VOLTAGE COLLAPSE PREDICTION BASED ON MINIMUM SINGULAR VALUE USING ARTIFICIAL NEURAL NETWORK (ANN)

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Abstract – This paper is about voltage collapse prediction based on minimum singular value using artificial neural network (ANN). The aim of the study is to predict the voltage collapse in a power system. The technical analysis methodology based on the use of Artificial Neural Network (ANN) which is characterized by fast computation and high ability to generalize. In this study, data were generated based on repetitive load flow studies taking Minimum Singular Value (MSV) as the indicator. The Minimum Singular Values must higher than unity that will indicate a stable system.

Keywords: Voltage Stability, Voltage Drop, Artificial Neural Network

1. INTRODUCTION.

Power System stability has been recognized as an important problem for secure system operation since the 1920s [1], [2]. Many major blackouts caused by power system instability have illustrated the importance of this phenomenon [3].Historically, transient instability has been the dominant stability problem on most systems, and has been the focus of much of the industry's attention concerning system stability. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example, voltage stability, frequency stability and interarea oscillations have become greater concerns than in the past. A clear understanding of different types of instability and how they are interrelated is essential for the satisfactory design and operation of power systems.

In recent years researches have been focused on studying proximity indicators, which could be used to detect the instability. Among all the stability indicators available in literature, the one based on the Minimum Singular Value (MSV) of the Jacobian matrix is very common, but it requires a tedious and time consuming iterative solution of the dynamic load flow equations, especially in real size power systems, and therefore it cannot be used for on-line applications.

2. ANN DEVELOPMENT

This study involved the development of an ANN that is capable of predicting voltage collapse based on the Minimum Singular Value (MSV) of the Jacobian matrix. The work comprised data collection, ANN development, training and testing processes and post-processing of results. The overall system block diagram is illustrated in Fig 1.

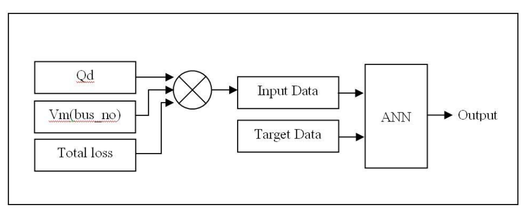

Fig 1 : Block diagram of the system

Load (Qd) data are cascaded with Voltage Magnitude (Vm(bus_no) and Total Loss in order to form the overall input data of the ANN. The developed ANN receives the input data, denoted as P and also the targeted output denoted as t.

2.1.1 Model Fitting

In general, the artificial neural network have been used successfully for the identification nonlinear system that offer the advantage of a simple nonlinear modeling through learning via a highly parallel and distributed processing paradigm [4],[5]. The most popular neural network architecture is the multilayer perceptron (MLP). The network consists of an input layer, a number of hidden layers and output layer. The output and hidden layers are made up of a number of nodes. However the input layer is essentially a direct link to the inputs of the first hidden layer and is included by convention. A typical three layer of neurons, the output of each node in a layer is connected to the inputs of all of the nodes in the subsequent layer. Data flows through the network in one direction only, from input to output; hence this type of network is called feed-forward network.

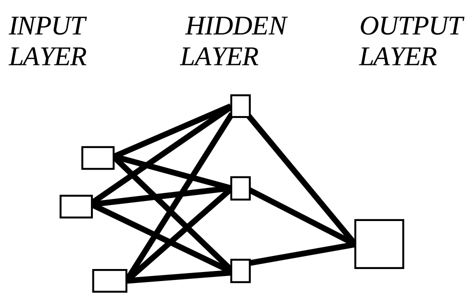

Fig 2: The multi-layer perceptron Artificial Neural Network

2.1.2 Data Preparation

Two type's data were used in the proposed ANN: input data and also target data. The data obtained from IEEE 30-BUS TEST SYSTEM (American Electric Power). This ensures that all patterns are captured for the purposes of training and testing.

2.1.3 Design of Neural Networks

In this study, an ANN with two hidden layers trained with back propagation technique is developed in MATLAB. The initial layer where the input comes into the ANN is called the input layer. It is immediately followed by two hidden layers while the last layer where the output is produced is called the output layer. Various four-layered network models having different network configurations were tested. Network configuration such as the number neurons, transfer functions, learning rate and momentum constant were determined heuristically. The syntax to represent the network configuration is written in the following form.

net=newff (minmax, [pn], {T1,T2,T3}, λ)

Where: p= number of nodes in the first layer
n= number of nodes in the first layer
T1, T2, T3=transfer functions for layers 1, 2, 3
λ = training technique

