

An Efficient Method of Fault Analysis using Artificial Neural Network

Vikash Kumar^{1,*}, Shashank Mishra²

Abstract

In the power system, there are many techniques to identify and classify the faults. So, it is utmost important to choose the suitable technique. In this paper, a novel technique based on ANN have been proposed. When abnormal conditions occur in the system, the purposed method identifies and classify the fault to protect the system from the faults and stop from the big hazards. Simulation of purposed Simulink model have been tested for the system. The current waveforms are used to identify and classify the fault by using ANN in the MATLAB software. The different types of symmetrical and unsymmetrical faults such as single line to ground fault, line to line fault, double line to ground fault and three phase faults are identified and classified with the proposed model. The identification, validation of faults, check and regression plot and classification are done by the mean square error (performance), gradient and 'Mu' in the ANN. With the help of these parameters, identification and classification is performed.

Keywords: Simulink, Signal, Classification, ANN, Type of fault, Feed forward network, Mu, Feed Back network.

INTRODUCTION

Transmission and distribution system are the main components of power system. In the modern electrical power system, Transmission line carries a large amount of power in the system and distribution also carries bulk amount of power. But, Distribution system operate at lower voltage and transmission line operate at high (or extra high voltage) in the system which is more complex. Due to voltage regulation, chance of fault are increases and from this system are affected [1]. Reliability, security and delivered the power to the customer is the main purposed and due to that it is very important to identify the fault in the system and after that classified the fault due to that known about the type of fault [2]. When it is known about the type of fault then Clear the fault and restoring the power supply to improve the power quality the transmission and distribution line as quickly as possible. The vast majority of faults (over 90%) are of the single line to ground faults type. There are mainly 10 type of fault in the power system- Single line to ground faults (a-g, b-g, and c-g), Line to line faults (a-b, b-c and c-a), Double line to ground faults (a-b-g, b-c-g, and c-a-g) and 3 Phase faults (a-b-c) [3].

*Author for Correspondence

Vikash Kumar

¹Student, Department of Electrical Engineering, Bansal Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India

²Professor, Department of Electrical Engineering, Bansal Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India

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Symmetrical fault are also called three phase fault or balanced faults. They are the (L-L-L-G) or (L-L-L). Symmetrical fault occurs only 2-5% in the system. When symmetric fault are occurs in the system then damage the electrical equipment. These type of fault are occur when three phase touch each other with ground or without ground due to that these type of fault arises [4].

Unsymmetrical faults are occur in the several time. So, it can be said that these type of fault

occur in the system very common and it occurs more as compare to symmetric type of fault. Unsymmetrical fault has three type of fault namely–Single line to ground (L-G), double line to ground (LL-G) faults and line to line (L-L). SLG faults are occur very common and it occurs 65-70% in the power system. These type of fault arises when one phase conductor touch with the ground. Double line to ground faults are occur only in 15-20% in the power system. These type of fault occurs when two phase conductor touch with the ground then this type of fault are arises [4]. LL faults occur when two phase conductors touch each other than these type of fault arises. It occurs 5-10% of the faults in the power system. Unsymmetrical fault are also called as unbalance type of fault.

ANN is the most powerful in the pattern recognition, classification and generalization. Many of the ANN-based algorithms have been discover to implement in power systems [10]. Neural Networks are mostly use to the trained the data [11]. Neural Network contain the supervised learning, unsupervised learning, feed forward, feedback and many. ANN is used to protect the power system from abnormal condition that converted into the fault [1].

FAULT IDENTIFICATION METHODS

Identification of faults are generally come under the abnormal condition which varied the current and voltage waveform. But in most of the cases like the line fault. It is generally take the current waveform data which is use to identified the fault. Voltage are taken when the over voltage, under voltage, Ferranti effect etc. are occur. All the calculation are done on the basis of per unit system. Line Fault are generally two type. In the Figure 1, one is Symmetric or balance fault and other is Unsymmetrical fault.

Symmetrical fault are also known three phase fault. In these condition

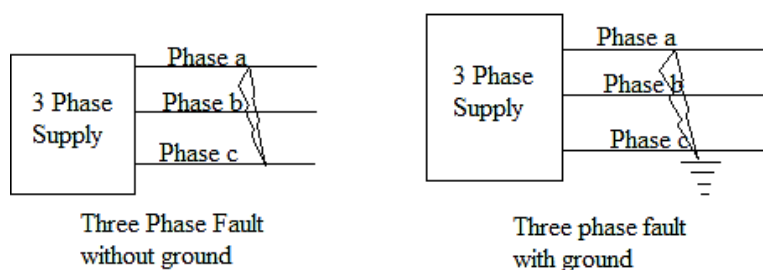


Figure 1. Symmetric fault.

In the balance fault condition, there is need of positive sequence for calculated the fault. In Balanced fault condition, three phase are equally displaced and due to that it can be say after fault remains under balanced condition. Three phase equally displaced by 120° [5]. Unsymmetrical fault never occurs in balanced condition as shown in Figure 2. So, in that case, Split the phase into three components to make the balanced condition. They split into three components namely Positive Sequence, Negative sequence and zero sequence. In positive sequence, it occurs in balance condition after the unbalance supply or fault occurs. Negative Sequence is opposite to the positive sequence and Zero Sequence having the same phase and hence no phase sequence [5].

FAULT IDENTIFICATION USING ANN

Neural networks is a process of information as the similar way the human brain does. The neural network is composed of a large number of interconnected system of elements that contain the neurones which are working in the parallel form to increase the speed of working for suitable purpose [6]. Neural Network provides the facilities of open loop and closed type functions that helps to solve the problem. It can use for many purposed like time-series prediction, data fitting, pattern recognition, clustering and control [7]. Feed forward networks have one-way connections from input to output layers. They are most commonly used for prediction, pattern recognition, and nonlinear function fitting [8]. In the ANN has the feed forward back propagation, cascade-forward back propagation,

feed forward input-delay back propagation, linear, and perceptron networks [9]. A feed forward neural network is an artificial neural network where connections are open loop in the system it does not make the closed loop cycle in these condition [10]. The feed forward neural network was the first and simplest type because it is open loop system and it is use for only in the one direction [11]. Feed forward networks consist of a series of layers. The first layer has a connection from the network input [12]. Each subsequent layer has a connection from the previous layer. The final layer produces the network's output. It is use to classified the fault in power system [13].

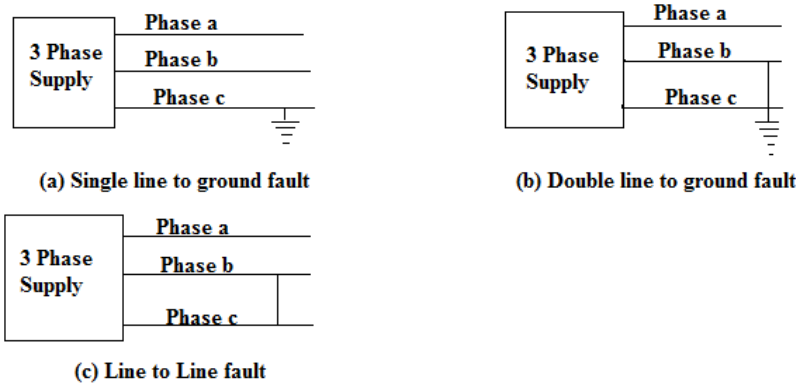


Figure 2. Unsymmetrical fault.

