A Comparative Study of Artificial Neural Networks for Fault Detection and Location in Mixed Transmission Lines: a Matlab Vs. Python Vs.R Analysis

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A Comparative Study of Artificial Neural Networks for Fault Detection and Location in Mixed Transmission Lines: A Matlab vs. Python vs.R Analysis

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Abstract

Artificial neural networks (ANNs) have been increasingly used for fault detection and location in mixed transmission lines. However, the performance of ANNs for this application may vary depending on several factors, including the choice of programming language. In this study, we conduct a comparative analysis of the accuracy of ANNs developed in Matlab Python AND R for detecting fault type and location in mixed transmission lines. We explore various factors that may affect the performance of ANNs, including the quality of training data, neural network architecture, selection of hyperparameters, and optimization algorithm used for training. We compare the accuracy of ANNs developed in Matlab and Python and analyze the advantages and limitations of each language for this application. Our findings suggest that Matlab, Python AND R can be used effectively for developing ANNs for fault detection and location in mixed transmission lines, with each language offering specific advantages and limitations. This study provides insights into the use of ANNs for fault detection and location in mixed transmission lines and offers guidance on the choice of programming language for this application.

Keywords - Neural Network, Python, Matlab, 132 Kv, Keras, Tensorflow, Fault, Dplyr, Pandas, R

1. Introduction-

Transmission lines are becoming more susceptible as transients in electrical power quality are increasing. Power engineers are always concerned with detecting faults in transmission lines. There are various methods for this purpose, such as single-end and double-end traveling-wave methods that determine the fault by velocity and arriving time of traveling-waves [1], but these methods have drawbacks such as traveling-wave dispersion and problems identifying fault near end lines or buses. In India, SCADA system is used in substations above 400 kV and generating plants to gather more information about transients. For data collection, the

SCADA system employs fault-passing devices at a remote location. These employ an upstream or downstream fault algorithm to determine precise fault locations [2]. Peter Mbamaluikem uses Artificial neural networks to design a fault identification system for identification and classification on a 33-kV Nigeria electric transmission line. The developed system feeds preprocessed instantaneous voltage and current values sampled at a frequency of 1.5 kHz into the ANN [3]. Ahmed Elnozahy proposes a fault classifier/locator based on a multilayer perceptron feed forward neural network with a back propagation algorithm for classifying and locating faults in power system transmission lines. It classifies and locates faults based on the magnitude of the fundamental frequency [4]. MATLAB is well-known in the field of electrical engineering, and much research has been done in it for fault classification and location in transmission lines [5-7] using the concepts of Discrete Fourier Transform and Wavelet Transforms. Data is extracted from a transmission line and passed through an anti-aliasing filter before sampling, than fundamenatal voltages and current are extracted for further processing. Comparisons of various machine learning techniques such as SVM, LR, KNN, and CN2 have also been proposed [8]. Herald Kundaeli proposed using IoT (internet of things) to build a recurrent neural network [9]. Prateem Pan proposed a CNN for fault detection in microgrids, but MATLAB has the disadvantage of being an interpreted language as well as being expensive.

All fault classification research has been done in MATLAB, using Feedforward and Backpropagation neural networks. The primary goal of this article is to compare and create a different type of neural network using different programming languages.

2. Material and methods

2.1 Material

The MATLAB/SIMULINK model is proposed of 33kV, 20km mixed transmission line. As shown in figure 1, the system is made up of two sections one for underground cable and other for overhead transmission line, each section having length of 10 km. Three-phase fault block is used for fault generation. The cable is simulated using 20 sq. mm a three-core copper cable with a screen (pi-model), and cable parameters are taken into account and can be calculated in MATLAB using the power cableparam command.

