International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

IJIEMR Transactions, online available on 05th Mar 2023. Link
:http://www.ijiemr.org/downloads.php?vol=Volume-12&issue=Issue 04

10.48047/IJIEMR/V12/ISSUE 03/103

Title **IMPROVEMENT OF DYNAMIC STABILITY USING ANN BASED POWER SYSTEM STABILIZER**

Volume 12, ISSUE 04, Pages: 716-722

Paper Authors

Mrs. I. Revathi G. Aravind Reddy, B. Mohan Kumar, I. Ganesh, K. Rahul

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

IMPROVEMENT OF DYNAMIC STABILITY USING ANN BASED POWER SYSTEM STABILIZER

Mrs. I. Revathi, Faulty, Department of EEE,
Vasireddy Venkatadri Institute of Technology, Nambur, Guntur Dt., Andhra Pradesh.

G. Aravind Reddy, B. Mohan Kumar, I. Ganesh, K. Rahul
[2,3,4,5] UG Students, Department of EEE,
Vasireddy Venkatadri Institute of Technology, Nambur, Guntur Dt., Andhra Pradesh.
[1] **E-Mail ID:** gopireddyaravindreddy91@gmail.com

Abstract

An artificial intelligent power system stabilizer is designed to damp the low frequency oscillations in the range 0.2 to 2.5 Hz. The low frequency oscillations are introduced in the power system due to disturbances, usage of fast acting regulators and interconnection of different power plants with weak tie lines. The low frequency oscillations are introduced, persist and continue to grow a level of complete shutdown of the system if adequate damping is not provided. The impact of these oscillations is more in multi machine system rather than single machine system. The objective of the Power System Stabilizer is to generate a stabilizing signal, which produces a damping torque component on the generator shaft. In order to damp out oscillations different conventional controllers are used such as lead lag PSS which are slow and can be used for limited operating range. The artificial intelligent techniques have been used to damp the low frequency oscillations which are fast and can be used for all operating conditions. In this project lead- lag, ANN based power system stabilizers are designed and simulated in MATLAB environment. The ANN is trained with Error Back Propagation (EBP) training algorithm. The Artificial neural network which is used here consists one hidden layer. The speed of the generator was taken as input and the output is stabilized value of voltage. It is trained by the various pairs of inputs with respect to different types of system's disturbances and the performances of the ANN with PSS are compared with the basic system having stabilizer as absent and also with CPSS. The result concluded that the proposed model can assure better damping of the electrical power system over a wide range of operating conditions and consequently improves the system performance dynamically.

Keywords: — SMIB power system, AVR, PSS, ANN

I. Introduction

Most of the new generating units added to electric utility systems were equipped with continuously acting voltage regulators. As these units came to constitute a large percentage of generating capacity, it became apparent that the voltage regulator action had adetrimental impact upon the dynamic stability of the power system. Oscillations of low frequency or low magnitude persists for long time periods and in some other cases can hinder the capability of power transfer. Stabilizers are developed to include damping the oscillations through modulation of the excitation of the generator. In order to provide damping, the anti-roll bar must produce an electrical torque component in the rotor that is in phase with the change in speed. The application of PSS is to generate an additional stabilizing signal that is applied to the excitation system or control loop of the power generating unit to produce positive damping.. PSS is used in conventional power systems and has helped to improve the dynamic stability of power systems. The PIDPSS values are determined based on the linearized model of the system around the normal operating point where they can perform in high efficiency. Because the power system is a highly non-linear system, with configureuration and values changing over time, the design of PIDPSS based on a model of the electrical power system cannot be assure its performance in the environment of actual operation. To improve the performance of PIDPSS, numerous techniques have been proposed fordeveloping their design, by other intelligent optimization methods.