TRAINING ALGORITHMS

The Widrow-Hoff learning rule are used for multi-layer of hidden layer and not use for linear type function. It can use in the Back Propagation Algorithm for identification and classification of fault in the power system and many other uses [14]. Input and target are used to train the network because in the input give the faulty data and in the target give the target data that to obtain [15].

The output values N_j of a given input pattern X_i do not always corresponds to their predetermined value M_j . The error P_j is given by the difference of M_j and N_j is to be minimized by the weight changes. The error of a neuron j in the output layer is:

$$P_j = \frac{1}{2} (M_j - N_j)^2 \quad (1)$$

The total error P of an output layer is

$$P = \sum_j P_j = \frac{1}{2} \sum_j (M_j - O_j)^2 \quad (2)$$

Output layer of error is back propagated to the hidden layer and the input layer. Back propagated error E_k is given by

$$P_k = \sum_j P_j = \frac{1}{2} \sum_j (M_j - N_j)^2 \quad (3)$$

By changing in weight in the hidden layer

$$\Delta E_{ik} = \alpha \cdot \sum_j (M_j - N_j) \cdot N_j (1 - N_j) \cdot E_{kj} \cdot H_k (1 - H_k) X_i \text{ Hidden layer input is } (H_k)$$

Back propagation learning method for hidden layer can approximate nonlinear function to accurate [16].

DESIGN OF FAULT IDENTIFICATION AND CLASSIFICATION

In the Figure 3, the design process of fault identification and classification of power system. From this flow chart, it can be known about the process of fault identification and classification of fault in the power system. This is the proposed flow chart in which helps us to know the process.

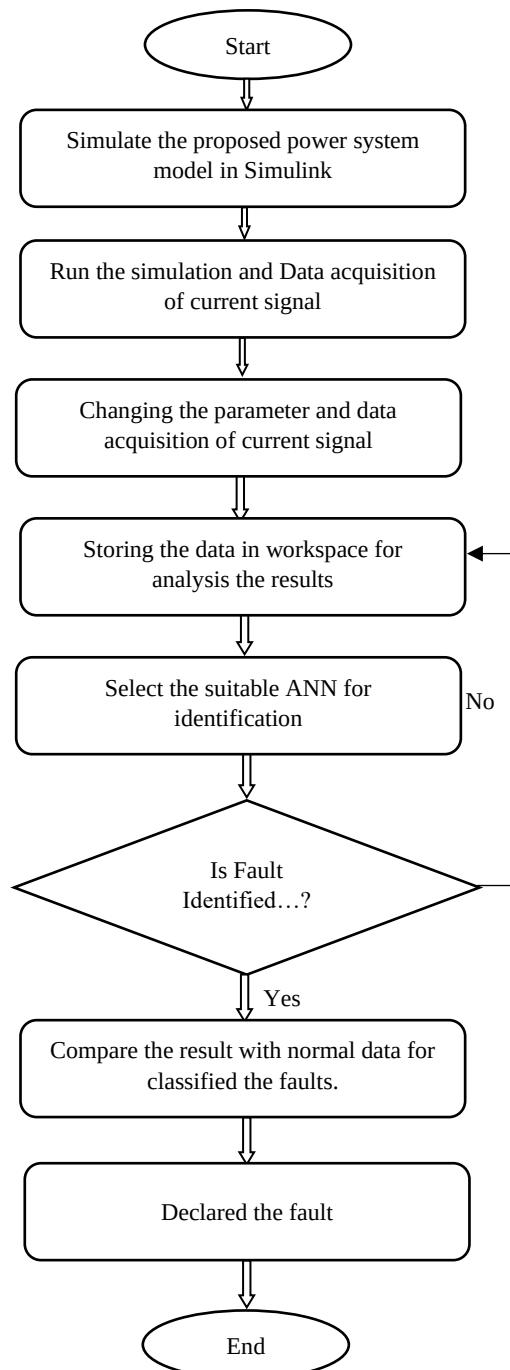


Figure 3. Flow chart for fault identification and classification.

PROPOSED POWER SYSTEM MODEL TO SIMULATE IN SIMULINK

In the Figure 4 Simulation Model, It has 4 generator, 2 transformer and 6 buses. Three phase fault are come between bus 2 and 3. The analysis of variation in the current at bus no 2 and identify, classified the fault in the power system.

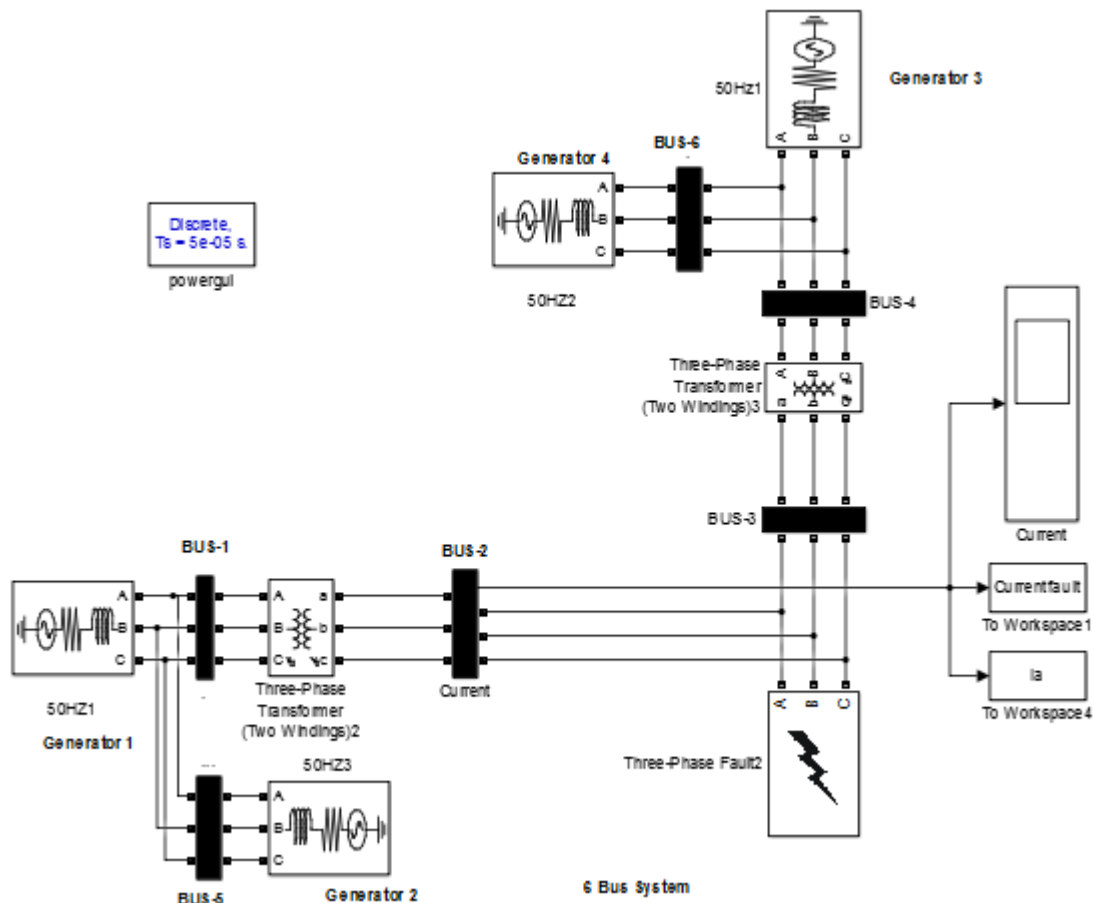


Figure 4. Simulation of proposed model in the power system.