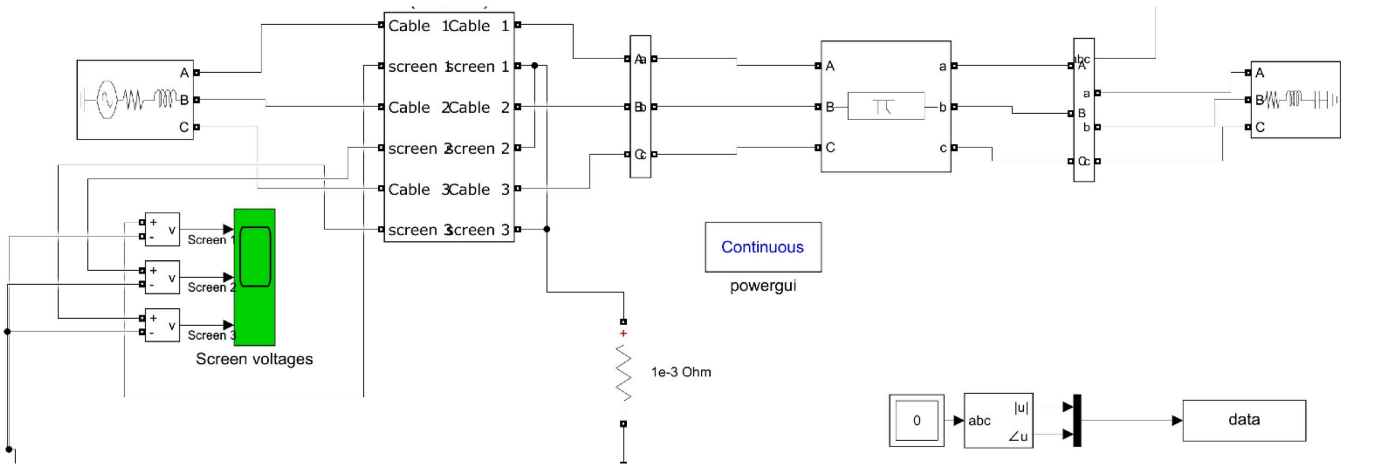


Figure 1 Mixed underground and overhead transmission line

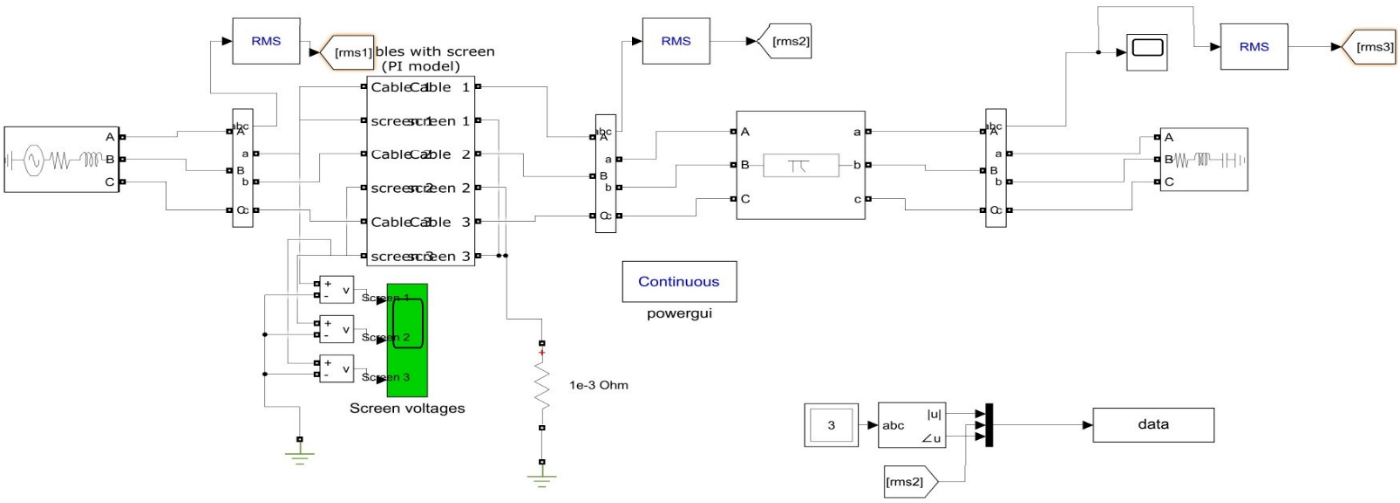


Figure 2 Additional measurement for data collection in mixed line

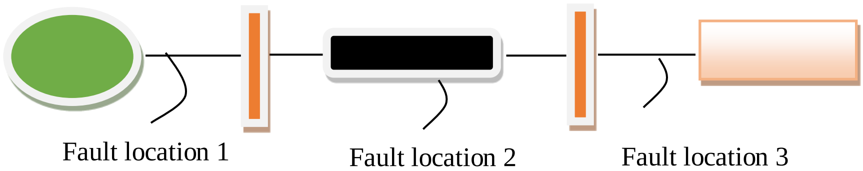


Figure 3 (A) Representation of fault: near generator, in cable, in overhead line

2.2 Data Generation-

Discussed line is simulated in simulink and fault voltage is measured using fault block and measurements are updated in multimeter block. Using the sequence analyzer block, the zeorth, positive, and negative sequences with their phase angles of the faulted voltage are extracted. The line is divided into three sections: before the cable or near the generator, underground cable, and overhead line connected to the load. By simulating various types of faults and varying fault resistance, faulty data is gathered from these sections.

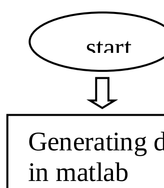


Figure 3 (B) Steps taken for collection of data from simulated line

3. Results

3.1 Fault classification

