Analysis of Steady State Stability of Power System using Artificial Neural Network

N Aishwarya[1],Manjula S Sureban[2]

1 P.G. Scholar, Department of Electrical and Electronics Engineering, SDMCET, Dharwad, India
2 Asst.Professor, Department of Electrical and Electronics Engineering, SDMCET, Dharwad, India

Abstract—Developed societies of today need an ever-increasing supply of electrical power, and demand has been increasing every year. To satisfy this increasing demand very complex systems are built. Successful operation of such complex system depends largely on the ability of that system to provide reliable and continuous supply to the loads. Ideally all the loads must be fed at constant voltage and frequency at all times. In this scenario, meeting the electric power demand is not the only criteria but also it is the responsibility of the power system engineers to provide a stable and quality power to the consumers. These issues highlight the necessity of analyzing the power system stability. In this paper analysis of steady state stability is carried out by using swing equation and the data obtained from analytical procedure is used to train Artificial Neural Network(ANN) so that system steady state stability status is determined.

Index Terms—Power System, Steady state,Stability, Artificial Nueral Network

◆

1 INTRODUCTION

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most of the system variables bounded so that practically the entire system remains intact". The disturbances mentioned in the definition could be faults, load changes, generator outages, line outages, voltage collapse or some combination of these. From the classical point of view power system instability can be seen as loss of synchronism (i.e., some synchronous machines going out of step) when the system is subjected to a particular disturbance. Three type of stability are of concern: Steady state, transient and dynamic stability

Steady-state Stability :- Steady-state stability relates to the response of synchronous machine to a gradually increasing load. It is basically concerned with the determination of the upper limit of machine loading without losing synchronism, provided the loading is increased gradually.

Dynamic Stability:- Dynamic stability involves the response to small disturbances that occur on the system, producing oscillations. The system is said to be dynamically stable if theses oscillations do not acquire more than certain amplitude and die out quickly. If these oscillations continuously grow in amplitude, the system is dynamically unstable. The source of this type of instability is usually an interconnection between control systems.

Transient Stability :- Transient stability involves the response to large disturbances, which may cause rather large changes in rotor speeds, power angles and power transfers. Transient stability is a fast phenomenon usually evident within a few second.

2 STEADY-STATE STABILITY

The steady state stability limit of a particular circuit of a power system defined as the maximum power that can be transmitted to the receiving end without loss of synchronism.
Now consider equation (1),

$$M(pu).\frac{d^2y}{dx^2} = (Pi-Pe) \qquad (1)$$

Where $M(pu) = \frac{H}{\pi f}$

And $Pe = \frac{|Eg||Vt|\ sin\delta}{xd}$

Let the system be operating with steady power transfer of Peo=Pi with torque angle δ0. Assume a small increment ΔP in the electric power with the input from the prime mover remaining fixed at Pi causing the torque angle to change to (δ0 +Δδ). Linearing the operating point (Pe0 , δ0) we can writ

$$\Delta Pe = \frac{\partial Pe}{\partial \delta}_0 \ \Delta\delta$$

The excursion of $\Delta\delta$ are then described by

$$M.\frac{d^2y}{dx^2} = Pi - (Peo + \Delta Pe) = -\Delta Pe$$

$$M.\frac{d^2y}{dx^2} + \frac{\partial Pe}{\partial \delta}_0 \Delta\delta = 0$$

$$[Mp^2 + \frac{\partial Pe}{\partial \delta}_0] \, \Delta\delta = 0$$

The system stability to small changes is determined from the characteristics equation

$$[\mathrm{M}p^2+\frac{\partial \mathrm{Pe}}{\partial \delta}_0]=0$$

Where two roots are

$$p=\pm[-\frac{\frac{\partial \mathrm{Pe}}{\partial \delta}_0}{\mathrm{M}}]^{1/2}$$

As long as $\left(\frac{\partial \mathrm{Pe}}{\partial \delta}_0\right)$ is positive, the roots are purely imaginary and conjugate and system behavior is oscillatory about δ_0.Line resistance and damper windings of machine cause the system oscillations to decay. The system is therefore stable for a small increment in power so long as $\left(\frac{\partial \mathrm{Pe}}{\partial \delta}_0\right) > 0$.