RESULTS AND DISCUSSION

Fault identification and classification are based on the current data. It is discuss about the fault by taking the each case of fault. With the help of ANN, Identification and classification of fault are possible by their pattern as well as their data which are comes from their output.

Case 1: Without fault

In the Figure 5, the current and voltage waveform of without fault. In the Figure 6, It has 237 iteration and in the Regression Graph value of $R=1$ taken because It is not under the fault condition. It comes under without fault condition and graph are for current value data. The regression plot shows the inputs as compare to target result. For the without fault data, it make the 45° as see in the regression plot. It comes under best condition and also value of will be 1 as see in the regression plot that make this type of plot shows the best condition and don't have their any fault. It comes under normal condition.

In the performance graph, it can see that train, validation, test, best all are meeting each other and it comes under best condition as shown in Figure 7.

In the Training state graph, it can see that validation check $=0$ at any epoch's .So it can see say that It is in the best condition as shown in Figure 8.

The blue bars represent training data, the green bars represent validation data, and the red bars represent testing data. The histogram can give you an indication of outliers, which are data points where the fit is significantly worse than the majority of data as shown in Figure 9.

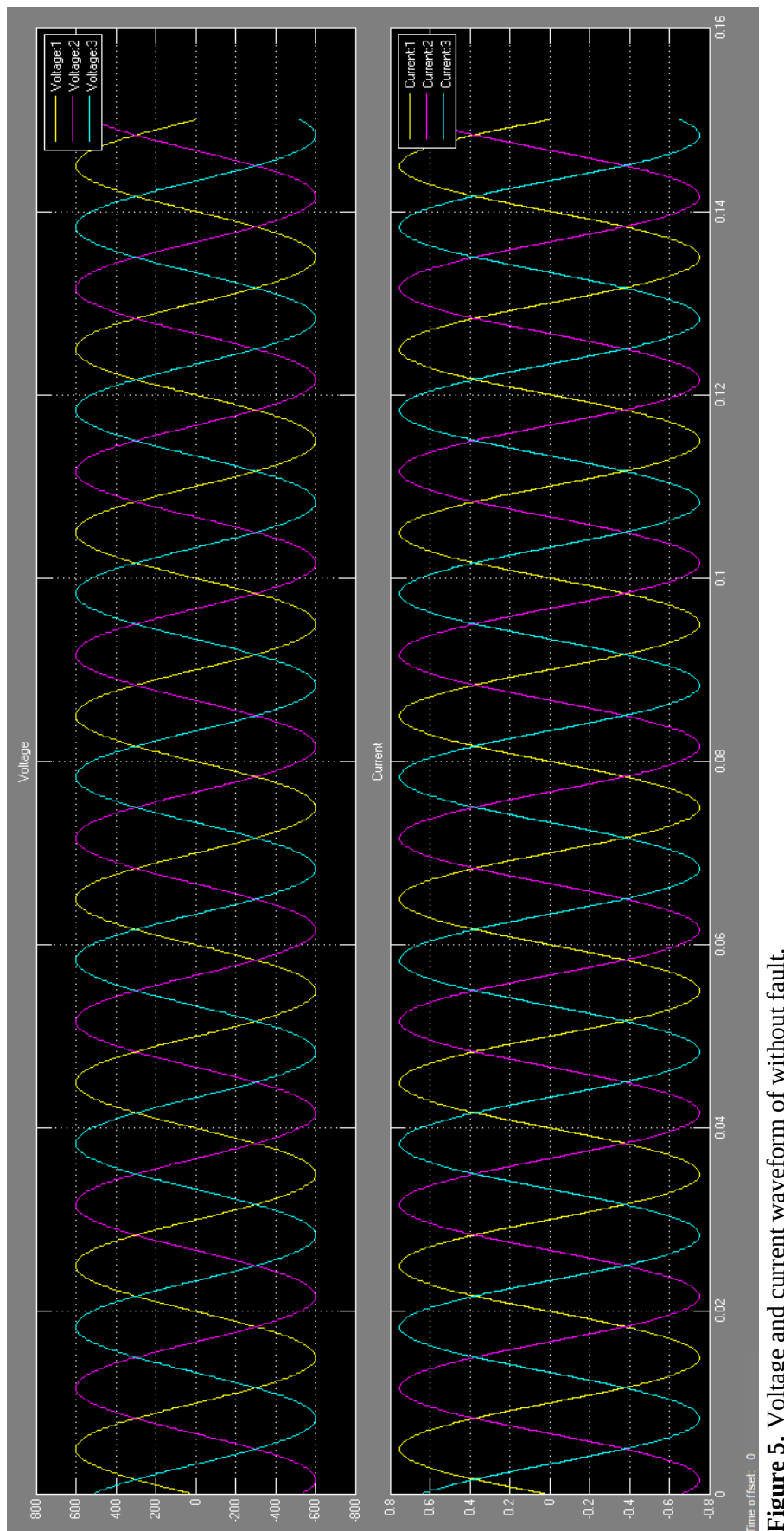


Figure 5. Voltage and current waveform of without fault.

