Power System Fault Diagnosis Using Artificial Neural Network (ANN)

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Abstract **- This paper presents the application of artificial neural network (ANN) as an approach for fault diagnosis in a large interconnected power system. Power system faults can be classified using the bus voltage, line fault current and line-to-line current between the buses. Monitoring the performance of these three factors is very useful for power system protection devices. In this paper, both balanced and unbalanced fault are to be focused. The data were generated from the MATLAB software using Power System Toolbox V3.3. This data are to be used as training and testing sets in the ANN. In this project, several three-layer feed-forward back-propagation ANNs were developed in MATLAB. ANN model with the best performance was selected as the best design. As a result, the developed fault diagnosis system is able to generalize well with new sets of input data. Therefore, diagnosis of the fault occurrence can be successfully done.**

Keyword – Fault diagnosis, MATLAB, back-propagation, Artificial Neural Network.

1. INTRODUCTION

This paper presents an alternative method solution for fault diagnosis in power system of random size when fault occurs at any system bus. Both balanced and unbalanced fault are considered and will be simulated using computer software tools MATLAB using Power System Toolbox V3.3. Among the important factors affecting the fault in the system network are bus voltage, line current, fault current and fault impedance [1]. This project involved designing a network-learning algorithm using Artificial Neural Network (ANN) based on Artificial Intelligence (AI) system technology.

2. FAULT ANALYSIS

The phenomenon of fault is a situation called a failure in the power system network. Most faults are caused by the results of short circuits which include lightning and wind of storms. The wind may cause lines and poles to break, or tree limbs to blow across lines [2].

The reason why it is to prevent faults within the system is they occur frequently and without warning. Quick action must be taken to determine the problem and location of these fault so that the proper action can be taken to restore the system.

Faults on power systems are divided into three-phase balanced fault and unbalanced fault. Different types of unbalanced fault are single line to ground fault, line-to-line fault and double line to ground fault [3].

In this project, the bus impedance matrix is used as a solution for balanced fault and unbalanced fault. It can be used for large power system to predict the value of fault current and also bus voltage during fault. In a general power system, voltage is given by;

$$V = Z_{bus}\, I \qquad (1)$$

Fault current at bus k is defined by;

$$I_k\,(F) = \frac{V_t(0)}{Z_{kk} + Z_f} \qquad (2)$$

Bus voltage during the fault at bus k becomes;

$$V_k\,(F) = V_k\,(0) - Z_{kk}\, I_k\,(F) \qquad (3)$$

Since the one-line diagram simplifies the diagnose of the balanced fault, the method of symmetrical components in bus impedance matrix to diagnose unbalanced fault can be used.

3. ARTIFICIAL NEURAL NETWORK

Artificial Neural Network (ANN) is a comprehensive multi-paradigm prototyping and development that can be used to solve complex problem. In ANN, the unit similar to the biological neuron is referred to as a processing element. A neural network consists of a large number of simple processing element called neurons or nodes.

This paper investigates the effectiveness of the ANN method to identify faults occurring in a large interconnected power system network. This involves an ability to detect rapidly the type of fault occurrence and its location. In this project, the most popular type of the ANN network, the multi-layer Back Propagation Neural Network (BPNN) has been developed to solve the problem.

3.1 Back Propagation Algorithm

Back Propagation Neural Network (BPNN) has three layers. They are input layer, output layer and hidden layer. These layers are connected with each other by parameter called weights, which are in the forms of numerical value.