The general features for the input matrix are prepared in the following form:

$$P=\begin{bmatrix} x_{11} & x_{12}\ldots\ldots\ldots\ldots\ldots\ldots & x_{1n} \\ x_{21} & x_{22}\ldots\ldots\ldots\ldots\ldots\ldots & x_{2n} \\ x_{31} & x_{32}\ldots\ldots\ldots\ldots\ldots\ldots & x_{3n} \end{bmatrix}$$

Where:

$x_{11}\ldots\ldots x_{1n}$ = Load (Qd)
$x_{21}\ldots x_{2n}$ = Voltage magnitude (Vm(Bus_no))
$x_{31}\ldots x_{3n}$ = Total Loss

The targeted output, denoted by t is given in the following matrix form:

$$t=\begin{bmatrix} c_1 & c_2\ldots\ldots\ldots\ldots\ldots\ldots & c_n \end{bmatrix}$$

Where:

$c_1\ldots\ldots\ldots c_n$ = Minimum Singular Value (MSV)

2.1.4 Indicator Matrix

Data indicator is a factor that helps the convergence of ANN training process [7, 8]. It is necessary to avoid the ANN solution from diverging and produce undesirable results. There are three indicators introduced to the original input data. The indicators are The Load Bus, Voltage Magnitude and also Total Loss. For the

Minimum Singular Value will introduced to the target data. The input data indicator is a matrix of size [k x n] where k denotes the entire indicator from Load Bus, Voltage Magnitude and Total Loss. For the target data indicator is a matrix of size [j x n] where j represents the minimum singular value (MSV) value. For this study, the matrices would be in the form of [4 x n]. The indicators prove to be useful in the study as they help in the convergence of the ANN training process. Without these features, it would cause a slow or even failure of the convergence during the training process.

2.1.5 System Algorithm

The training and testing processes are embedded together in a single algorithm. The whole processes are represented in the form of a flowchart as in Fig 2 below.

2.1.6 Training Process

The training can be made more efficient if certain preprocessing steps are performed. Depending on the steps, the data are normalized so that they always fall within a specified range. The normalize equation embedded in Matrix toolbox is given as:

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pn= 2 * (p-minp)/(maxp-minp) -1 ;
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Where: p=input data

For this study, the data is preprocessed using their min and max values giving the data in the range of [-1, 1]. After training, the results can be seen in its original form by performing the post-processing step (de-normalize). Other processing routines include using the mean & standard deviation and principal component analysis. The network is trained until it achieves a very small error. The network is then saved for the testing process.

2.1.7 Testing Process

Testing process is carried out to measure the performance of the developed network. This can be achieved by either measuring the errors obtained during the training, validation and test sets; or by performing a linear regression analysis. Before the testing can be done, though, the data should be preprocessed so that they are transformed according to the min and max values of the training data. A fully trained network should be able to predict voltage collapse using minimum singular value (MSV). However, it should be noted that developed neural network may not necessarily perform well during the testing in which case, re-training is essential.

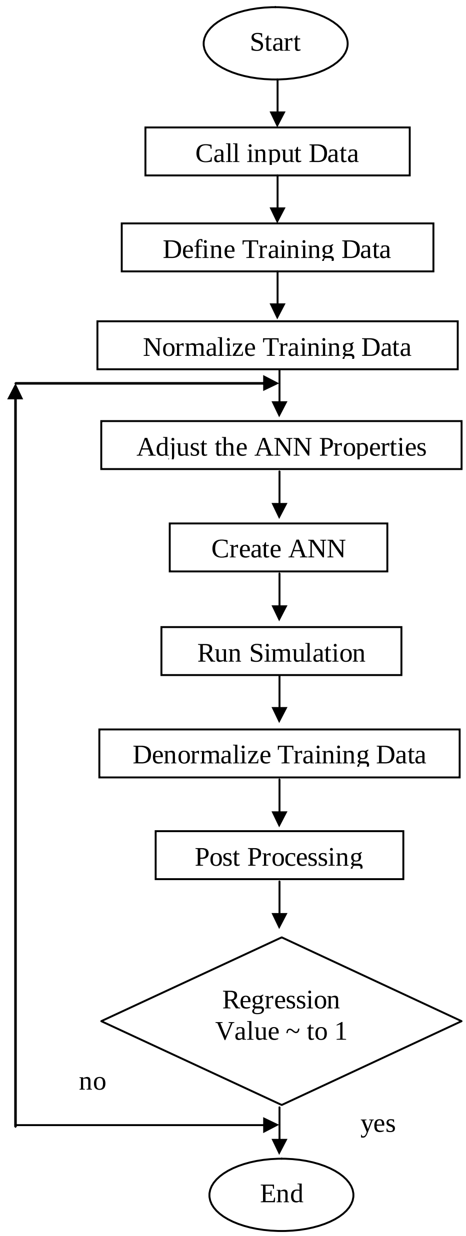

Fig 2: System Algorithm

3. RESULT & DISCUSSIONS

In this experiment, the data was randomly selected from a pool of database collected from the IEEE 30-BUS TEST SYSTEM (American Electric Power). 584 patterns were utilized for training the network for 8 buses while 357 patterns were employed for the testing process for 5 buses. The data were divided into two sets, one for training and remaining data will be used for testing.