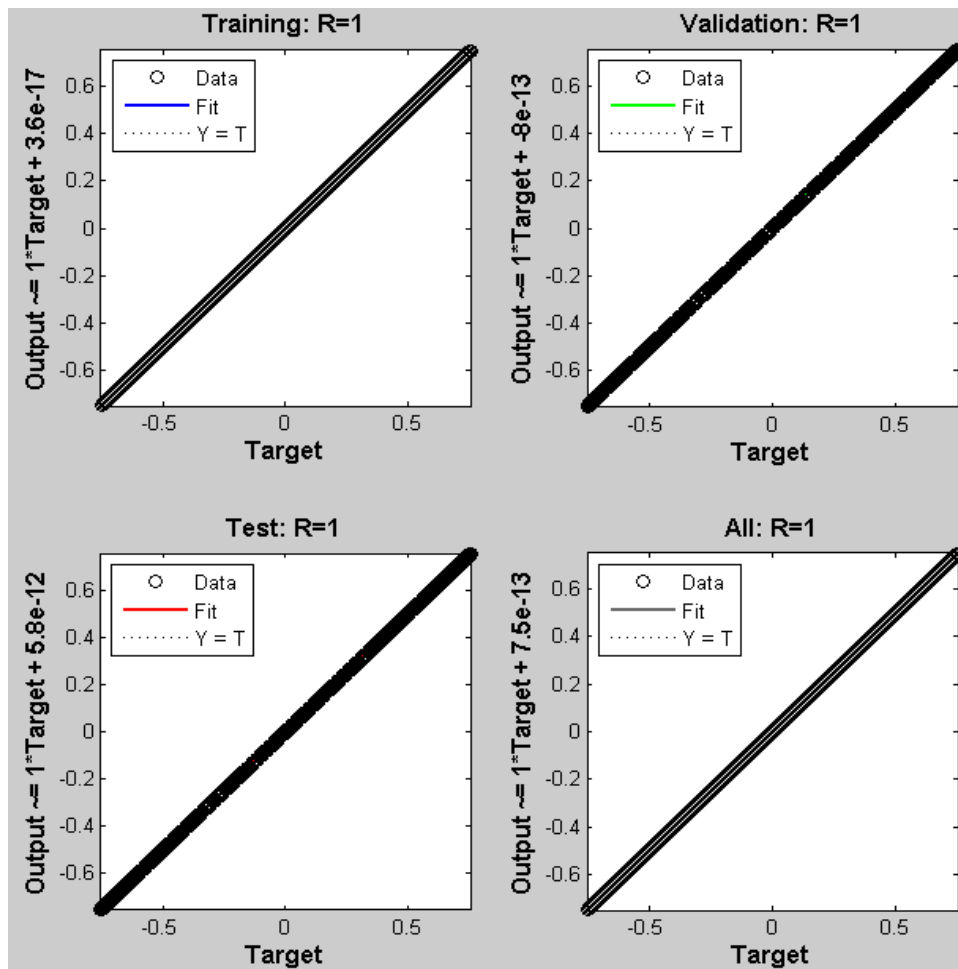


Figure 6. Regression plot of without fault current.

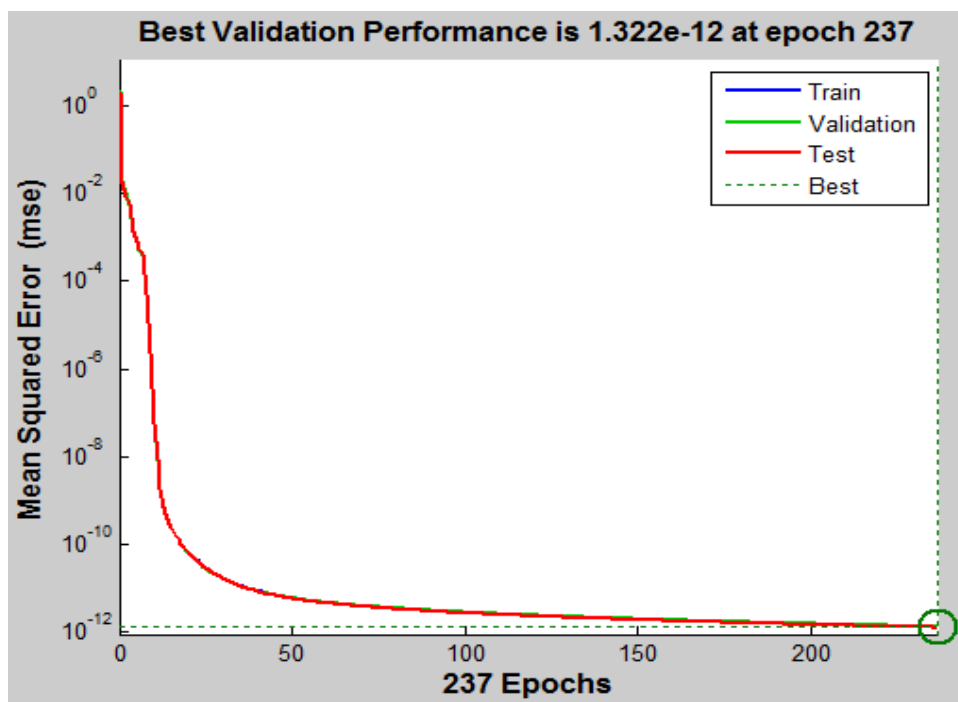


Figure 7. Performance of without fault current.

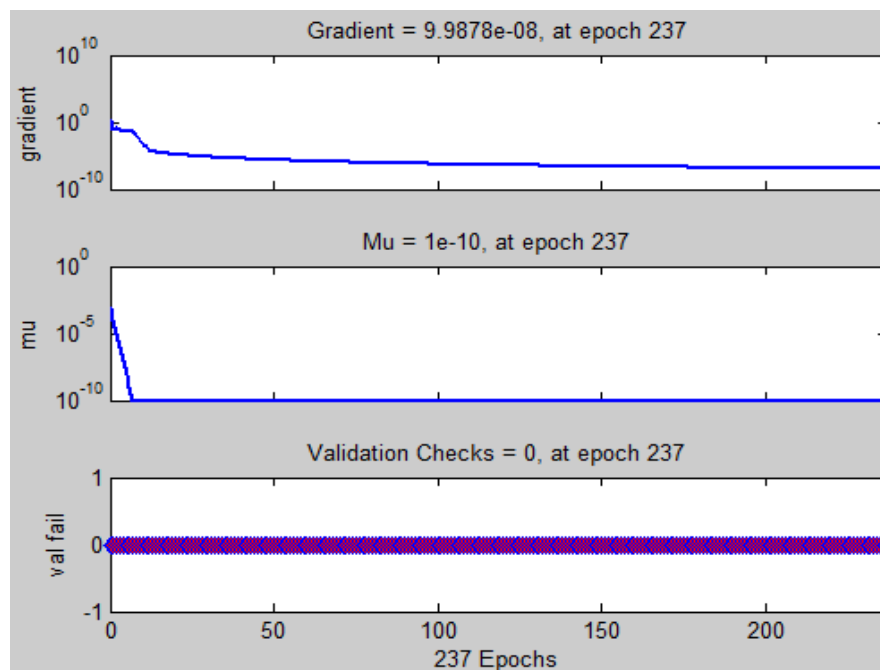


Figure 8. Training state of without fault current.

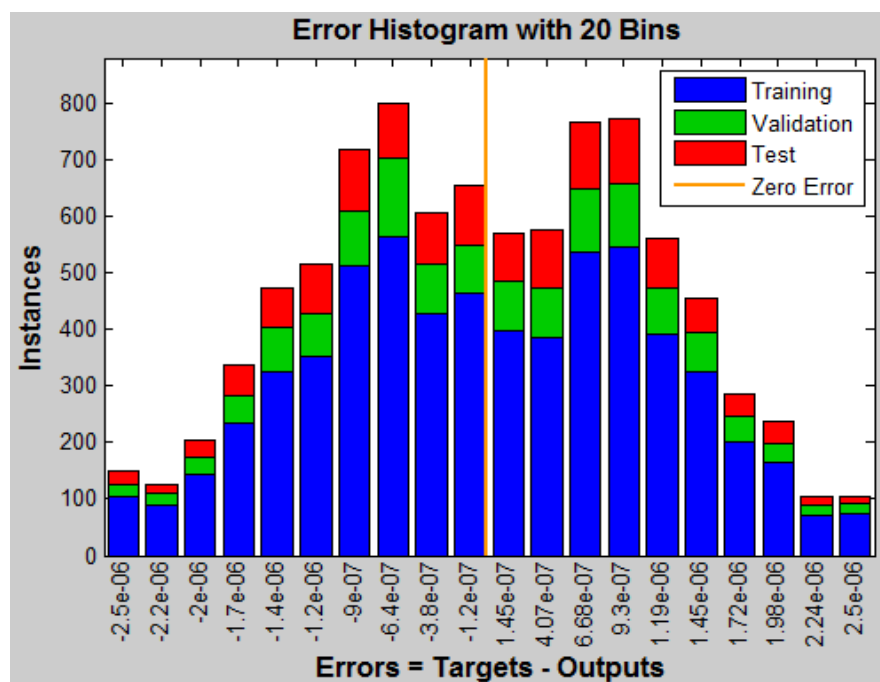


Figure 9. Histogram of without fault current.