The output produced by the BPNN is called target output and the output produced by the theoretical method is actual output. The difference between target output, t_k and actual output, O_k is called error. This error is used in the calculation of Least Mean Square Error (LMS) provided in equation (4). BPNN operates by propagating errors backward from the output layer and will stop operation when zero error is obtained.

$$Error, E = \frac{1}{2} (t_k - O_k)^2 \quad (4)$$

The formula used for adjusting weights between hidden nodes to output layer and hidden nodes to input layer are shown in equation (5) and equation (6) respectively.

$$\Delta W_{jk} \ (n+1) = \eta \ \delta_k \ O_j + \alpha \ \Delta \ W_{jk} \ (n) \quad (5)$$

$$\Delta W_{ij} \ (n+1) = \eta \ \delta_j \ O_i + \alpha \ \Delta \ W_{ij} \ (n) \quad (6)$$

Parameters η, is a constant of proportionality of weights. A large value of this constant will offer the most rapid learning. A momentum term, α is to increase the learning speed. It is used to determine the effect of past weight changes on the current direction of movement in weight space. Test are carried out to find the effect of α, η and the number of hidden nodes, H on the RMS error. Both of the η and α parameters can be vary from 0.1 to 0.9. The overall process of the MATLAB and ANN is shown in Figure 1.0 and Figure 2.0 .

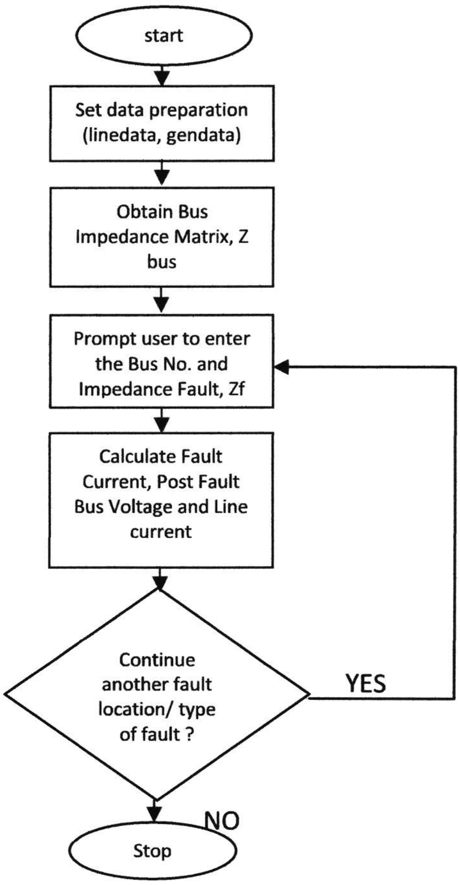

Figure 1.0 : Basic Flow Chart of MATLAB process to do Fault Analysis.

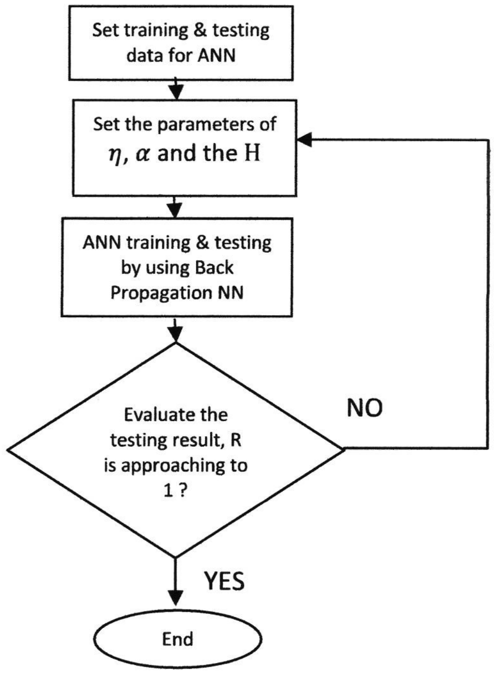

Figure 2.0 : Flow Chart of Training in ANN

4. RESULT AND DISCUSSION

The power system network simulated for fault diagnosis was on 11-bus power system network of an electric utility company shown in Figure 3.0. Balanced and Unbalanced fault conditions was run to generate data needed for the ANN simulations.