For fault classification, 5686 samples were created. Neural network consists of 6 inputs which are magnitude and phase angle of sequences of faulted voltage and target data is various type of faults. A, A-B, A-C, A-B-G, A-C-G, A-B-C-G, A-B-C lines fault are given to transmission line for gathering of data. The ANN performance plot and regression plot are shown in figure 4. All of the data gathered is only in the time domain. Data is not subjected to any further conversion.

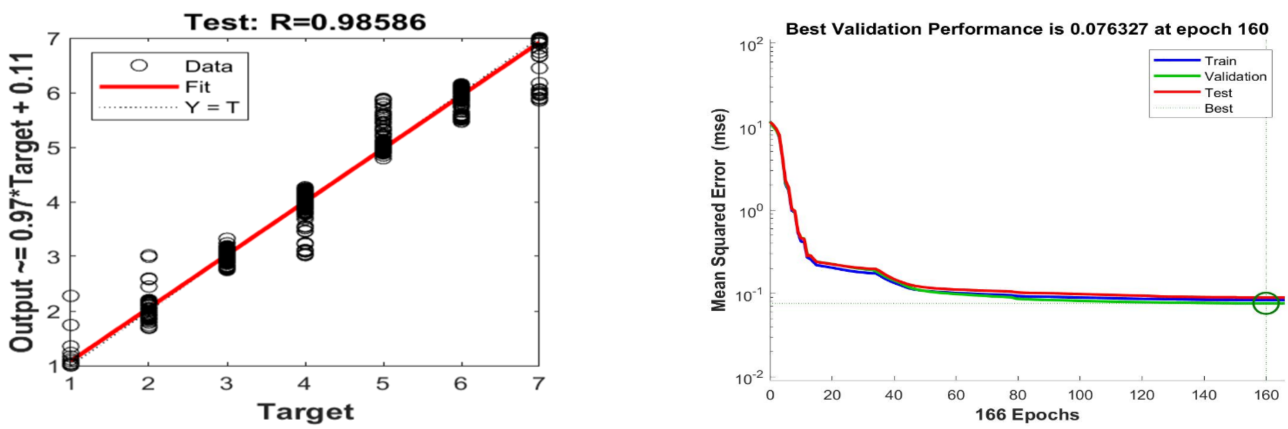


Figure 4 (A) Regression curve for fault classification (B) Performance curve of neural network for fault classification

3.2 Fault location

3.2.1 Feed forward propagation neural network

For fault location first 4026 samples were gathered by simulating line described in fig2.1. To determine the location of the fault, faults were assigned near the generator, in the cable, and in the overhead transmission line. The magnitude and phase angle of the faulted voltage were used as inputs, and the target data was the location of the fault.

