Voltage Stability Prediction in Power System Network Using Artificial Neural Network

Mohd Khairul Azlan Bin Wahab

Faculty of Electrical Engineering
Universiti Teknologi Mara
40450 Shah Alam, Selangor
emkay_madrid@yahoo.com

***Abstract* – Voltage stability has been identified as a crucial issue in power system study which causes several problems such as blackout. This phenomenon has made this subject a very relevant issue in power system planning and operation. This paper presents an Artificial Neural Network (ANN) approach for determine voltage stability prediction in power system network. The objective of this paper is to develop ANN model for the voltage stability in power system. Other objective is to develop ANN training codes and ANN testing codes of the network. The proposed technique was tested on the IEEE 30 bus reliability test system (RTS) power system and the result shows that an accurate prediction for voltage stability condition of the system was obtained.**

Keywords: Voltage Stability, Artificial Neural Network (ANN), ANN Training Code, ANN Testing Code, Reliability Test System (RTS).

1.0 INTRODUCTION

Ability of power system to maintain at acceptable voltage at each bus at normal operating voltage with load increases or disturbances is called voltage stability [1]. Nowadays enhancement of growth in interconnection and very high operating condition have attracted an engineer because of it is related to voltage stability problem [2]. Voltage instability is one of major problem in power system planning and operation around the globe. The cause of this voltage instability is by forcing the transmission line to operate nearly to their maximum or minimum capacity due to not enough of reactive power margin because to avoid the cost of power plant facilities and new lines for the networks system. There are several incident of the power system networks collapse because of voltage instability problem were reported in many country such Japan, France, Italy, Great Britain and USA [3]. Voltage instability which has led to voltage collapse incidents has found to be a critical issue despite numerous studies has been conducted. Failure to take immediate actions to avoid collapse of the entire system has motivated the development of voltage stability prediction to be in place. The problem that has been addressed indicates the urgency to develop new algorithm which is ANN algorithm, specifically to predict voltage stability in power system networks. The importance of developing the ANN algorithm has reduced the possible inaccuracy due to human error. This ANN algorithm is feasible to be implemented in large system and reduced computation time to perform repetitive load flow analysis. The objective of the study is to develop ANN model for voltage stability prediction. Others are to develop ANN training codes and ANN testing codes for voltage stability prediction using IEEE 30 bus system. The study involves the development ANN model for voltage stability prediction of load buses in power system network using IEEE 30 bus reliability test system. To achieve this, an ANN algorithm was developed which implement repetitive load flow against various value in reactive power loading at load bus. In this approach, the various reactive powers are based on the Q-V curves analysis.

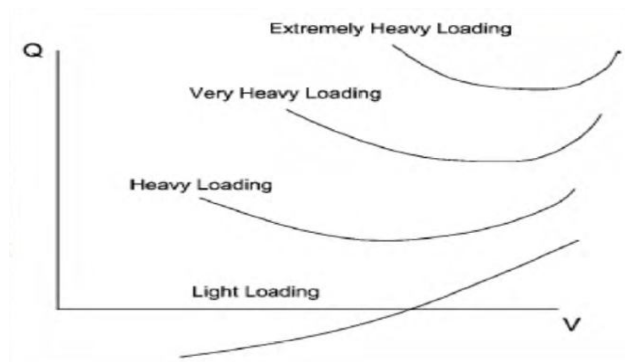

Figure 1: Q-V Curves for Several Systems Loading

The Q-V curves are one of the most popular ways to investigate voltage instability problems in power system [4-6]. Q-V curves are used to determine the reactive power injection required at a bus in order to vary the bus voltage to the required value. A maximum load margin can be achieved by varying the reactive power in increasing manner where the voltage is minimum at stability point while the active power is maintained and kept constant. The load voltage is determined by the load flow process. The load flow solutions are obtained from IEEE 30 bus system by using the load flow toolbox developed by Hadi Saadat.

2.0 METHODOLOGY

2.1 Data Collection

There are two type of data used in the proposed ANN which is the input variable and the targeted output. The input variables are the reactive power at load bus. The input variables were obtained from IEEE 30 bus system reliability test system using load flow as shown in Figure 2. The targeted output is the voltage stability condition whether stable or unstable. The voltage stability condition is determined by range of voltage. The range of voltage will be:

$$V_{min} \leq V_{bus} \leq V_{max}$$

When the voltage is in the range, it consider as stable while if the voltage is out of range, it consider as unstable. The data that collected will be use in training and testing process. The process of data collection is shown in Figure 4.