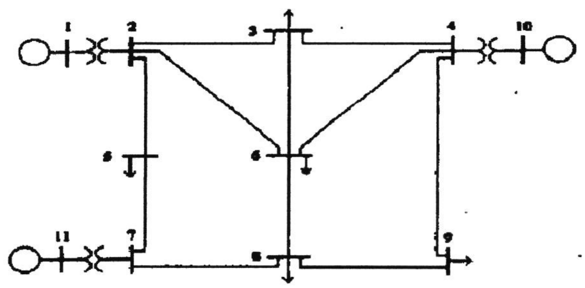

Figure 3.0 : Power System Network

4.1 Balanced Fault

The MATLAB software was simulated for different cases by changing the values of impedance impedance fault. Figure 4.0 shows that the results of fault current when a generator in the network shuts down at a time. When generator 11 shuts down, fault current at bus 11 is found to be 5.7486 A. This observation was done when fault impedance, Z_f is assumed to be zero at bolted fault. By shutting down the generator, the fault current at each busbar will decrease continuously in the system. Figure 4.0 provides the effect of fault current when the impedance at that bus is zero.

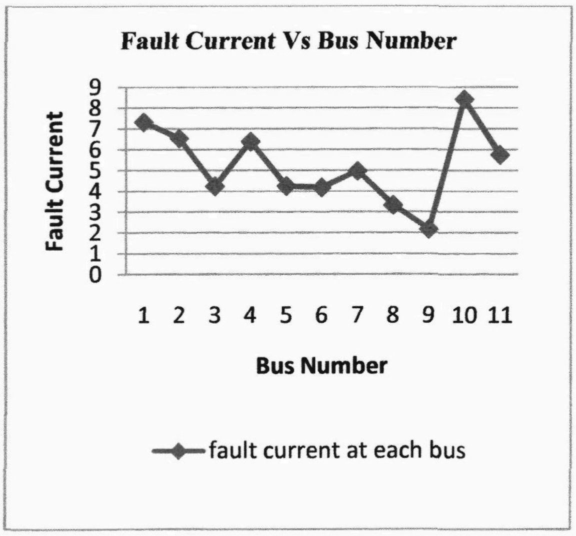

Figure 4.0 : The Effect of Generator Operates to Fault Current at Bolted Fault

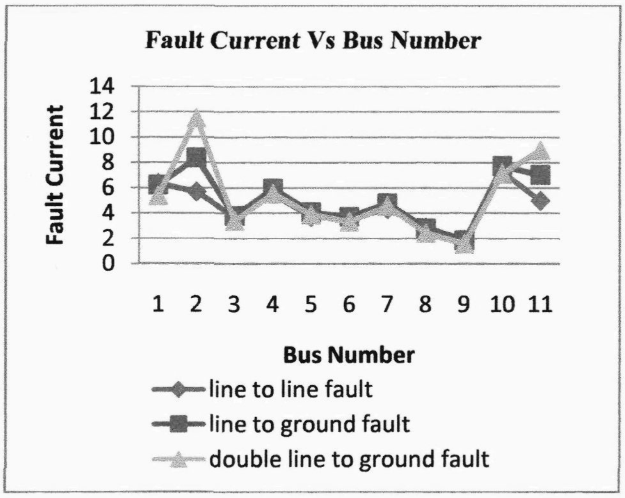

Figure 5.0 : Fault Current at Different Types of Fault

Table 1.0 : The Effect of the Line Current (A) at Every Bus when Fault Occurs at Bus 2

From bus to bus	Line Current			
	Balanced Fault	Unbalanced Fault (Single Line to Ground Fault)		
		Phase A	Phase B	Phase C
2 to 1	3.8462	3.2622	1.6311	1.6311
2 to F	6.5384	8.3721	0	0
3 to 2	0.9744	0.9269	0.3297	0.3297
3 to 6	0.1063	0.1022	0.0320	0.0320
4 to 3	0.8690	0.8248	0.2977	0.2977
4 to 6	0.5102	0.4902	0.1686	0.1686
4 to 9	0.1272	0.1162	0.0430	0.0430
5 to 2	0.9923	0.9436	0.3216	0.3216
6 to 2	0.7413	0.7088	0.2482	0.2482
7 to 5	0.9923	0.9436	0.3216	0.3216
7 to 8	0.2100	0.2045	0.0687	0.0687
8 to 6	0.3370	0.3207	0.1117	0.1117
8 to 9	0.1272	0.1162	0.0430	0.0430
10 to 4	1.5058	1.4312	0.5092	0.5092
11 to 7	1.2021	1.0256	0.5128	0.5128

Table 1.0 provides the effect of line current at each bus when fault occurs at Bus 2. It is obviously noted that the current at Bus 2 is very high.