Optimal control of the system cannot be applied directly to the PID based PSS designing. But, it is being so much difficult for PID gains to be tuned, because most of industrial systems are often being burdened with so many problems like complexity In its structure, non-linearities and some other uncertainities. In parallel with other industries, the PID controllers are commonly used in power systems control and operation. However, because of increasing physical setups, functionality and complexities in different power systems, it is analyzed to be very difficult to maintain a required level of system's performance in different conditions of operation ofsystem using conventional PID which is tuned and based on controllers of power system. In a try to maintain a wide range of different operating conditions, some techniques which are developed by choosing Neural Network as a base has been developed as one of therequired solution to the problem mentioned above, and thereby using the neural network based technique mathematical model of the any given system can be avoided ,along with providing better performance underin different and various operating conditions of the system.

II. INFINITE BUS FOR A SINGLEMACHINE (SMIB)

This research investigates a single machine connected to a infinite bus power system . It is characterized by a group of similar machines installed in a power station that are linked by a transmission line to a huge transmission network,and the developed system is reduced to a system of SMIB utilizing thevenin's equivalent network of the transmission network [9]. Figure 1 showsa typical single-line representation of the system configuration. [9] For SMIB, the micro signals mathematical models are constructed in many stages, as follows [9]:

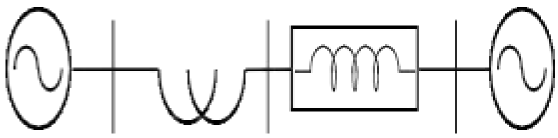

Figure .1 : Synchronous machinewhich is connected to infinite bus

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

A. Proposed System classical model The generator's classical model is depictedin figure.2 [9], The current in line is as below:

$$\tilde{I}_t = \frac{E'\angle 0^\circ - E_B\angle -\delta}{jX_T} \quad (1)$$

$$S' = P + jQ' = \tilde{E}'\tilde{I}^*_t = \frac{E' E_B \sin\delta}{X_T} + j\frac{E'(E' - E_B\cos\delta)}{X_T} \quad (2)$$

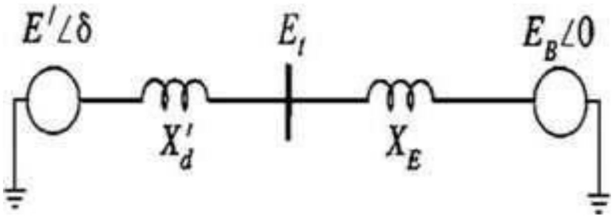

Figure.2 Classical model of generator

Equation of the classical model of the proposed system's generator can be linearized as below:

$$\frac{d}{dt}\Delta\omega_r = \frac{1}{2H}(T_m - T_e - K_D\Delta\omega_r) \quad (3)$$

$$\frac{d}{dt}\delta = \omega_0\Delta\omega_r \quad (4)$$

From above, System's state equation is:

$$\frac{d}{dt}\begin{bmatrix}\Delta\omega_r \\ \Delta\delta\end{bmatrix} = \begin{bmatrix}-\frac{K_D}{2H} & -\frac{K_s}{2H} \\ \omega_0 & 0\end{bmatrix}\begin{bmatrix}\Delta\omega_r \\ \Delta\delta\end{bmatrix} + \begin{bmatrix}\frac{1}{2H} \\ 0\end{bmatrix}\Delta T_m$$

(5)

By applying the equations,the system's state equations are:

$$A = \begin{bmatrix}0 & -0.1089 \\ 376.991 & 0\end{bmatrix}, B = \begin{bmatrix}0.1429 \\ 0\end{bmatrix}$$

(6)