PROBLEM OBSERVED-

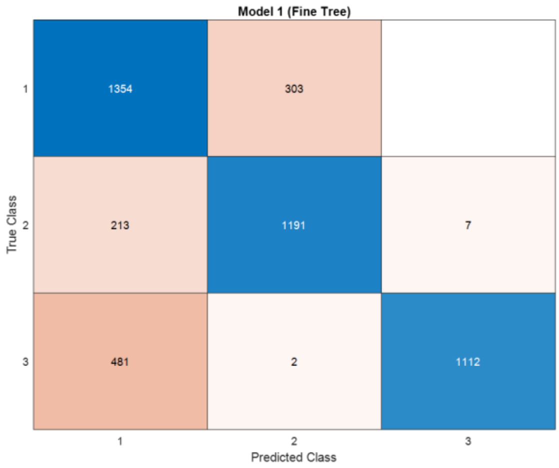


Figure 5 Confusion matrix of classifier for fault location

It is clear from the figure 5 that a fault has been detected, but the neural network is having difficulty determining the location between 1 and 2. To address this issue, an additional measurement is calibrated in line using the rms block(fig 2.2). The number of fault location samples was also increased from 4062 to 10,002 by changing fault resistance. The data is preprocessed by removing all duplicates and rescaling it. Now, the neural network has 9 inputs obtained from the sequence analyzer block and the rms block, which are combined and saved in a single file. As shown in the figure3.4, the results are encouraging with these additional measurements, and the fault can now be easily located. The Artificial Neural Network is then trained using two hidden layer with 10 and 20 neurons and purelin as the activation function, and one output layer that shows the type of a fault with tangish as the activation function. The ann performance plot is shown in figure 6.

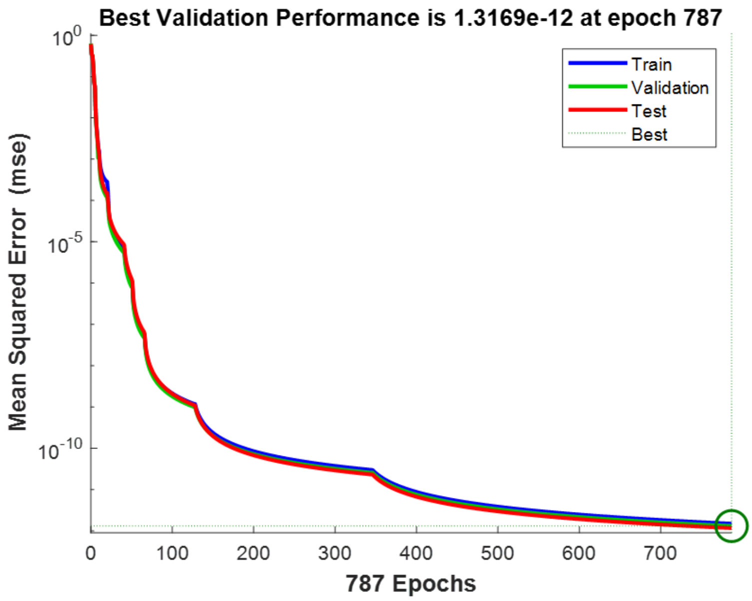


Figure 6 Performance curve of ann for fault location

3.2.2 Resilient back propagation neural network

The data is accessed in Google Collab via Google Drive. The same data was previously used in developing a feed forward propagation network with 9 input data and a target data as the location of the fault. This network is different from previous one beause in order to obtain weights, this network does not use the magnitude of the gradient but rather its signs. Keras library is utilized in developing of neural network. A neural network with 90% accuracy is developed for fault detection in mixed transmission line. The network is trained using two hidden layers, one input layer and one output layer, with activation functions tanh, relu, relu, tanh, and Rsprop as optimizers. The ann accurracy graph and tabular form of ann are shown in figure 7.