4.2 Unbalanced Fault

In this project, three types of unbalanced faults which are line to ground, line to line and double line to ground fault calculations were carried out as an unbalanced network. Figure 5.0 shows that the effect of the fault current for a bolted faulted at each bus. From the results, it is noted that fault in power system can lead to abnormal currents and voltage may go to zero as shown in Figure 5.0 and Table 2.

Table 2.0 : Bus Voltage at different Types of Fault

Bus number	Line to line fault			Line to ground fault			Double line to ground fault		
	A	B	C	A	B	C	A	B	C
1	1	0.5	0.5	0	1.0848	1.0848	1.1329	0	0
2	1	0.5	0.5	0	0.8955	0.8955	0.6259	0	0
3	1	0.5	0.5	0	1.0615	1.0615	1.1022	0	0
4	1	0.5	0.5	0	1.0384	1.0384	1.0680	0	0
5	1	0.5	0.5	0	1.0261	1.0261	1.0479	0	0
6	1	0.5	0.5	0	1.0636	1.0636	1.1051	0	0
7	1	0.5	0.5	0	1.0222	1.0222	1.0412	0	0
8	1	0.5	0.5	0	1.0871	1.0871	1.1357	0	0
9	1	0.5	0.5	0	1.0892	1.0892	1.1383	0	0
10	1	0.5	0.5	0	1.0453	1.0453	1.0787	0	0
11	1	0.5	0.5	0	0.9105	0.9105	0.7196	0	0

4.3 Result of ANN for Balanced and Unbalanced Fault

Two sets of training data have been prepared from MATLAB simulations for balanced and unbalanced fault. These balanced and unbalanced data will be used as the inputs and outputs in ANN. The design methodology can be seen as shown in Figure 6.0 and the summarized of the input and output paramater are provided in table 3.0 and table 4.0 .

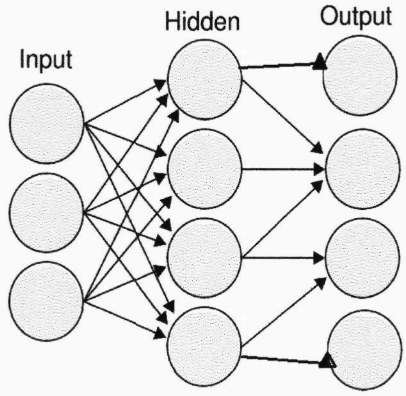

Figure 6.0 : Design Methodology

Table 3.0 : Summarized of the Input and Output Parameter for Balanced Fault

Input			Output	
Resistance	Reactance	Bus Number	Fault Current	Bus Voltage
0	0	1	7.3203	0
0	0	2	6.5384	0
0	0	3	4.2476	0
0	0	4	6.3865	0
0	0	5	4.2519	0
0	0	6	4.1846	0
0	0	7	4.9736	0
0	0	8	3.3319	0
0	0	9	2.1806	0
0	0	10	8.4222	0
0	0	11	5.7486	0

Table 4.0 : Summarized of the Input and Output Parameter for Unbalanced Fault

Input			Output			
Resistance	Reactance	Bus Number	Fault Current	Bus Voltage		
				A	B	C
0	0	1	6.3644	1	0.5	0.5
0	0	2	5.6989	1	0.5	0.5
0	0	3	3.7169	1	0.5	0.5
0	0	4	5.5701	1	0.5	0.5
0	0	5	3.7204	1	0.5	0.5
0	0	6	3.6584	1	0.5	0.5
0	0	7	4.3289	1	0.5	0.5
0	0	8	2.6090	1	0.5	0.5
0	0	9	1.9154	1	0.5	0.5
0	0	10	7.3204	1	0.5	0.5
0	0	11	4.9916	1	0.5	0.5

The optimum number of parameters for ANN used in this project are tabulated in Table 5.0.