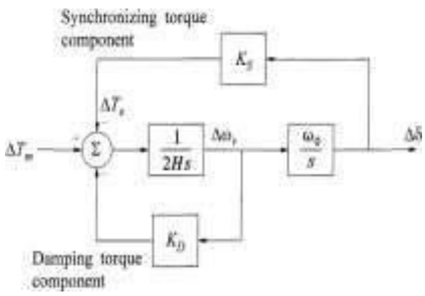

Figure.3 classicalmodel ofsystem generator

III. THE FIELD VOLTAGE SYSTEM

To construct the model of the system, evaluate performance of the system, including the influence of field flux change, while ignoring effects and sets a constant field voltage; hence, the produced system's state space model is as follows [9]:

$$\begin{bmatrix}\Delta\dot{\omega}_r \\ \Delta\dot{\delta} \\ \Delta\dot{\psi}_{fd}\end{bmatrix} = \begin{bmatrix}a_{11} & a_{12} & a_{13} \\ a_{21} & 0 & 0 \\ 0 & a_{32} & a_{33}\end{bmatrix}\begin{bmatrix}\Delta\omega_r \\ \Delta\delta \\ \Delta\psi_{fd}\end{bmatrix} + \begin{bmatrix}b_{11} & 0 \\ 0 & 0 \\ 0 & b_{32}\end{bmatrix}\begin{bmatrix}\Delta T_m \\ \Delta E_{fd}\end{bmatrix}$$

(7)

When,

$$\frac{d}{dt}\psi_{fd} = \omega_0\left(e_{fd} - R_{fd}i_{fd}\right) = \frac{\omega_0 R_{fd}}{L_{adu}}E_{fd} - \omega_0 R_{fd} i_{fd} \quad (8)$$

From above equation and information:

$$A = \begin{bmatrix} 0 & -0.1089 & -0.1250 \\ 376.991 & 0 & 0 \\ 0 & -0.1967 & -0.4133 \end{bmatrix}, B = \begin{bmatrix} 0.1429 \\ 0 \\ 0 \end{bmatrix} \quad (9)$$

It is shown in block diagram:

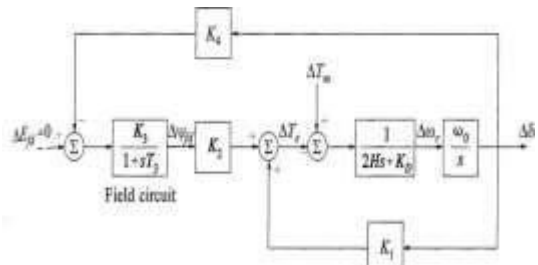

Figure.4, Representation of system along with excitation system

The system created along with the excitation system, which in this case is not a dynamic excitation system, will be developed byusing simplest form that consists the elements required for modeling a high level of exciter gain without derivative feedback, as well as the time constant of transducer of terminal voltage It represents a AVR as shown in figure 5.

IV. AVR : AUTOMATICVOLTAGE REGULATOR

By adjusting machine excitation,this control aims to keep the voltage of the system within given limits. The terminal voltage error and its derivative serve as input signals for voltage control. The terminal voltage magnitude falls as the reactive power demand fluctuates. The magnitude of the voltage is measured and compared with a d.c signal using a potential transformer on one phase rectified. The amplified error signal controls the exciter, causing the voltage at the exciter terminal to rise. So, the generator field current increases, causing the emf generated to rise. Non- active power is increased to a new level, resulting in the desired output voltage [10]. System's state equation:

$$\begin{bmatrix} \Delta\dot{\omega}_r \\ \Delta\dot{\delta} \\ \Delta\dot{\psi}_{fd} \\ \Delta\dot{v}_1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 \\ a_{21} & 0 & 0 & 0 \\ 0 & a_{32} & a_{33} & a_{34} \\ 0 & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} \Delta\omega_r \\ \Delta\delta \\ \Delta\psi_{fd} \\ \Delta v_1 \end{bmatrix} + \begin{bmatrix} b_1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \Delta T_m \quad (10)$$

The following matrices are generated using the equation provided :

1. System matrices without AVR:

$$A = \begin{bmatrix} 0 & -0.1089 & -0.1250 & 0 \\ 376.991 & 0 & 0 & 0 \\ 0 & -0.1967 & -0.4133 & -0.13708 \\ 0 & -7.2968 & 20.9090 & -50 \end{bmatrix}, B = \begin{bmatrix} 0.1429 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