When $\left(\frac{\partial \mathrm{Pe}}{\partial \delta}_0\right)$ is negative, the roots are real,one positive and the other negative but of equal magnitude.The torque angle therefore increases without bound upon occurance of a small power increment and the synchronism is soon lost.The system is therefore unstable for $\left(\frac{\partial \mathrm{Pe}}{\partial \delta}_0\right) < 0$.

3 CASE STUDY

A generator is connected to an infinite bus through an external impedance of jxe. The generator is represented by a voltage source Eg$\angle\delta$ in series with a reactance xg.If Eg=Eb (infinite bus voltage)=1.0, xe=-0.5, xg=0.3 (all in p.u), for Pb=1.0 p.u, it is required to find the equilibrium values of δ, in the range of $(-\pi,\pi)$ and test their stability (Pb is the received power at the infinite bus). Infinite bus angle is assumed as zero.

Solution:

The expreesion for the electrical power output, Pe is given by

$$\mathrm{Pe}=\frac{|Eg||Eb|\, sin\delta}{xe+xg}=Pb$$

Substituting the values for Eg, Eb, xe and xg,

Pe=-5sinδ

For Pb=Pe=1.0 pu, the equilibrium points are,

$\delta e^1 = -11.54°$, $\delta e^2 = -168.46°$

Testing for stability,

$\mathrm{dPe/d}\delta|_{\delta=}\delta e^1 = -5 \cos\delta e^1 < 0$

$\mathrm{dPe/d}\delta|_{\delta=}\delta e^2 = -5 \cos\delta e^2 > 0$

Hence $\delta e^1 = -11.54°$, is an unstable equilibrium point (UEP) and $\delta e^2 = -168.46°$ is a stable equilibrium point (SEP).

Note that whenever (xe+xg) > 0, the SEP corresponds to the solution with smaller absolute value of δ,while for (xg+xg) < 0, SEP corresponds to the solution with larger absolute value of δ.The current supplied by the generator (and losses) are higher for the case with larger (absolute) angle,Hence,it is fortunate that, for all practical purposes, the external reactance is positive (inductive), viewed from generator terminals. This results in lower losses as compared to the case if the net reactance was capacitive.

Note that, negative xe can result from overcompensation of the transmission line reactance using series capacitors (although this is never done in practice).

4 ANALYSIS USING ARTIFICIAL NEURAL NETWORK

An ANN, which simulates the behavior of human brain, is an interconnected network of neurons. A neuron is a summing junction of n weighted inputs and a weighted bias to yield a single output. A set of neurons forms a layer. A typical architecture of ANN would have inputs, one output layer, and one or more hidden layers. This type of ANN is known as Multi-Layer Perceptron Feed-Forward (MLPFF). The input layer receives information from an external source and passes it to the hidden layer where the information will be processed. The hidden layer passes the processed information to the output layer where the latter sends the results out to an external receptor, which is the power system.

Recently, there has been considerable interest in the application of Artificial Neural Network (ANN) to power system. ANN has the ability to classify complex relationships properly. The relationships classified by ANN are highly nonlinear and often result from large mathematical models. Once trained, the ANN can classify new data much faster than it would be possible by solving the model analytically: An integrated based systems, ANN, and conventional power system solution methodologies have potential to provide real-time optimization and control of power system.This paper presents the application of ANN to for steady state stability studies.

5 RESULTS AND DISCUSSION

5.1 Data set Preparation:

As explained in the case study one of the equilibrium value obtained from dynamic equation solution results in stable operation and another one results in unstable operation of a system. Hence thirty values of external reactance and generator reactance are considered as input and using MATLAB code corresponding status of system is determined and for unstable condition target is fixed as 0 and for stable target is fixed as 1. Such data is used for training pattern recognition tool of ANN toolbox using MATLAB. Once the ANN is trained the same can be used to display the status whether it is stable or unstable for new input.

5.2 INPUTS:

INPUT 31 SAMPLES	
Xe	Xg
-0.1	0.1
0.2	0.1
-0.3	-0.2
0.4	0.3
-0.4	0.2
0.5	0.4
-0.5	0.1
0.3	0.1
-0.6	0.3
0.6	-0.2
0.6	0.3
0.15	0.2
-0.25	-0.1
-0.45	-0.35
-0.32	0.21
0.55	0.4
0.21	-0.32
-0.45	-0.15
0.33	0.46
0.45	0.53
0.35	-0.27
-0.38	-0.12
-0.59	-0.38
-0.26	0.54
-1.2	0.9
-0.5	0.3
0.33	0.43
-0.51	-0.32
-0.25	0.41