These outliers are also visible on the testing regression plot. It is a good idea to check the outliers to determine if the data is bad, or if those data points are different than the rest of the data set.

Case 2: Single Line to Ground Fault

In the Figure 10, Current and voltage waveform of SLG fault are shown. In Figure 11, levenberg - Marquardt take 639 iterations and it complete the validation checks .It completely checks 6. And it can see that there is changing in the graph at the middle. This middle approx. target (-100 to 100) and output approx. (-100 to 100). For this problem, the fit is reasonably good for all data sets, with R values in each case of 0.99979 or above.

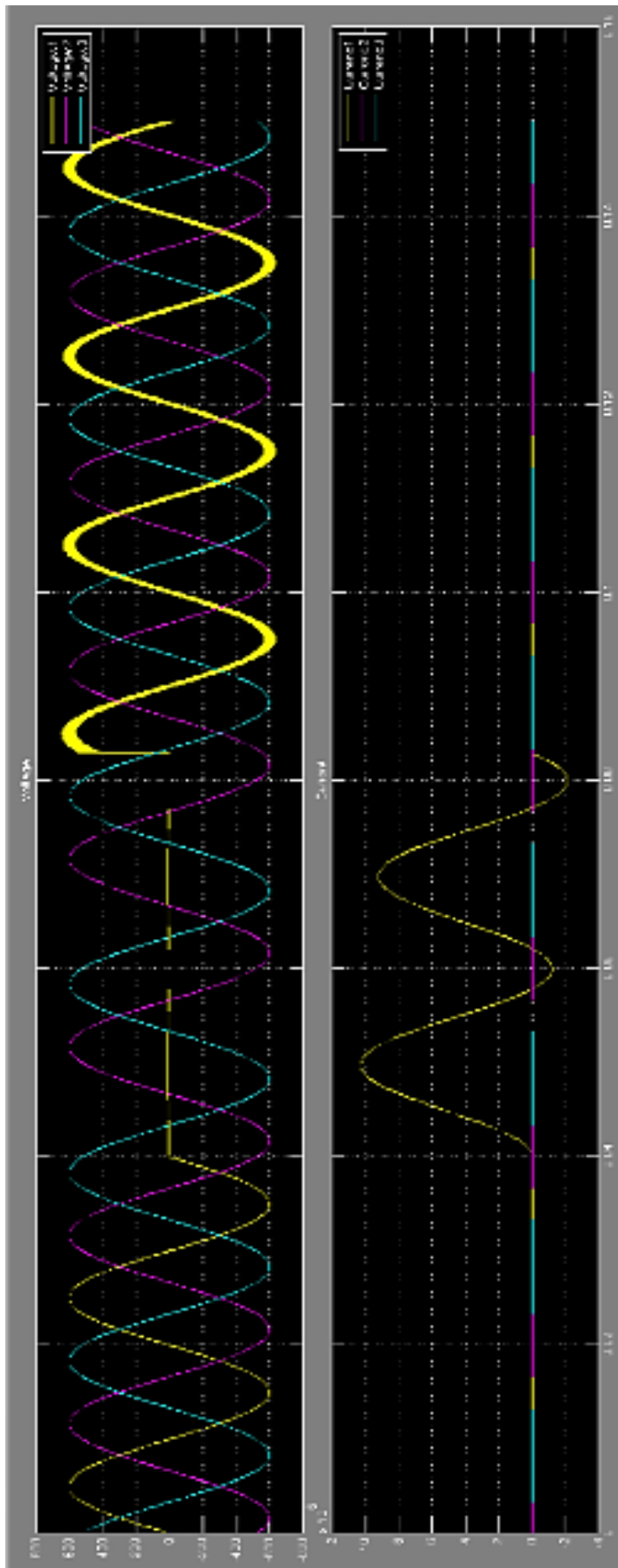


Figure 10. Voltage and current waveform of SLG fault current.

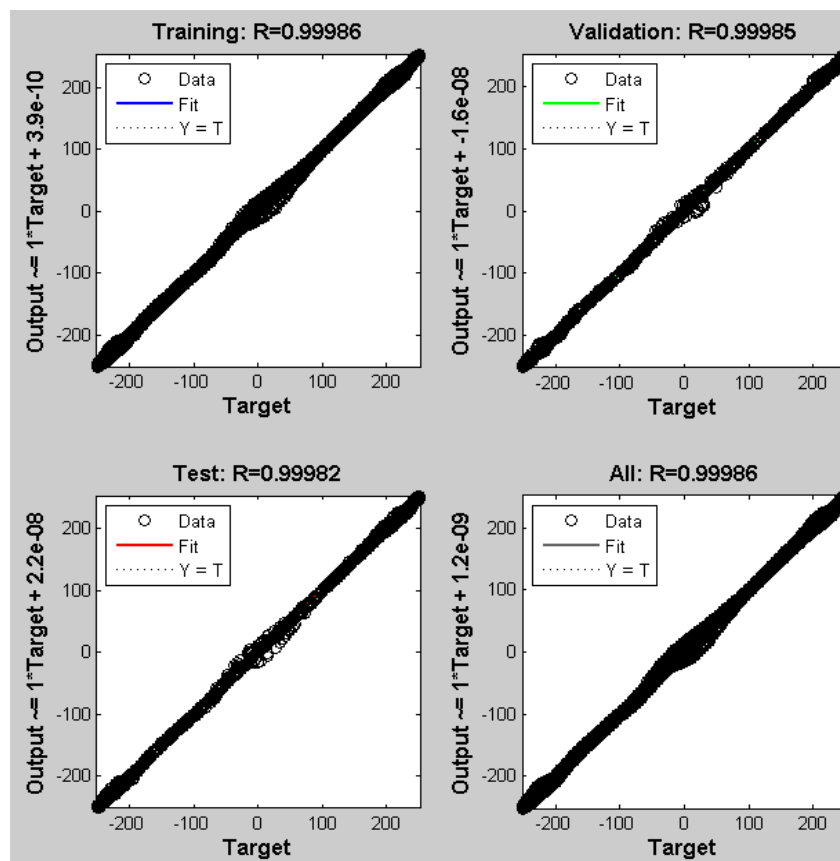


Figure 11. Regression plot of SLG fault current.

Table 1. Neural network training by changing the hidden layer for without faults.

Hidden layer	Epoch	Performance	Gradient	Mu	Validation Check
5	488	1.10e-10	9.94e-08	1.00e-08	0
10	243	4.09e-10	9.87e-08	1.00e-08	0
15	89	6.15e-15	9.89e-08	1.00e-14	0
20	205	6.16e-13	9.87e-08	1.00e-10	0
25	152	1.48e-11	9.94e-08	1.00e-09	0
30	228	2.37e-10	9.98e-08	1.00e-08	0

Table 2. Neural network training by changing the hidden layer for SLG faults.