2. System matrices With AVR:

$$A = \begin{bmatrix} 0 & -0.1089 & -0.1250 & 0 \\ 376.991 & 0 & 0 & 0 \\ 0 & -0.1967 & -0.4133 & -27.4175 \\ 0 & -7.2968 & 20.9090 & -50 \end{bmatrix}, B = \begin{bmatrix} 0.1429 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

In these instances, the system block diagram is as depicted in picture 5 [9]:

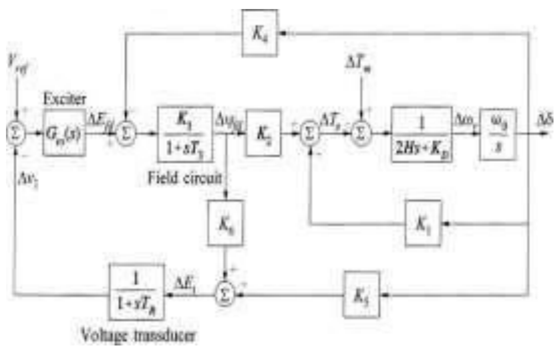

Figure.5: Block diagram of the proposedsystem along with excitor

V. STABILIZER OF THE POWER SYSTEM

The PSS is utilized to increase the low signal stability. A power system stabilizer's principal function is to reduce the oscillation of the rotor of the generator by regulating its supply with some other a stabilizing signals to provide signals of damping. When the voltage regulator produces a damping torque which is negative, causing oscillation and instability, the stabilizer must provide an electrical torque is in phase with the speed deviation of rotor.

VI. PSS STRUCTURE AND TUNING

The general power system stabilizer (PSS) block manages the excitation of the synchronous machine's rotor to moderate its oscillation. Power outages generate oscillation in power generators. The system must be suitably damped to remain stable. The output of PSS is a signal which is used to provide a additional input in the block of excitation (V-stab). PSS input signals might be variations in acceleration power or machine speed.

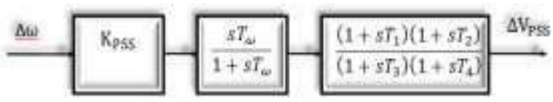

Figure.6 Structure of powersystem stabilizer

In order to compensate for the inherent lag between field excitation and electrical torque created by the PSS action, the PSS should give a moderate phase advance at frequencies of interest. Figure 6 depicts model that includes a low pass filter, a general gain, and a

The function as below:

- Gain: The gain k of the system determines the damping rate induced due to the system's stabilizer. The gain k range can be selected (20-200).

- Time constant: It is the time constant of the model's washout system's first order high pass filter in seconds (s). The high pass filter is to eliminate low frequencies from the signal of speed deviation, allowing the PSS to respond to fluctuations in speed. For general modes of oscillation, the time () is frequently set in between (1-2); if interarea modes are damped, it must be selected in between (10-20).

- Lead and lag time constants : The phase compensation system's time constants (T1,T2) are utilized to reduce for the lag in phase between the synchronous machine's electrical torque and excitation voltage.

The system's final state equation with the inclusion of a power system stabilizer is as follows:

$$\begin{bmatrix} \Delta\dot{\omega}_r \\ \Delta\dot{\delta} \\ \Delta\dot{\psi}_{fd} \\ \Delta\dot{v}1 \\ \Delta\dot{x}1 \\ \Delta\dot{x}2 \\ \Delta\dot{vs} \end{bmatrix} = \begin{bmatrix} 0 & a_{12} & a_{13} & 0 & 0 & 0 & 0 \\ a_{21} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & a_{32} & a_{33} & a_{34} & 0 & 0 & a_{37} \\ 0 & a_{42} & a_{43} & a_{44} & 0 & 0 & 0 \\ 0 & a_{52} & a_{53} & 0 & a_{55} & 0 & 0 \\ 0 & a_{62} & a_{63} & 0 & a_{65} & a_{66} & 0 \\ 0 & a_{72} & a_{73} & 0 & a_{75} & a_{76} & a_{77} \end{bmatrix} \begin{bmatrix} \Delta\omega_r \\ \Delta\delta \\ \Delta\psi_{fd} \\ \Delta v1 \\ \Delta x1 \\ \Delta x2 \\ \Delta vs \end{bmatrix} + \begin{bmatrix} b_{11} \\ 0 \\ 0 \\ 0 \\ b_{51} \\ b_{61} \\ b_{71} \end{bmatrix} \Delta Tm$$

A=

$$\begin{bmatrix} 0 & -0.1089 & -0.125 & 0 & 0 & 0 & 0 \\ 376.99 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.1967 & -0.4133 & -0.4133 & -27.4175 & 0 & -27.4175 \\ 0 & -7.2968 & 20.909 & -50 & 0 & 0 & 0 \\ 0 & -1.03455 & -1.1875 & 0 & -0.1 & 0 & 0 \\ 0 & -4.8279 & -5.54167 & 0 & 29.836 & -30.303 & 0 \\ 0 & -5.5902 & -6.41667 & 0 & 34.547 & -27.5689 & -7.5188 \end{bmatrix}$$

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

$$B = \begin{bmatrix} 0.14286 \\ 0 \\ 0 \\ 0 \\ 1.357143 \\ 1.357143 \\ 1.357143 \end{bmatrix}$$

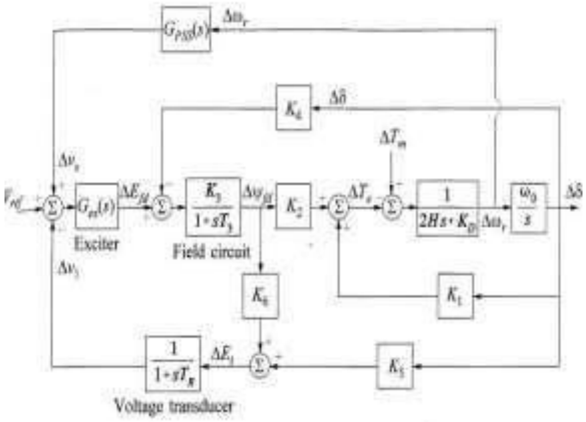

Figure.7 Block diagram of the system integrated with AVR and PSS

Heffron Phillip's proposed constants are six constants (-) that characterize the relationship between the voltage control equations and rotor speed of the machine. The machine settings and operational conditions determine them. (,,) are generally favorable. is more likely to be effective in situations where RE is high. Low to medium loadings are positive and low to externally added impedances is also positive. For medium to high externally added impedances and severe loads it is negative [9,12].

VII. ARTIFICIAL NEURAL NETWORK(ANN)

The ANN is a network which consists of neurons that communicate with one another in order to transfer and process data [13]. It is the network of connecting parts inspired by biological nervous system research. Neural networks are one of the choice to create computers that operate similarly to the human brain by including components that respond similarly to neurons . The conventional ANN model consists of an input layer with any no.of neurons, a no.of hidden layers along with any no.of neurons which is supported by the system for a given task, and the output layer that provides a specified output based on the sum of weights of all hidden layer neurons [13]. Because of their capacity to mimic complex interactions, ANNs outperform standard controller systems. Conventional controllers need a complete grasp of the controlled system's mathematical model, which are not to be available. Most of the ANN controllers, and also they do not require such values and are capable of properly handling complex systems.

VIII. RESULTS OF SIMULATION

MATLAB (R 2018) and Simulink version 7.11,and Artificial neural network software are used to generate simulation results. The Simulink model of the system along with constant field is shown in figure.8 below:

Simulation Model of Exciter with AVR

In this block diagram representation, the dynamic characteristics of the system are expressed in terms of the so-called K - constant.