Table(1): Input external reactance and generator reactancedata

5.3 TARGETS :

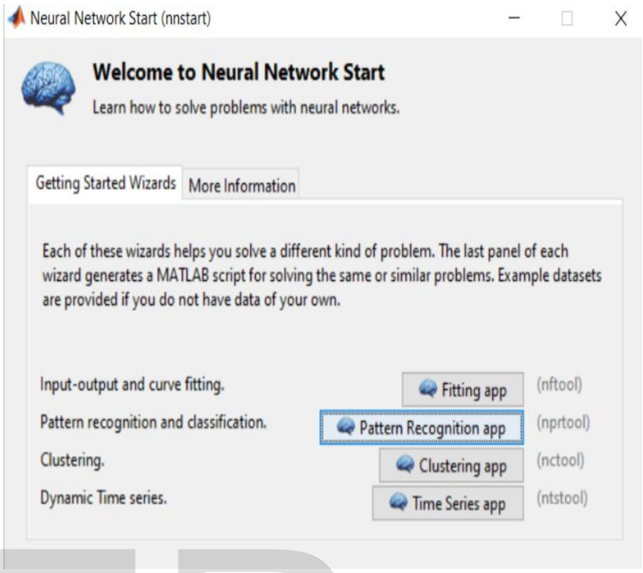
TARGETS 31 SAMPLES SYSTEM CONDITION
1
1
0
1
0
1
0
1
0
1
1
1
0
0
0
1
0
0
1
1
1
0
0
1
0
0
1
0
1
1
0

Table(2): system condition targets

6 TRAINING ANN USING PATTERN RECOGNITION TOOL IN MATLAB

STEP 6.1:

In the welcome window of ANN toolbox pattern recognition app is selected as shown in the figure1.



Neural Network Start (nnstart)

Welcome to Neural Network Start

Learn how to solve problems with neural networks.

Getting Started Wizards | More Information

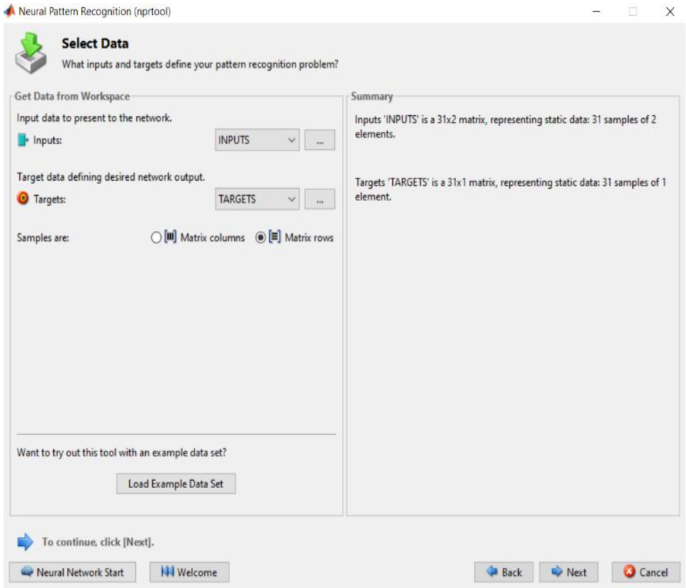
Each of these wizards helps you solve a different kind of problem. The last panel of each wizard generates a MATLAB script for solving the same or similar problems. Example datasets are provided if you do not have data of your own.

Input-output and curve fitting. — Fitting app (nftool)
Pattern recognition and classification. — Pattern Recognition app (nprtool)
Clustering. — Clustering app (nctool)
Dynamic Time series. — Time Series app (ntstool)

Fig.1: Start to Neural Network

STEP 6.2:

The prepared data set in the excel sheet is imported through import wizard of matlab as shown in figure 2 and 3



Neural Pattern Recognition (nprtool)

Select Data

What inputs and targets define your pattern recognition problem?

Get Data from Workspace

Input data to present to the network.
Inputs: INPUTS

Target data defining desired network output.
Targets: TARGETS

Samples are: ○ Matrix columns ● Matrix rows

Want to try out this tool with an example data set?