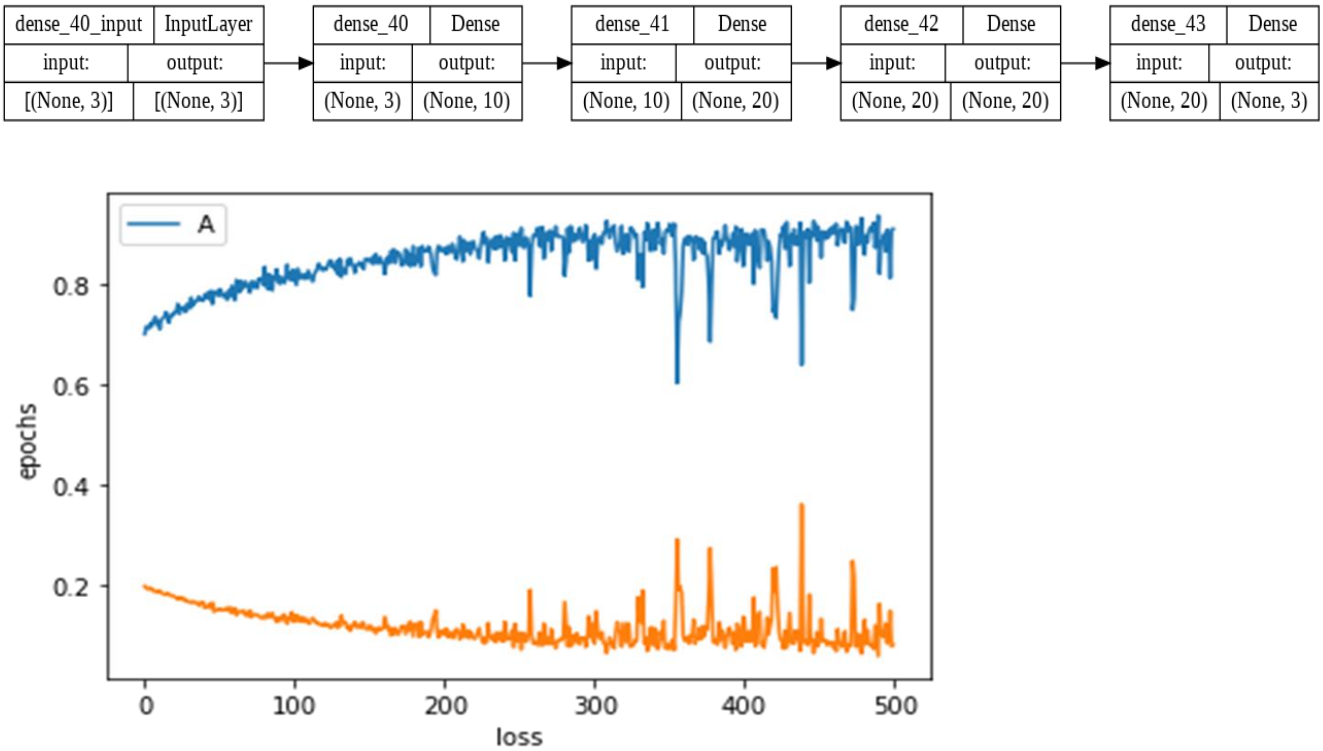


Figure 7 (A) Tabular form of ann (B) Accuracy graph

3.2.3 Multi layer neural network

In rstudio, a data set is accessed and a multilayer neuron is created. The data is the same as that used previously for developing another network, which has nine inputs and one target data. Data is separated for training and testing. 6,000 samples were used for training, while 4,000 were used for testing. As the impact of one variable can affect the accuracy of a neural network, data is resclaed using the normalisation technique. A neural network in figure 8, is built to detect the location of a fault by taking 5,31,831 steps.