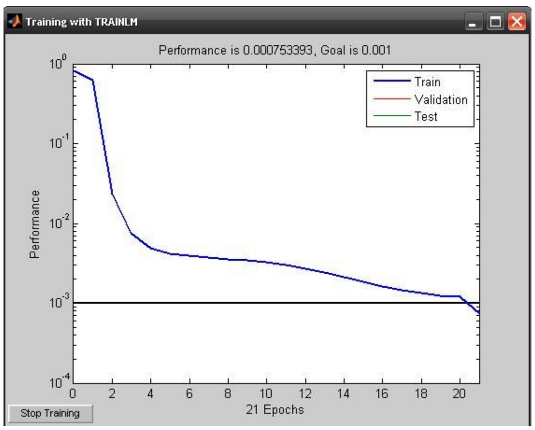

Fig 4: Mean Square Error plot

The Mean Square Error (MSE) plot above demonstrates how fast the prediction error and network training converge. Training was initially done for 1000 iterations and MSE during the max value is 2.5264 and during the min value is 1.4683.

3.1.1 Table for Actual & Predicted output for Process & Testing Process

This is the result for training and testing processes. It shows that the ANN can predicted that the value of the actual output always same like the predicted one. Table 1 below was apart of 584 patterns for training and 357 patterns for testing.

Training		Testing	
Actual	Predicted	Actual	Predicted
2.3121	2.3200	2.3096	2.3203
2.3105	2.3186	2.3074	2.3191
2.3083	2.2992	2.3047	2.2997
2.3065	2.2978	2.3024	2.2985
2.3047	2.2964	2.3000	2.2972
2.3027	2.2951	2.2977	2.2960
2.3007	2.2937	2.2953	2.2947
2.2986	2.2923	2.2930	2.2934
2.2965	2.2909	2.2906	2.2922
2.2942	2.2895	2.2881	2.2909
2.2920	2.2881	2.2857	2.2896
2.2896	2.2867	2.2833	2.2884
2.2872	2.2853	2.2808	2.2871
2.2848	2.2839	2.2784	2.2858
2.2823	2.2824	2.2759	2.2845
2.2798	2.2810	2.2735	2.2832

Table 1: The Actual & predicted value for training and testing process.

3.1.2 Training Process & Testing Process

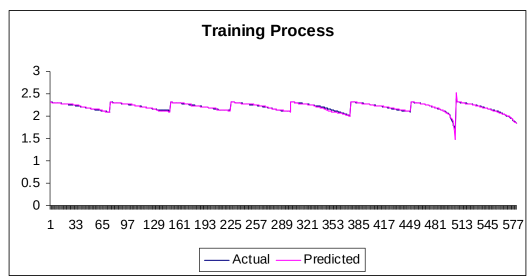

Fig 5: The Actual & Predicted value for training process

Fig 5 above shows that the actual and predicted value taken for 584 patterns for training. It shows that the actual value almost same with the predicted value. The mean average accuracy is 99.91%.

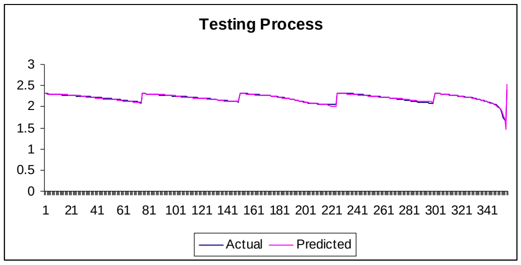

Fig 6: The Actual & Predicted value for testing process

Fig 6 above shows that the actual and predicted value taken for 357 patterns for testing. It shows that the actual value almost same with the predicted value. The mean average accuracy is 99.93 %.

4. CONCLUSIONS

This study has shown that using ANN it can predict successfully the voltage collapse and can detect voltage instability in the power system based on the Minimum Singular Value (MSV). It can be characterized by fast computation and high ability to generalize. Using a heuristic technique it will determine different network structures, training algorithm and all the activation functions. The end results were excellent, and could be possibly used for other power system problems.

5. ACKNOWLEDGEMENTS

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