K_1= - 0.12 K_2= 0.3 K_3= 1.4189 K_4= 9.5
K_5= 1.591 K_A= 200

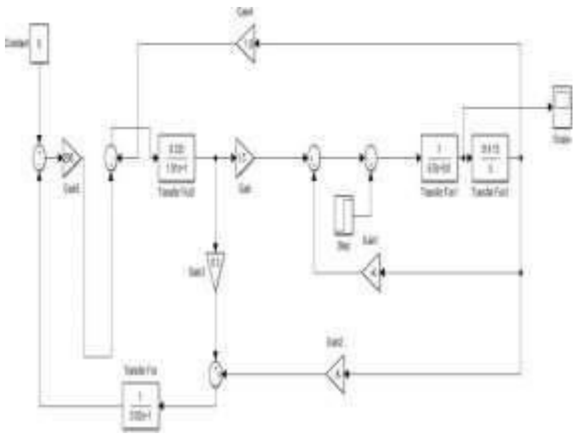

Figure 8: Simulation Model of Exciter With AVR

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

Rotor Speed Deviations:

The Rotor Speed deviations for single machine infinite bus system with exciter andAVR, when a step disturbance of 1p.uis shown in figure

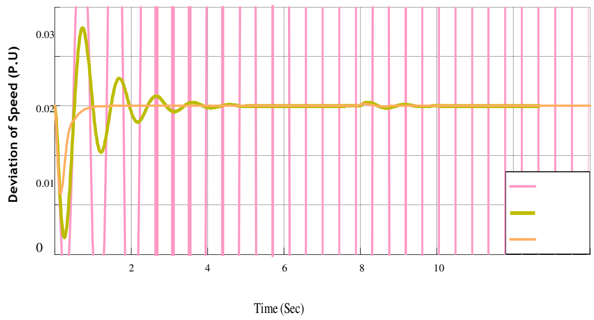

Figure: Rotor speed deviations of Exciter With AVR

Peak :- 0.02 pu , Settling Time:- 5 sec

Simulation Model of AVR with PSS :

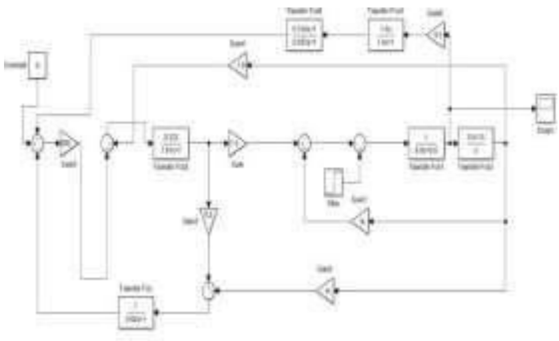

Figure: Simulation Model of AVR with PSS

Rotor Speed Deviations:

The Rotor speed deviations for single machine infinite bus system with Lead-LagPower System Stabilizer, when a step disturbance of 1p.u is shown in Figure.