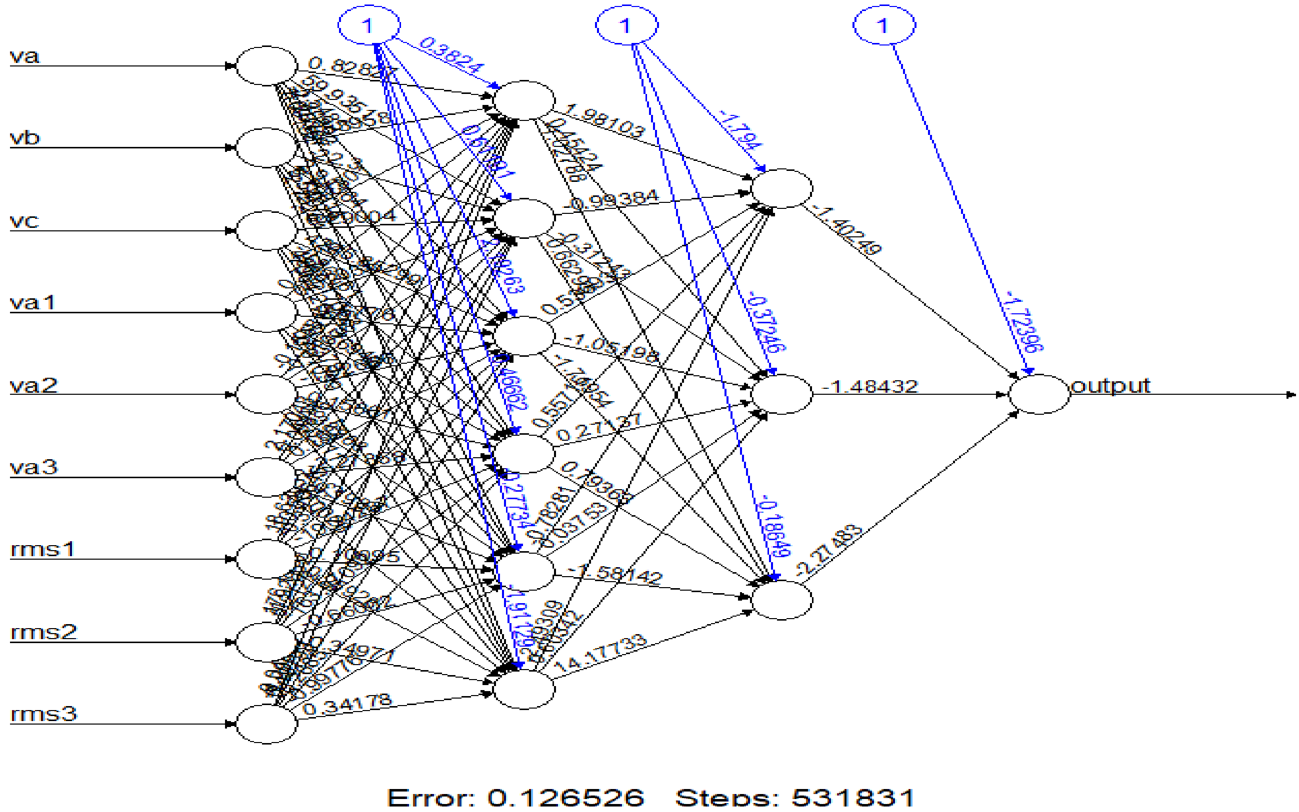


Figure 8 Multi layered neuron network in r studio for fault location

3.3 Regression-

Linear regression is performed on data using various libraries in various programming languages. For linear regression, matlab's regression learner, Python's scikit-learn library and lm()function of r are used .