Summary

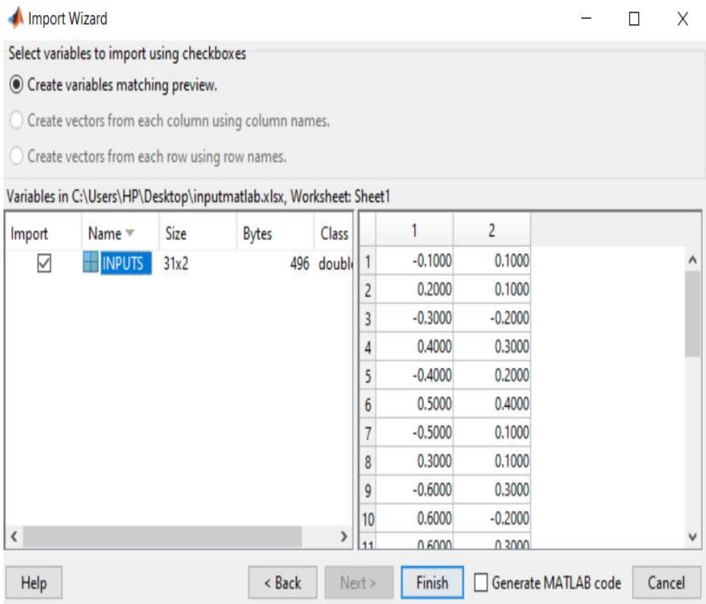
Inputs 'INPUTS' is a 31x2 matrix, representing static data: 31 samples of 2 elements.

Targets 'TARGETS' is a 31x1 matrix, representing static data: 31 samples of 1 element.

To continue, click [Next].

Fig.2: Importing the INPUT and TARGET variables

STEP 6.3:



Import Wizard

Select variables to import using checkboxes

● Create variables matching preview.

○ Create vectors from each column using column names.

○ Create vectors from each row using row names.

Variables in C:\Users\HP\Desktop\inputmatlab.xlsx, Worksheet: Sheet1

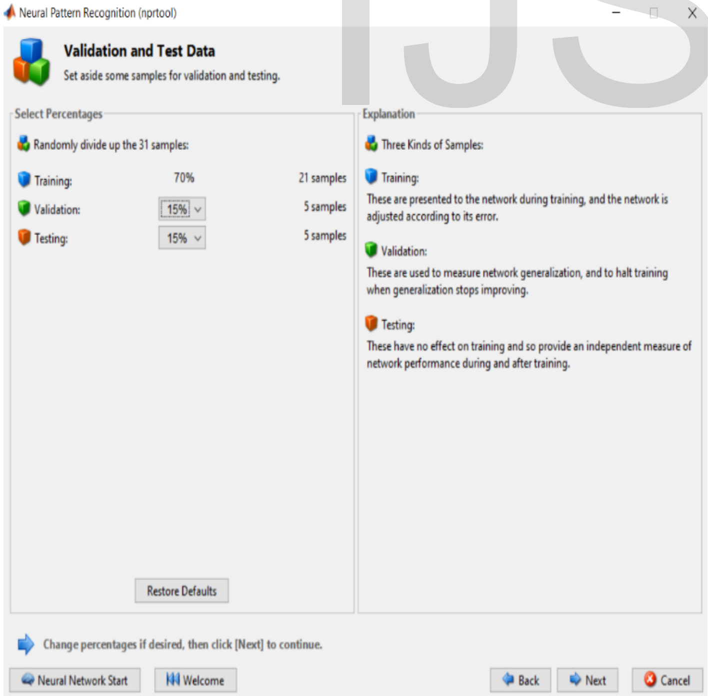
Import	Name	Size	Bytes	Class
☑	INPUTS	31x2	496	doubl

	1	2
1	-0.1000	0.1000
2	0.2000	0.1000
3	-0.3000	-0.2000
4	0.4000	0.3000
5	-0.4000	0.2000
6	0.5000	0.4000
7	-0.5000	0.1000
8	0.3000	0.1000
9	-0.6000	0.3000
10	0.6000	-0.2000

Fig.3: Selecting inputs and targets for Pattern recognition Problem.

STEP 6.4:

The percentage of data used for training validation and testing are fixed then ANN is trained using suitable algorithm as shown in figure 4.



Neural Pattern Recognition (nprtool)

Validation and Test Data

Set aside some samples for validation and testing.

Select Percentages

Randomly divide up the 31 samples:

Training:	70%	21 samples
Validation:	15%	5 samples
Testing:	15%	5 samples

Explanation

Three Kinds of Samples:

Training:
These are presented to the network during training, and the network is adjusted according to its error.