Table 5.0 : Final Result to get Minimum RMS Error

ANN Properties	Balanced Fault	Unbalanced Fault
No. Of hidden	3	5
No of iteration	1000	1000
Momentum Rate	0.5	0.3
Learning rate	0.6	0.8
Learn coef Ratio	0.7	0.3
Regression	0.8995	0.9995

Figure 7.0 to 12.0 show the result obtained from MATLAB and ANN respectively. The result shows that the network correctly classified fault current, bus voltage, bus number and types of fault.

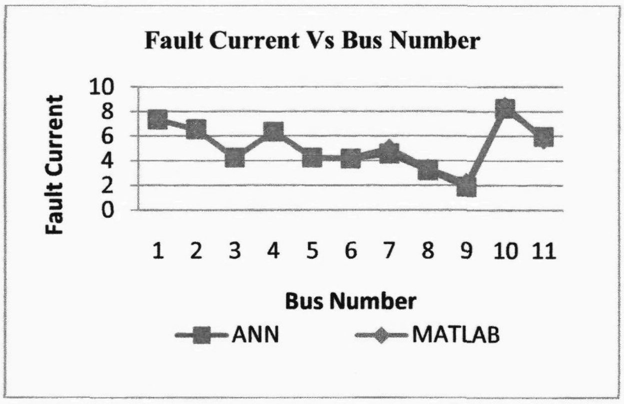

Figure 7.0 : Comparison Between MATLAB Result and ANN Result for Fault Current Balanced Fault.

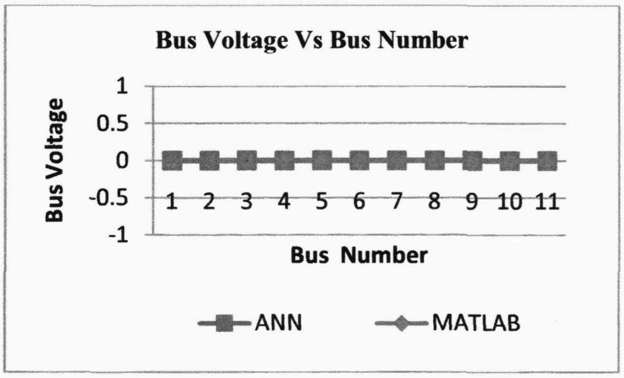

Figure 8.0 : Comparison Between MATLAB Result and ANN Result for Bus Voltage Balanced Fault

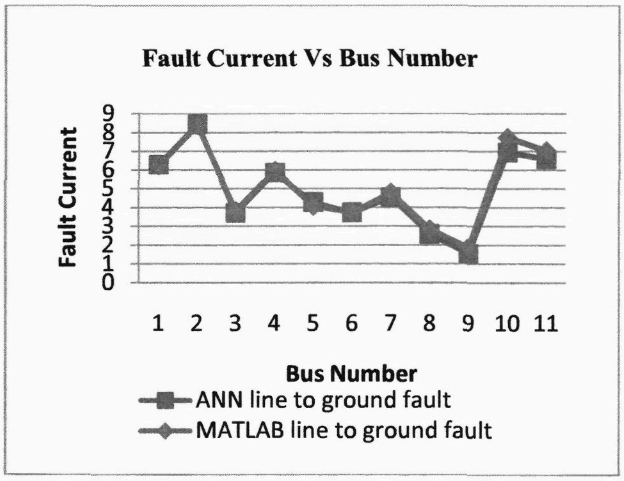

Figure 9.0 : Comparison Between MATLAB Result and ANN Result for Fault Current Unbalanced Fault Type Line to Ground