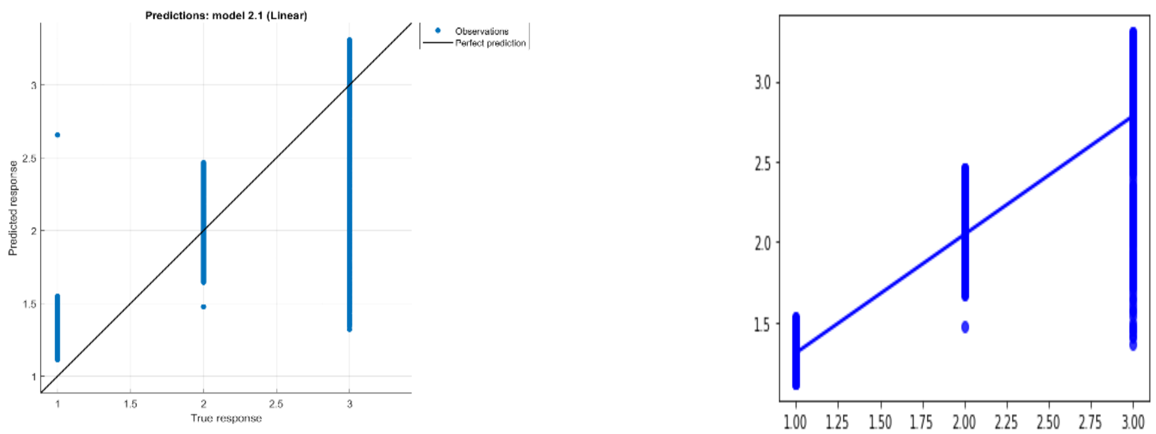


Figure 9 (A) Linear regression in Matlab (B) Linear regression in Python

The summary of linear model generated in R language: Residual standard error: 0.3475 on 9990 degrees of freedom, Multiple R-squared: 0.7446, Adjusted R-squared: 0.7444, F-statistic: 3236 on 9 and 9990 DF, p-value: < 2.2e-16

The output is the same in all libraries, with an R-square of 0.74. The fine tree model is best for regression, with an R-square of 1.