Hidden layer	Epoch	Performance	Gradient	Mu	Validation Check
5	341	2.68000	3.05e-05	1.00e-07	6
10	639	8.41000	0.008500	1.00e-05	6
15	330	2.14e-05	0.000305	1.00e-08	6
20	463	1.08e-05	0.000100	1.00e-06	6
25	526	1.068e-05	2.09e-05	1.00e-04	6
30	435	1.03e-05	0.003493	1.00e-03	6

Case 3: Double line to Ground Fault

In the Figure 12, Current and voltage of DLG fault are occur. In the Figure 13, Levenberg – Marquardt take 16 iterations and it complete the validation checks. It completely checks 6. And it can see that there is changing in the graph at the middle. This middle approx. target (-0.8 to 0.6) and output approx. (-1 to 1). For this problem, the fit is reasonably good for all data sets, with R values in each case of 0.78963 or above.

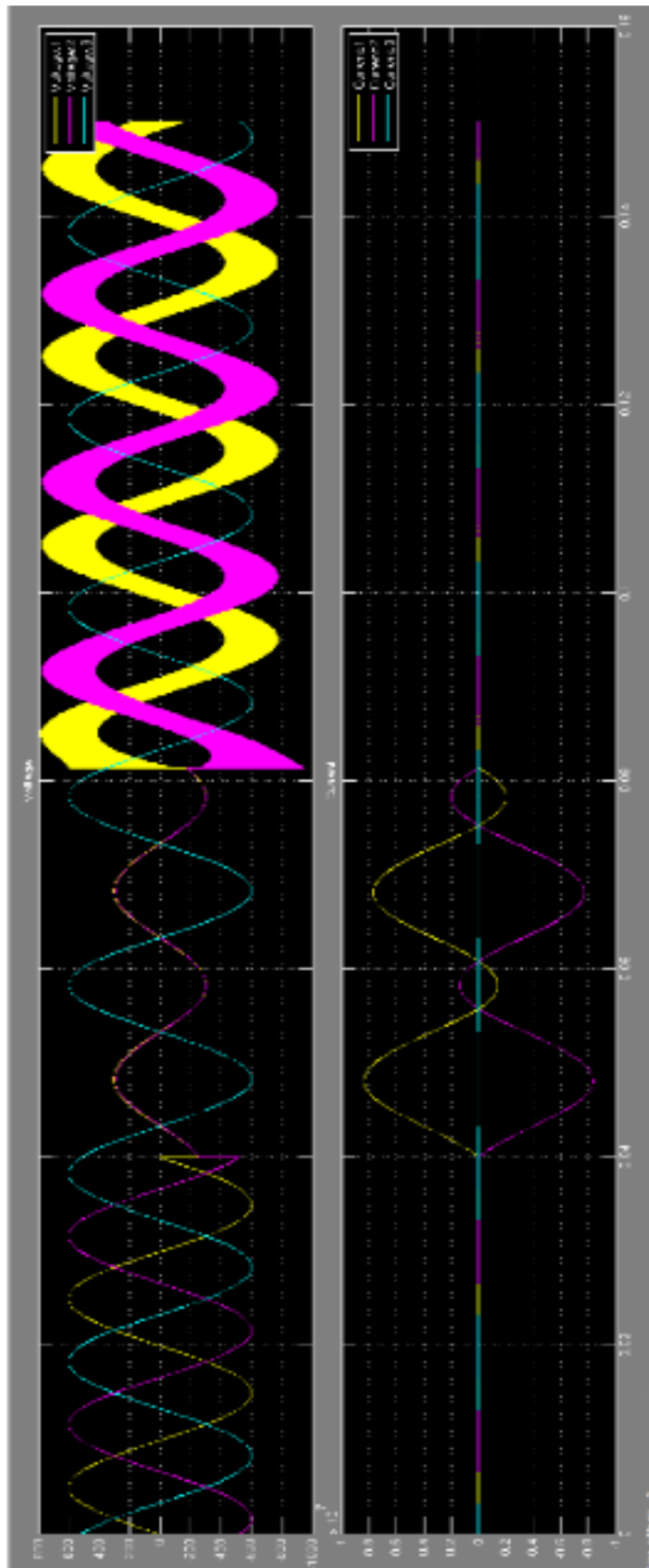


Figure 12. Voltage and current waveform of DLG fault.

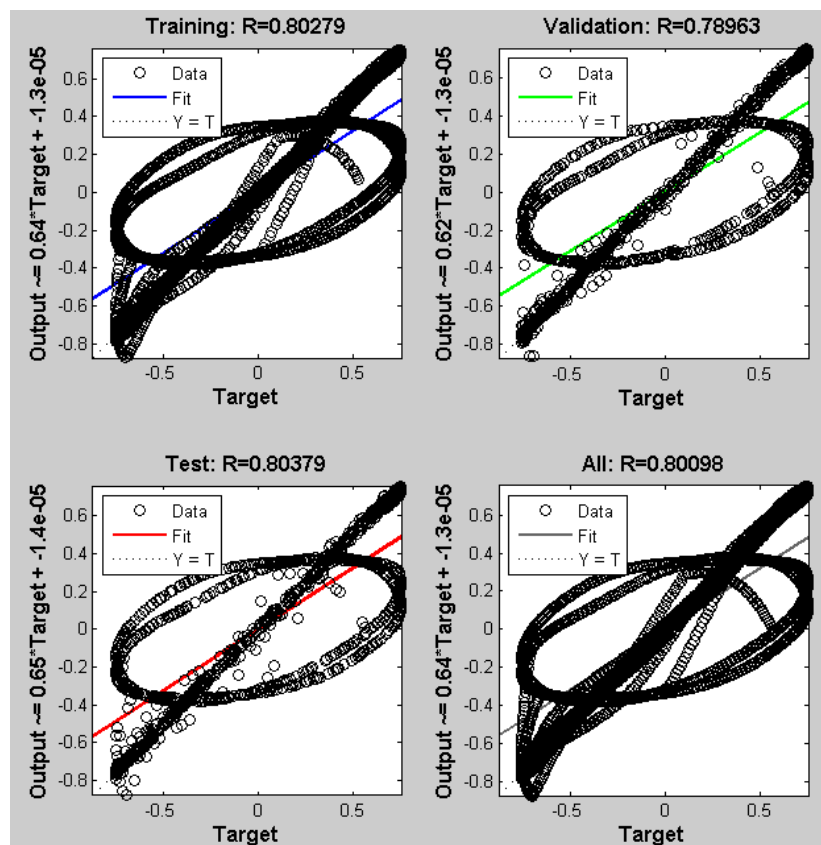


Figure 13. Regression plot of DLG fault current.

Table 3. Neural network training by changing the hidden layer for DLG faults.

Hidden layer	Epoch	Performance	Gradient	Mu	Validation Check
5	47	0.102	0.00050	1.00e-05	6
10	121	0.0994	0.00036	1.00e-05	6
15	20	0.101	0.00066	1.00e-05	6
20	44	0.101	0.00065	1.00e-05	6
25	11	0.101	0.00092	1.00e-05	6
30	22	0.0997	0.00091	1.00e-05	6

Case 4: Line to Line Fault

In the Figure 14, Current and voltage waveform of LL fault. In the Figure 15, levenberg – Marquardt take 19 iterations and it complete the validation checks .It completely checks 6.And it can see that there is changing in the graph at the middle. This middle approx. target (-0.8 to 0.6) and output approx. (-1 to 1). For this problem, the fit is reasonably good for all data sets, with R values in each case of 0.72944 or above.

Table 4. Neural Network training by changing the hidden layer for LL faults.