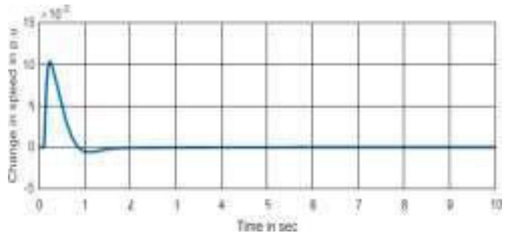

Figure: Rotor speed deviations of AVR with Neural Network-PSS

Peak:- 0.0007 pu , Settling Time:-2.5 sec

Simulation Model of AVR with Neural Network-PSS

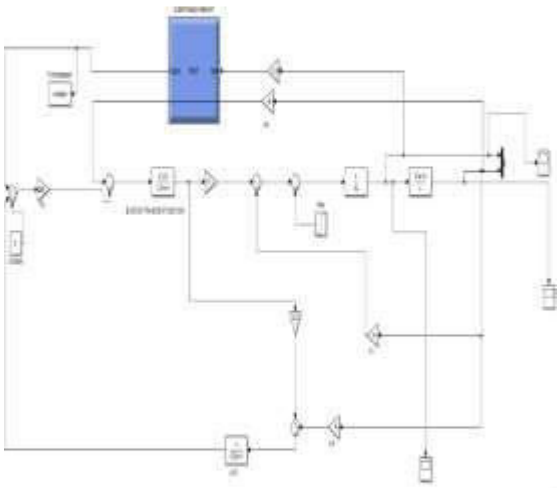

Figure: Simulation Model of AVR withNeural Network-PSS

Rotor Speed Deviations:

Figure shows the rotor speed variations for a single machine infinite bus system with back Propagation Neural Network and PSS when a step disturbance of 1p.u is applied.

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

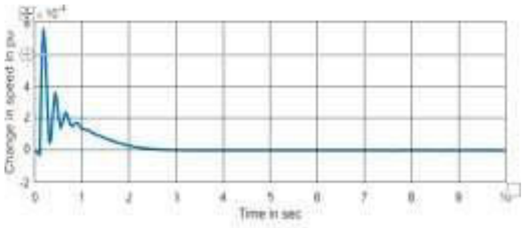

Figure: Rotor speed deviations of AVR with Neural Network-PSS

Peak:- 0.0007 pu , Settling Time:-2.5 sec

IX. Conclusion:

According to the Matlab/Simulink simulation, the response of typical controllers (lead-lag compensators) displays oscillations that last for a long time before reaching the steady state operating point. In the face of numerous disturbances, this type of stabilizer cannot work. These problems can be solved using a neural network-based power system stabilizer.

The performance of the Neural Network-based PSS controller exceeds the standard controller when run on a single machine and numerous machines. A neural network outperforms a standard controller, it was revealed.

X. REFERENCES:

[1] R. Grondin, I. Kamwa and R. Champagne, "An Approach to Design for Stability Improvement through Supplementary Damping of the Common Low-Frequency ", IEEE Transactions on Power Systems, vol. 8, No. 3, August 1993.

[2] A. Al-Hinai, „Dynamic stability enhancement using genetic algorithm power system stabilizer",in Power System Technology (POWERCON), 2010 International Conference on,Oct. 2010, pp. 1-7.

[3] P. Kundur, M. Klien, G. J. Rogers, and M. S. Zywno, "Applications of power system stabilizers for enhancement of over stability ", IEEE Transactions on Power Systems, Vol. 4, No.2, pp. 614 – 626, 1989.

[4] P. H. Huang, and Y. Y. Hsu, 'An output feedback controller for a synchronous generator', IEEE Transactions on Aerospace and Electronic Systems, Vol. 26, No. 2, pp, 337-344, March 1990.

[5] Y. J. LIN 'Systematic Approach for the Design of a Fuzzy Power System Stabilizer', in International Conference on Power System Technology- POWERCON 2004, Singapore,IEEE Proceedings of Nov-200421-24.

[6] K. Al-Olimat, A. Farhoud, and J. Hurtig, Power system stabilizers with fuzzy logic switching," in Power Systems Conference and Exposition, 2006.PSCE '06. 2006 IEEE PES, 292006-Nov. 1 2006, pp. 2152- 2157

[7] BHAVANS SHAH 'Comparative Study Of Conventional and Fuzzy Based Power System Stabilizer' International Conference On Communication System and Network Technologies,IEEE Transactions, 2013.

[8] O. P. Malik, 'Self-Learning Adaptive-Network-Based Fuzzy Logic Power System Stabilizer', IEEE Transactions 1996.

[9] K.A EI-Metwally and O.P. Malik, 'Fuzzy logic power system stabilizer',IEE Procgener. Trans. Distrib., Vol. 142, No. 3, May 1995. .