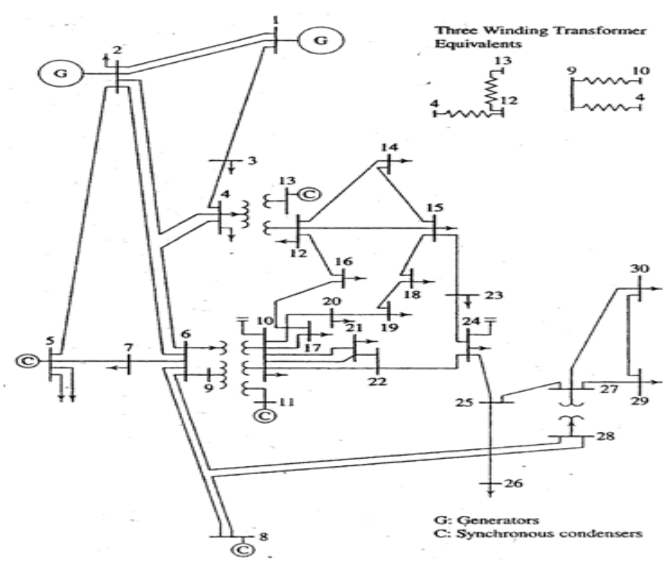

Figure 2: IEEE 30 Bus System

2.2 Development of the ANN

In this study, four-layer feed forward back-propagation ANN is developed in Matlab. The initial layer is input layer where the input data comes into the ANN. Then, it followed by two hidden layer while the last layer is output layer where the output is produced. ANN configurations like number of neurons and activation function are determined heuristically [7-9]. The reactive power at load bus is used as the input and the stability condition is target output to the ANN. The developed ANN receives the input data and the targeted output to produce network output.

2.3 Training Process

Training is the process by which ANN determines the different network parameters such as weights and biases. The training data pattern should cover the range of input patterns to train the network to recognize and predict the relationship between input variables and target output [10]. ANN are trained following a supervised training where comparison between the output and the target until the ANN output match the target and the training process then do the adjustment of weights to match the output [11].

In the training process, there are several activation function that have been used such as *TANSIG* transfer function have been used for the neurons at the input layer and *LOGSIG* transfer functions have been used for the neuron at the hidden layer. *PURELIN* transfer function for the neurons at the output layer [12]. The training function for the ANN is *TRAINLM* which is a training function that updates weight and bias values according to Levenberg-Marquardt optimization. The Levenberg-Marquardt algorithms is used to train the developed network since it provides a good compromise between fast convergence and a low computation cost [13][11], meanwhile the error function is Mean Square Error (MSE).

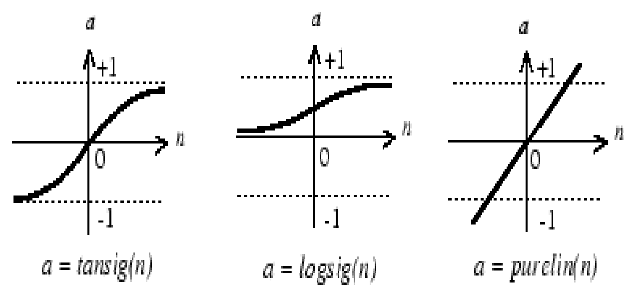

Figure 3: Type of Activation Function

The ANN is used a back propagation learning algorithm which is Levenberg-Marquardt back propagation optimization [14]. During learning, the back propagation algorithm used the information to propagate back through the network to adjust the connection weights [15]. Back propagation algorithm minimize the mean squared error between the desired output and the output of ANN. Training is achieved through adjustment of weights to reduce the mean squared error [16]. Usually, back propagation needs a large number of training epochs in order for the network to converge below an acceptable error tolerance.

After training process have been successful which is the neural network is converged, it is indicated that the neural network learning processes is successful and the 'net' file at the workspace is being saved. The training network that has been saved is actually the "black box" of the system where it is needed in the testing process.