Hidden layer	Epoch	Performance	Gradient	Mu	Validation Check
5	18	0.128	0.00156	0.00001	6
10	236	0.109	0.0239	1.00e-06	6
15	305	0.109	0.00051	0.00010	6
20	11	0.129	0.00430	1.00e-05	6
25	9	0.126	0.0275	1.00e-05	6
30	47	0.124	0.00138	0.0001	6

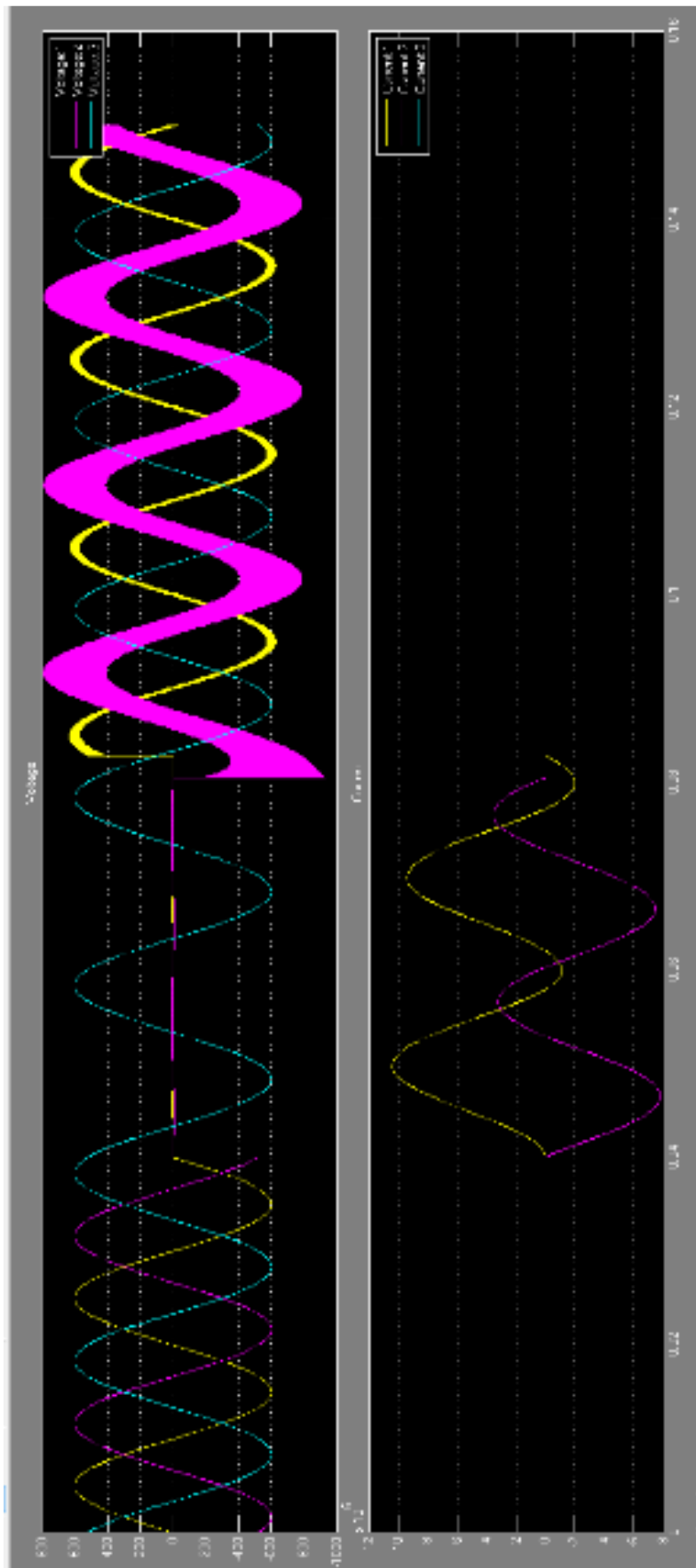


Figure 14. Voltage and Current waveform of LL fault.

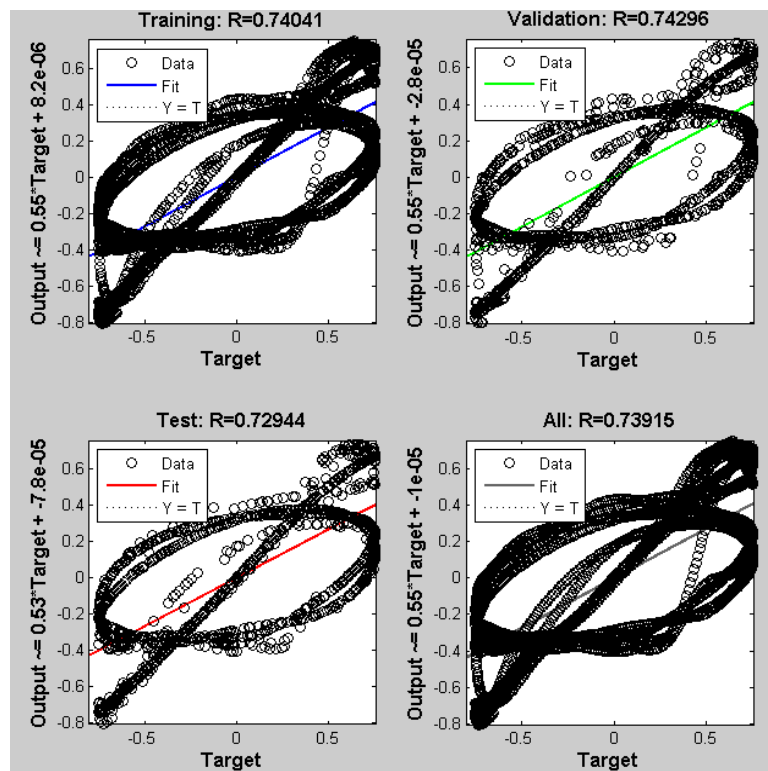


Figure 15. Regression plot of LL fault current.

Case 5: Three Phase Fault

In the Figure 16, current and voltage waveform of three phase fault. In the Figure 16, levenberg – Marquardt takes 72 iterations and it completes the validation checks. It completely checks 6. And it can be seen that there is a change in the graph at the middle. This middle approx. target (-0.8 to 0.8) and output approx. (-1 to 1). For this problem, the fit is reasonably good for all data sets, with R values in each case of 0.54533 or above.

Table 5. Neural Network training by changing the hidden layer for three phase faults.

Hidden layer	Epoch	Performance	Gradient	Mu	Validation Check
5	8	0.139	0.00237	0.0001	6
10	12	0.127	0.00604	1.00e-05	6
15	161	0.109	0.00105	1.00e-05	6
20	24	0.126	0.00604	1.00e-05	6
25	23	0.126	0.00678	1.00e-05	6
30	11	0.128	0.0120	1.00e-05	6

Table 6. Type of fault in ANN as an output.