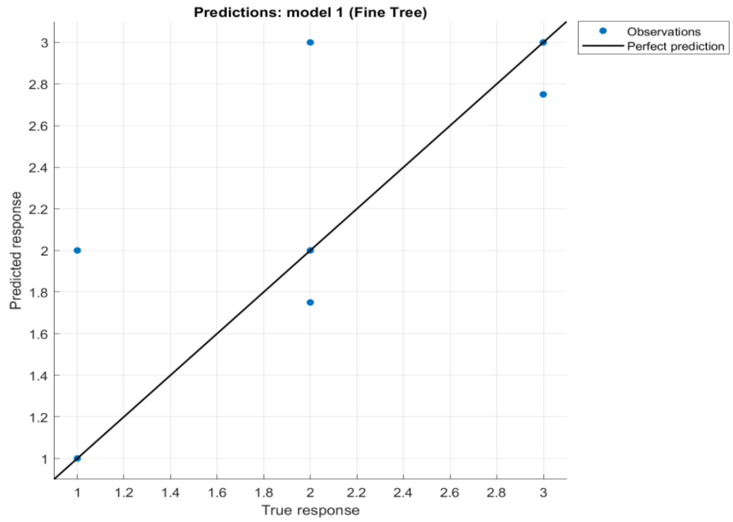
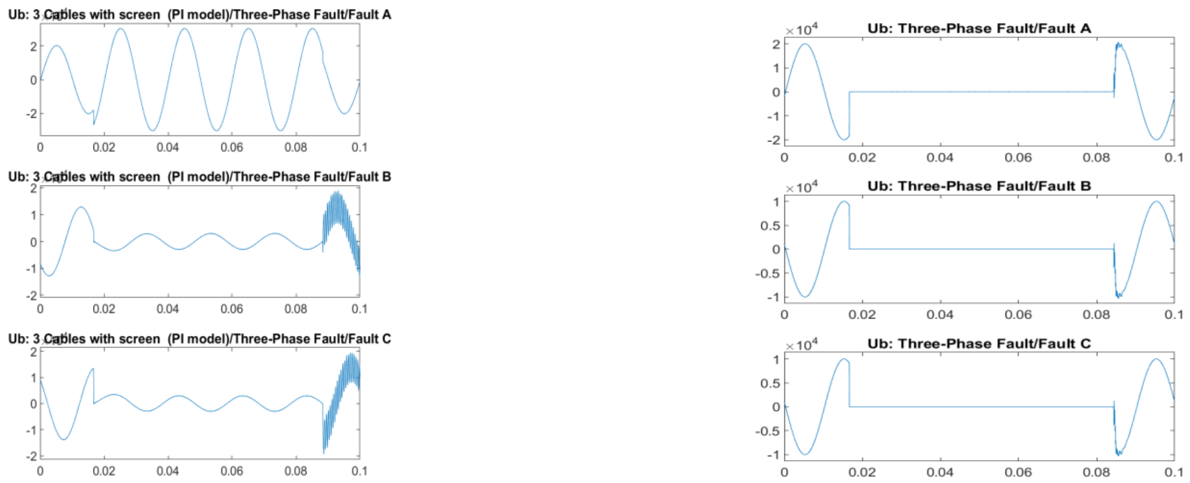


Figure 10 Fine tree regression model

3.4 Testing



l**Figure 11** Phase voltages during (A) b-c fault (B) a-b-c-g fault respectively

The ANN is tested using a separate set of data. Table 1 displays the ANN outputs as well as the real data. It demonstrates a very acceptable error . The feed forward propagation network and Multi layered network is used for testing. Figures 11 depict phase voltages during the b-c fault and the a-b-c-g fault, respectively, with table 1 displaying the predicted value of ann.

Actual output	Type of fault	Fault resistance	Predicted	Error
1	a	3	1	0
	b-c	8	1	0
	a-b-c-g	27	2	1
2	a-b	25	2.9998	-0.998
	b-c	10	2	0
	a-b-c-g	14	2	0
3	a-c	1	3	0
	a-b-c	28	2.7333	0.267
	a-b-c-g	22	3	0

Actual output	Type of fault	Fault resistance	Predicted	Error
1	a	3	1	0
	b-c	8	3.82967	-2.829
	a-b-c-g	27	3.8296511	-2.829
2	a-b	25	-3.8296511	5.8296511
	b-c	10	2	0
	a-b-c-g	14	2	0
3	a-c	1	3	0
	a-b-c	28	0.9999961	2.0000039
	a-b-c-g	22	0.9999961	2.0000039

Table 1 Actual result and predicted response from ann (A) Feedforward propagation (B) Multi layered network

4. Conclusion

In this paper, an Artificial Neural Network was used to detect faults and determine distances in a Mixed Underground Cable and Overhead Transmission Line. The Fundamental Positive sequence, Negative sequence, Zeroth sequence of voltages is measured in line had been used for fault detection and distance location. The results had been greatly improved with help of additional measurment. Each language has its own advantages, and they all provide good support for neural network training. Pandas, Keras, TensorFlow, Dplyr, neural net, nntool, Graphviz, NumPy, and Matplotlib are excellent libraries for data manipulation. The feed forward propagation neural network has a higher rate of accuracy in determining fault location. The fine tree model is best for regression and classification in detection of fault location.

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