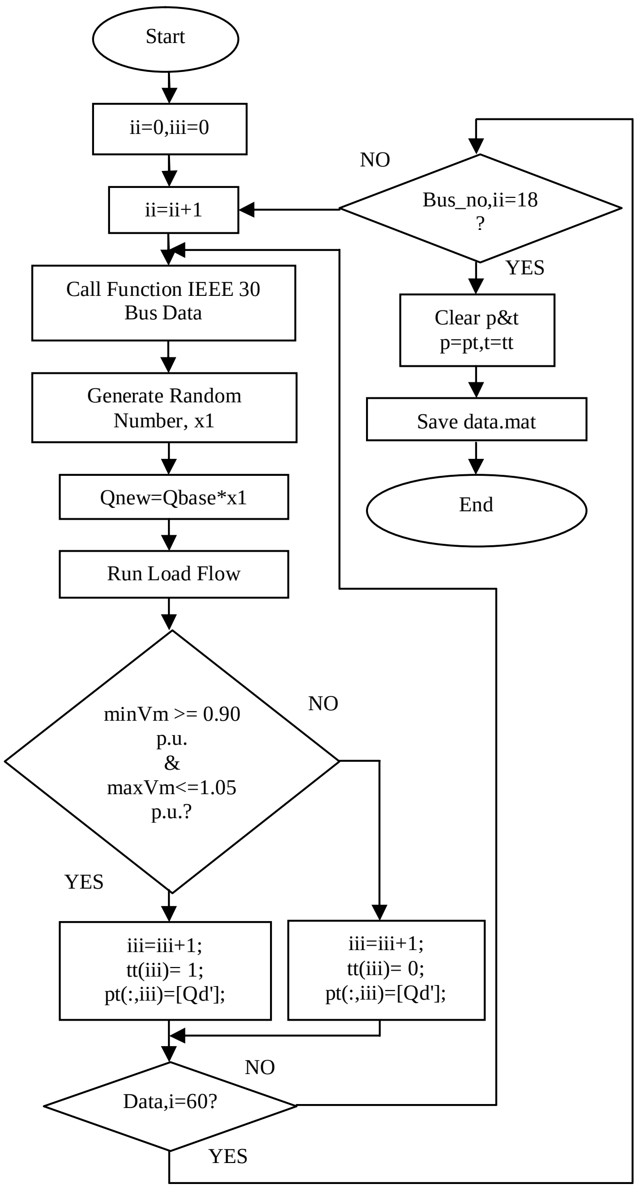

Figure 4: Flow Chart of Data Collection from IEEE 30 Bus System for Training Data and Testing Data

2.4 Testing Process

Testing process is carried out to measure the performance of the trained network, which can be measured by performing a linear regression analysis between the network and the corresponding targets. The regression test was conducted in order to determine the accurancy of the predicted voltage stability condition after the testing process. Process of measure the condition of the predicted values following the profile of the past actual value is called regression test. Hence, the measure of the predicted value from a forecast model whether is appropriate with the real life or historical data [17]. The regression test produces a certain value called regression value or the correlation coefficient at the end of the testing process.

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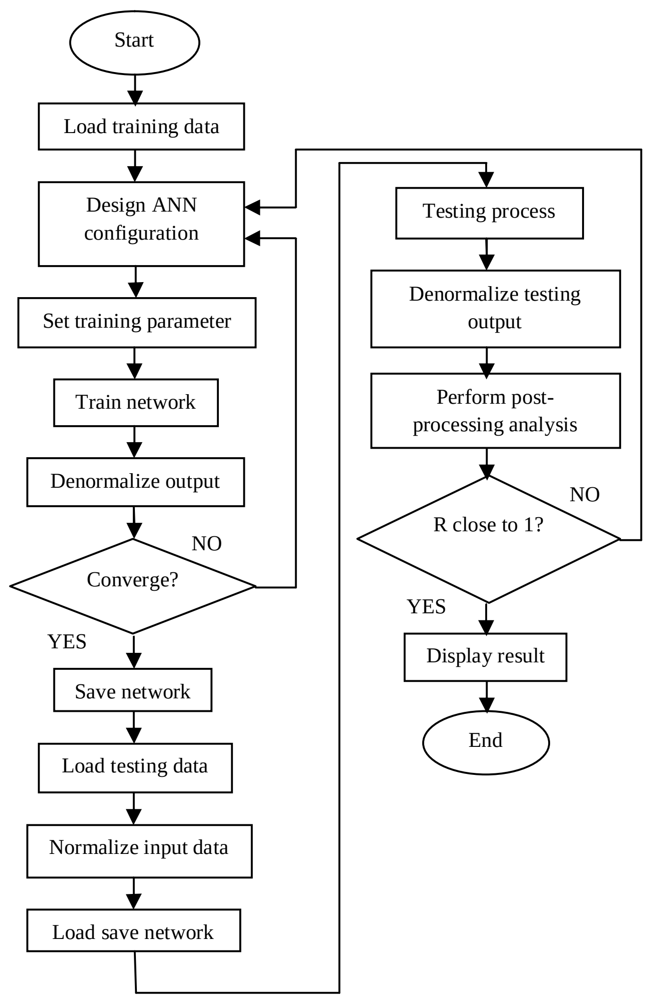

Figure 5: Flowchart ANN Algorithm

The regression value number is between 0 until 1. If the regression value is very low or 0, that mean there is no relationship between the actual values and the predict values. Meanwhile if the regression value approaches to 1, it means that the relationship between the actual values and predicted values is strong. When the regression value is 1, it means perfect relationship between actual values and predicted values. Hence, higher the regression value gives better prediction of the output [1]. The ANN algorithm for the whole process described above can be represented in a flowchart as in Figure 5.

