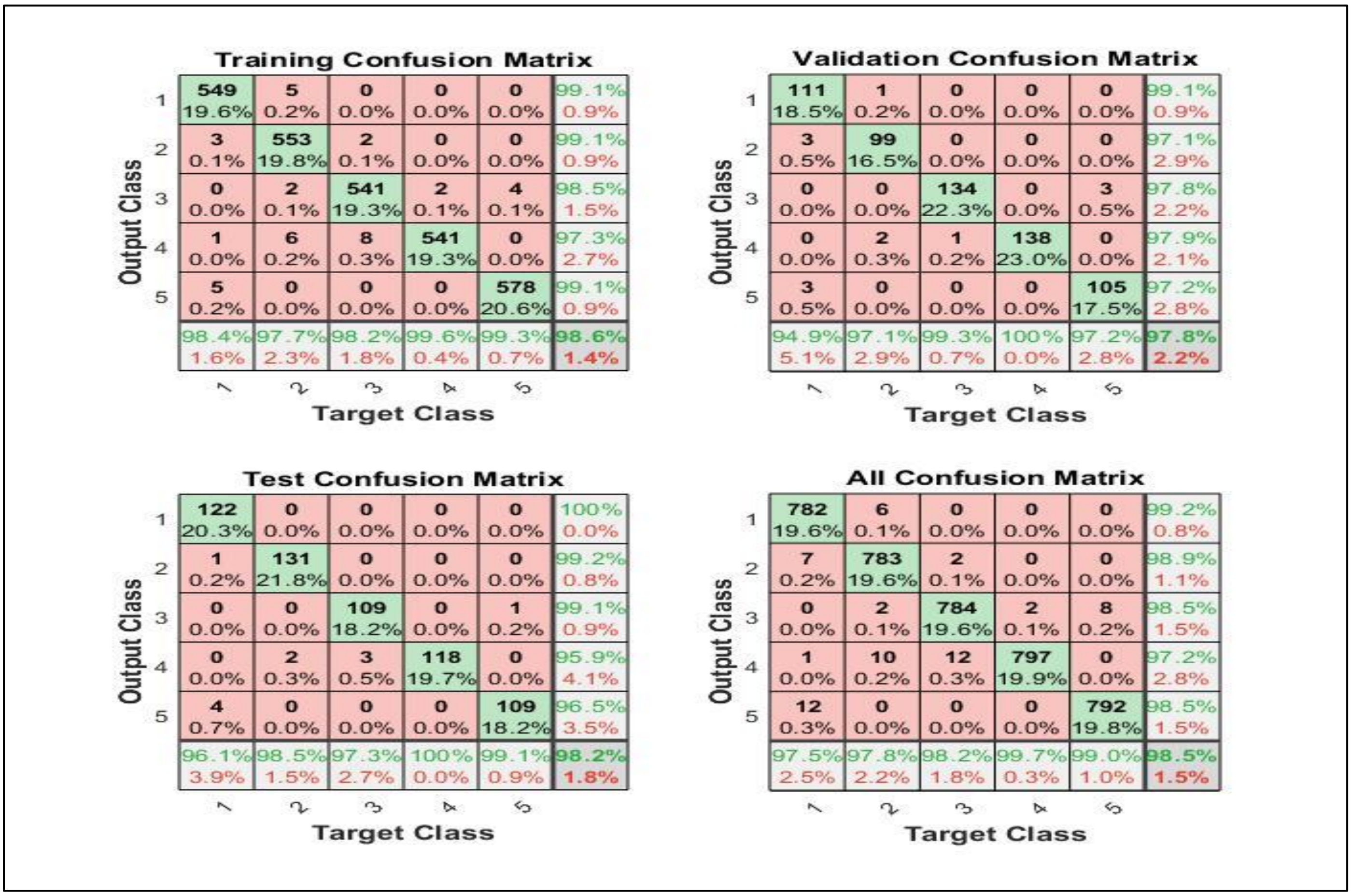

Fig 8 Confusion Matrix of the ANN Performance

V. CONCLUSION

In this paper, the application of an artificial neural network was explored for the detection of transmission line faults. Four types of faults were considered, along with a fifth condition representing no fault. The developed model utilized three-phase currents and voltages as input signals. The results demonstrated the success of the developed model in identifying various types of fault conditions, as well as system parameters, on the Gwagwalada-Katampe 330kV transmission line, modeled using MATLAB Simulink.

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