Validation:
These are used to measure network generalization, and to halt training when generalization stops improving.

Testing:
These have no effect on training and so provide an independent measure of network performance during and after training.

Change percentages if desired, then click [Next] to continue.

Fig.4: Validation and Test Data

STEP 6.5:

Figure 5 shows the Trained Neural Network, In this the number of Neurons is choosen as 10 so as to have minimum error for trained network.

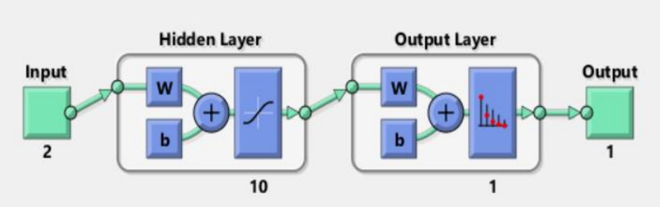


Fig.5: Trained Neural Network

Validating the performance of trained network

The colored lines in each axis of figure 6 represent the ROC curves. The *ROC curve* is a plot of the true positive rate versus the false positive rate (1 - specificity) as the threshold is varied. A perfect test would show points in the upper-left corner, with 100% sensitivity and 100% specificity. For this problem, the network performs very well.

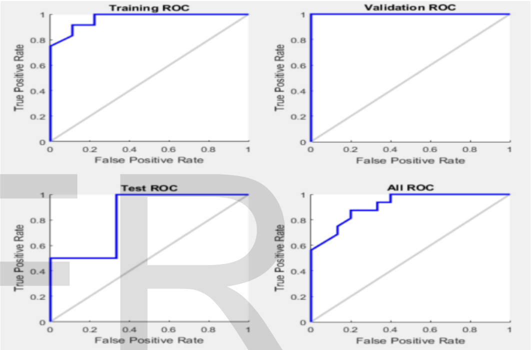
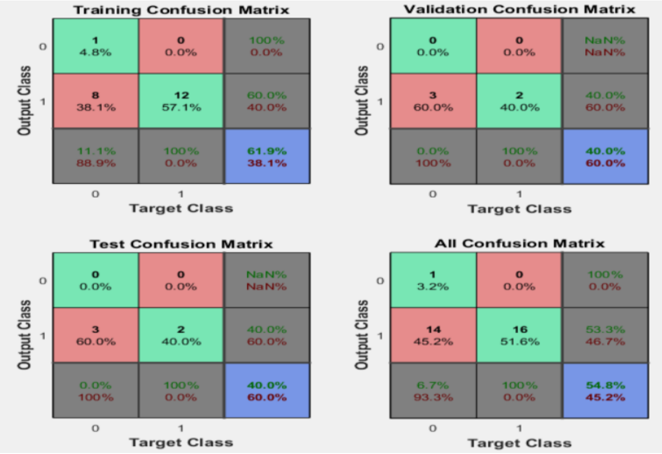


Fig.6: Receiving Operating Characteristics

The figure 7 shows the confusion matrices for training, testing, and validation, and the three kinds of data combined. The network outputs are very accurate, as wecan see by the high numbers of correct responses in the green squares and the low numbers of incorrect responses in the red squares. The lower right blue squares illustrate the overall accuracies.



Training Confusion Matrix

Output Class \ Target Class	0	1	
0	1 4.8%	0 0.0%	100% 0.0%
1	8 38.1%	12 57.1%	60.0% 40.0%
	11.1% 88.9%	100% 0.0%	61.9% 38.1%

Validation Confusion Matrix

Output Class \ Target Class	0	1	
0	0 0.0%	0 0.0%	NaN% NaN%
1	3 60.0%	2 40.0%	40.0% 60.0%
	0.0% 100%	100% 0.0%	40.0% 60.0%

Test Confusion Matrix

Output Class \ Target Class	0	1	
0	0 0.0%	0 0.0%	NaN% NaN%
1	3 60.0%	2 40.0%	40.0% 60.0%
	0.0% 100%	100% 0.0%	40.0% 60.0%

All Confusion Matrix

Output Class \ Target Class	0	1	
0	1 3.2%	0 0.0%	100% 0.0%
1	14 45.2%	16 51.6%	53.3% 46.7%
	6.7% 93.3%	100% 0.0%	54.8% 45.2%

Fig.7: Confusion plot

7 RESULTS FOR NEW DATA

Onec the ANN is traned correctly the simulink diagram is generated and the same is used to produce system stability status for new set of input. As shown in figure 8 for one set of input it is showing the status as one which means system is stable which is verified analytically to ensure the correctness of trained network.