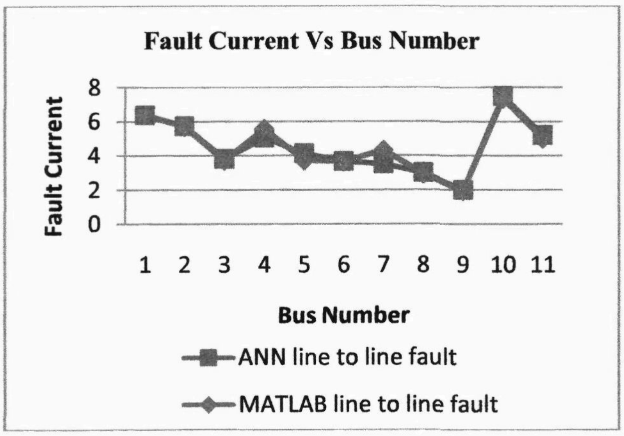

Figure 10.0 : Comparison Between MATLAB and ANN Result for Fault Current Unbalanced Fault Type Line to Line

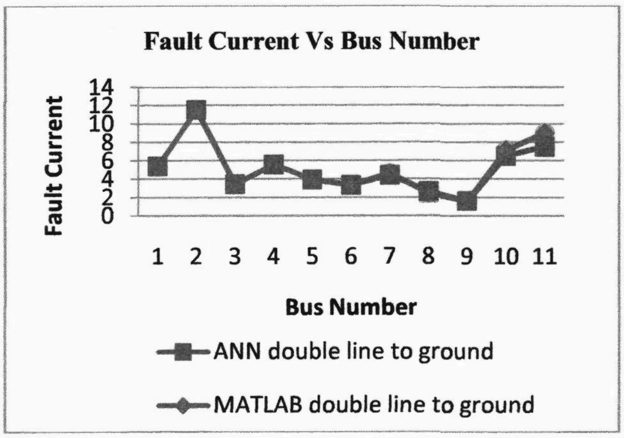

Figure 11.0 : Comparison Between MATLAB and ANN Result for Fault Current Unbalanced Fault Type Line to Ground

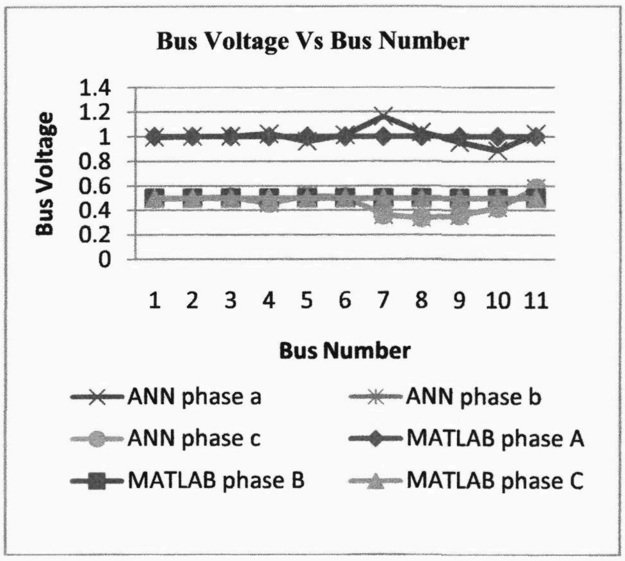

Figure 12.0: Comparison Between MATLAB Result and ANN Result for Bus Voltage Unbalanced Fault

5. CONCLUSION

From the results obtained, it can be observed that MATLAB programming can be a powerful tool for solving fault analysis. By exploiting the elements of the bus impedance matrix and symmetrical component, the fault current as well as the bus voltages will be effected.

By this observation, maximum and minimum fault current can be calculated. The detection and classification the power system faults i.e. bus voltage, faults and line current is very useful in monitoring the performance of relays, circuit breakers and other protection and control element.

In this paper, the result show that ANN could be a promising technique to be used in solving fault diagnosis. This effort has been motivated by the utility needs for more accurate and reliable software tools for the fact ANN can solve some of the keys weakness of traditional fault diagnosis methods.So it is concluded that ANN approach can produce a high diagnostic accuracy as well as the capability to deal with more complicated problems.

6. ACKNOWLEDGEMENT

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