Type of Fault	Network Outputs			
	A	B	C	G
A-G Fault	1	0	0	1
B-G Fault	0	1	0	1
C-G Fault	0	0	1	1
A-B Fault	1	1	0	0
B-C Fault	0	1	1	0
C-A Fault	1	0	1	0
A-B-G Fault	1	1	0	1
B-C-G Fault	0	1	1	1
C-A-G Fault	1	0	1	1
A-B-C Fault	1	1	1	0

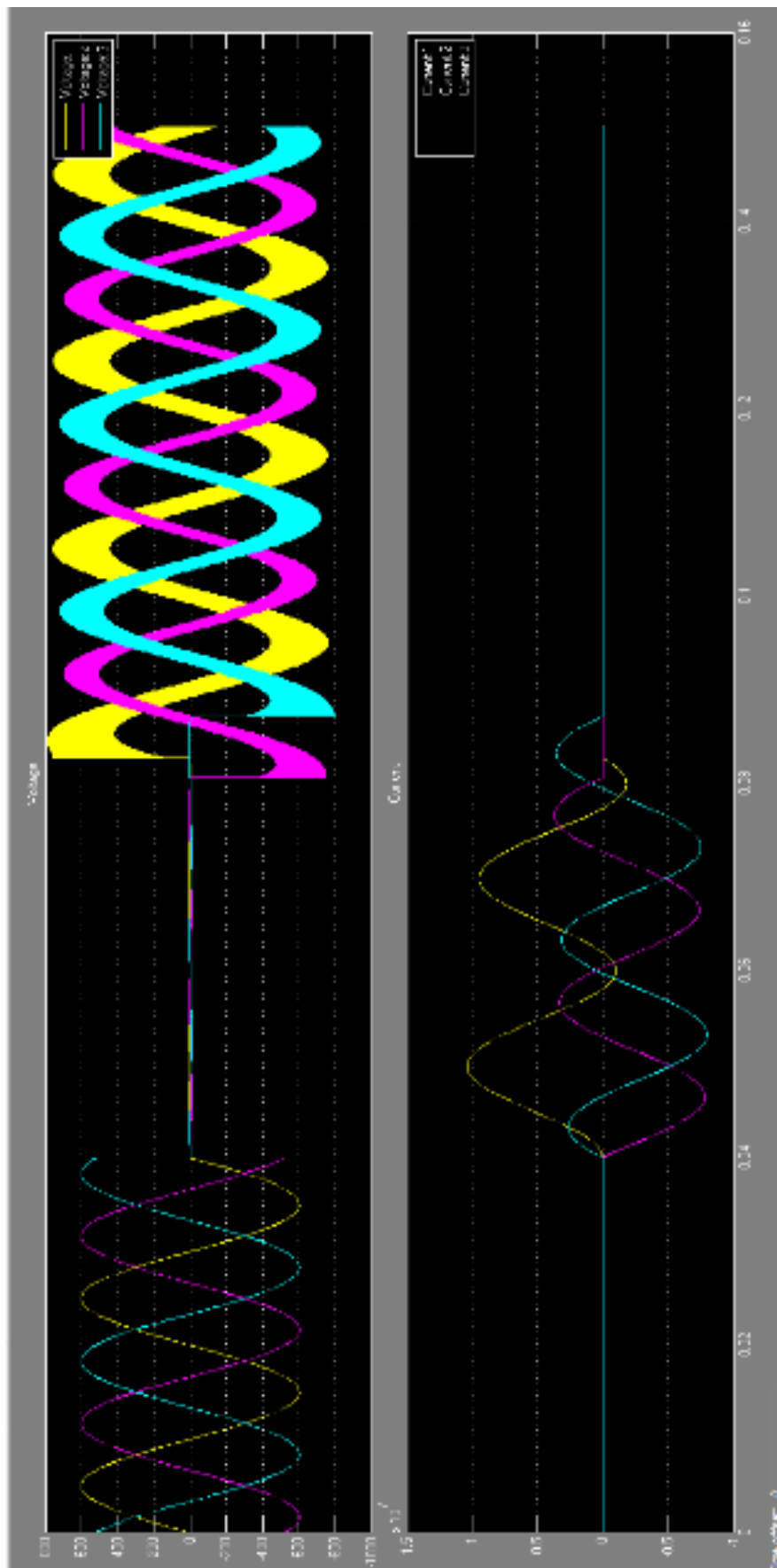


Figure 16. Voltage and Current waveform of three phase fault.

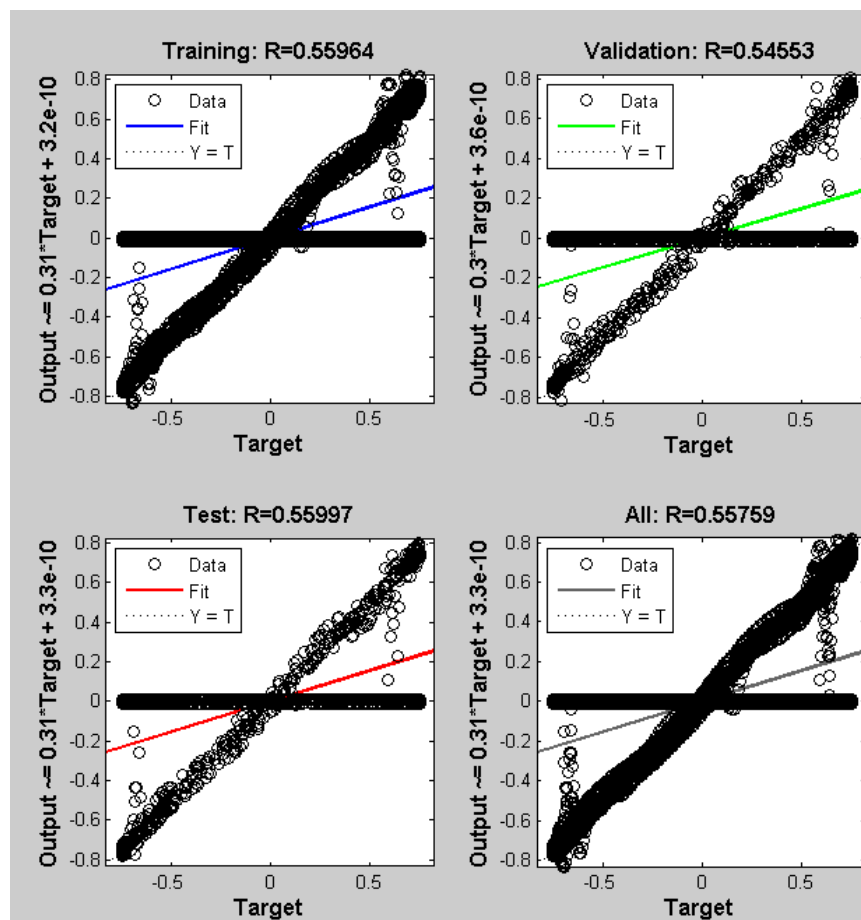


Figure 17. Regression plot of three phase fault current.

CONCLUSION

In case of faults, the current is an important parameter to deal with power system because it directly affects the system and it may be harmful for electronic and electrical equipments. This paper has proposed the usage of ANN as an alternative method for the identification and classification of line faults the power system. With the help of regression plot and validation check, the identification of faults with the help ANN is carried out in this work. The main parameters such as Mean square error (performance), gradient and Mu are used for the classification of faults in the proposed power system model by ANN. In this work, the methods employed make the use of line currents as inputs to the artificial neural network. Only line currents is needed as input to the ANN for the training in case of line faults. Various possible kinds of faults namely single line to ground, line to line, double line to ground and three phase faults have been taken into consideration and ANN have been proposed for these faults in the current work.

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