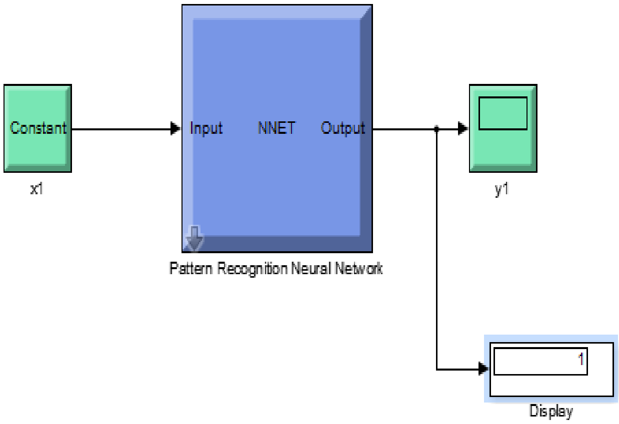


Fig.8: Simulink diagram for Neural Network

8 CONCLUSION

Due to economic reasons arising out of deregulation and open market of electricity, modern day power systems are being operated closer to their stability limits. Power system stability is one of the challenging problems faced by the utilities. Online stability monitoring is becoming an integral part of the modern day Energy Management Systems (EMS). There has been works reported in the literature on the use of analytical methods to monitor stability of a power system on a real time basis. The methods are generally complex in nature and pose considerable computational burden on the EMS. An important issue with the use of analytical methods is the computational time, even with the state-of-the art processors. The estimated results obtained from ANN showed that this technique is able to predict the steady-state stability of a system with a reasonable degree of accuracy. Since ANNs have high computation rates, parallel distributed processing, fault tolerance, and adaptive capability, they are excellent alternatives for real-time application.

REFERENCES

[1] Chao-Rong Chen, Yuan-Yih Hsu, Senior member department of Electrical Engineering, National Taiwan University, Taipei, Taiwan, ROC "Synchronous Machine Steady State Stability Using an Artificial Neural Network" IEEE Transaction on Energy Conversion, Vol 6, No 1, March 1991.

[2] J.JARJIS, student member IEEE and F.D.GALIANA, member, IEEE Dept of electrical Engineering McGill University, Montreal, Quebec, Canada. " QUANTITATIVE ANALYSIS OF STEADY STATE STABIL IN POWER NETWORKS", IEEE transaction on power Apparatus 1981 System, Vol PAS-100, No. 1, January.

[3] Md Multan Biswas, Kamol Kanto Das Bangladesh University of Engineering and technology(BEUT), Dhaka, Bangladesh, "steady State Stability Analysis of Power System Under Various Fault Condition', Global Journal of Research in Engineering, Vol 11, Issue 6, Version 1.0,November 2011.

[4] Manish Mishra, Monika Srivastava, Electrical Department, "Dr. VerendraSwarup group of Institutions, Unnao, India, "A View of Artificial Neural Network", IEEE international conference on advance in Engineering and Technology Research, August 01-02, 2014.

[5] B. Jeyasurya, Artificial Neural Network og Power System Steady-stateVoltage Instability Evaluation, Electrical Power and Energy System, 2010, 29:85-90.

[6] SafaaAbdulgabbar, Dr. Ali Hussian Ahmed, "ANN Based Power System Stability Improvement", International Journal of Engineering and Innovative Technology(IJEIT), Volume 7, Issue 4, October 2017.

[7] Emmanuel P Kejariwal, "Steady State security assessment of power system using neural networks", TENCON 89 Fourth IEEE Region 10 International Conference, 22-24 Nov, 1989 Pages:742-745.

[8] J M G SA DA Costa, N Munro "Pattern recognition in power system security", Electrical Power & Energy System VOL-6, No 1, January 1984.

[9] A.K. Sinha, "A Hierarchical clustering-based pattern Recognition Scheme for power system security assessment", IEEE transaction on power system vol 1, feb 1989.

[10] AAFouad, Qin Zhou Jennifer Davidson, "Application of ANN in power system security and vulnerability assessment", IEEE transaction on power system Vol 9, No 1, February 1994.