3.0 Results and Discussion

The data were randomly collected from run load flow of IEEE 30 bus systen reliability test system. The data for training the network is 1080 patterns while 1080 were employed for testing process.

A four-layer feed forward back-propagation ANNs were developed in Matlab. Network configurations such as the number of neurons and transfer functions were determined heuristically. For each network design, the learning rate was chosen to be 0.75 while the momentum constant 0.3415.

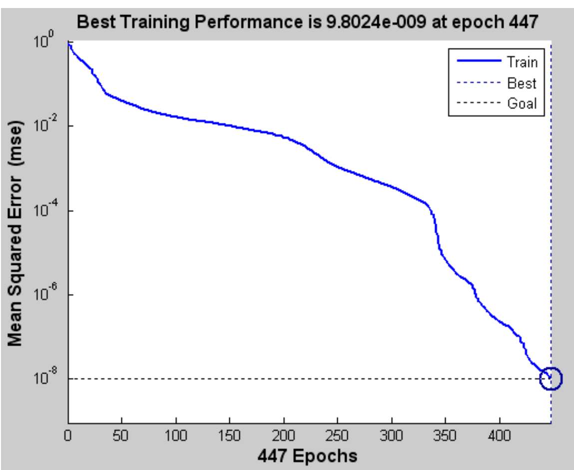

Figure 6: Training process shown that solution is converge

The proposed technique has been used for the voltage stability prediction of the IEEE 30 bus reliability test system. The simulation data were separated into 2 categories which is ANN training data and ANN testing data. 1080 data were used for training process while 1080 data were used for testing process. The ANN training process was carried out many times until it meets stopping criterion which is solution will be converge which can been seen from Figure 6. Then, the testing process was executed right after training process. In the ANN testing process there is regression test in order to determine the accurancy of the voltage stability prediction. This process will repeat until the regression test gives the value of correlation coefficient approaches to R=1.

In the testing process, result show that the regression coefficient value which determines the reliability of the overall voltage stability prediction of the system produces a good prediction with 0.97004 of regression value which can been seen from Figure 7. It means that the predicted output and targeted output give the good value in the determing voltage stability prediction.

Table 1: Properties of Developed Network for the Voltage Stability Prediction

ANN Properties	Properties
Network configuration	[30,9,5,1]
Transfer function	tansig,logsig,purelin
Learning rate	0.75
Momentum constant	0.3451
Training technique	trainlm
Epochs	1000
Regression coefficient, R	0.97004
Training patterns	1080
Testing patterns	1080
No of input variables	30

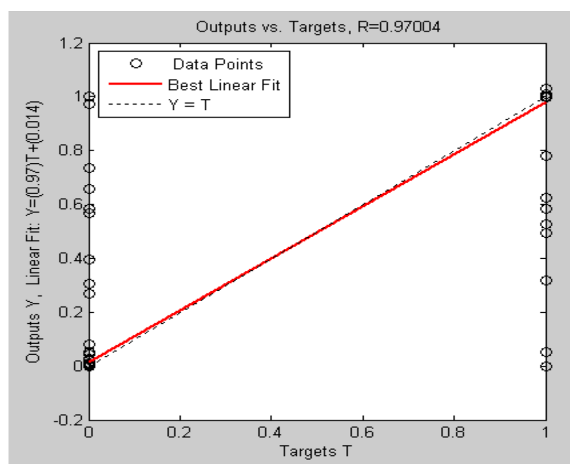

Figure 7: Testing process shown that regression test, R=0.97004

4.0 CONCLUSION

This paper has proposed an artificial neural network technique for predicting the voltage stability condition of power system network. The The developed system was tested using the IEEE 30 bus reliability test system and the results shows there is a good agreement between the desired output and the predicted output based on the regression analysis. In this study, the proposed technique will able to predict the voltage stability condition of a power system and could be a significant tool for voltage stability assessment.

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