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ANN Based Power System Stability Improvement

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***Abstract*— In this paper, Artificial Neural Network (ANN) is applied to replace a PSS/AVR controller for improving both steady state stability and voltage regulation of power system. A simulation is performed for the different types of controllers (AVR with no PSS, AVR with PSS, ANN) by taking a single machine infinite bus (SMIB) as test system. Simulation are obtained for rotor speed variation, stater terminal voltage, rotor angle variation during the change in the mechanical input power (dpm). The results at the system responses with different types of control are compared. ANN shows to be the best one.**

***Index Terms*— SMIB power system, AVR, PSS, ANN.**

I. INTRODUCTION

In the past decades, with the emergence of large interconnected power systems all over the world, stability has become an important consideration [1]. Power system stability is the ability of an electric power system, for given initial operating condition, to regain a state of operating equilibrium after being subjected to a an external disturbance and remain the power system in equilibrium state [2].the desired characteristics of the power system are:

1) The system must be able to meet the continuous changing load demand of active and reactive power.

2) There must be consistency in supply frequency and voltage.

For reliable power supply, the system must be able to withstand the disturbances occurring in the system and therefore the system must be designed and operated in a manner to bear these disturbances without loss of load[3].Power systems often undergo faults, load changes and many other disturbances, which in turn introduce low frequency oscillation (LFO) [1]. Low frequency oscillation is a generator rotor angle oscillation having a frequency between (0.1-0.3 HZ) and created or where defined by how they are created or where they are located in the power system, low frequency oscillation can be created by small disturbance in the system, such as changes in the load, the combined oscillatory behavior of the system encompassing the three modes of oscillation are popularly called the dynamic stability of the system. In more precise terms it is known as the small signal oscillatory stability of the system, these oscillation limit the power transmission capability of a network and sometimes may even cause loss of synchronism and an eventual breakdown of the entire system [4]. Power systems control requires a continuous balance between electrical generation and a varying load demand, while levels [5], load frequency control (LFC) and automatic voltage regulator (AVR) equipment are installed for each generator, the controllers are set for a particular operating condition and take care of small changes in load demand to maintain the frequency and voltage magnitude within the specified limits, LFC loop controls the real power and frequency but AVR loop which connected with excitation system regulates the reactive power and voltage magnitude, when the excitation system is considered as the source of field current for the excitation of synchronous generator and includes exciter and (AVR) when the excitation control system is the feedback control system, which includes the synchronous machine and its excitation. The objective of the control strategy is to generate and deliver power in interconnected systems as economically and reliably as possible while maintaining the voltage and frequency within permissible limits [6]. To enhance the system transient stability and to damp its oscillation [7]. But this high gain for (AVR) often introduce negative damping torque to produce sustained oscillation, In order to mitigate these long-standing low frequency oscillation, power system stabilizer (PSS) are used in conjunction with AVR [1], PSS contributes in maintaining power system stability and improving the dynamic performance by providing a supplementary signal to excitation system. A PSS provides a supplementary control signal to the automatic voltage regulator (AVR) loop for excitation control. The PSS is a control device used to damp out low frequency oscillation and to provide supplementary feedback that stabilizing signals in the excitation system [8], Normally the parameters of these conventional AVR and lead –lag PSS are determined at a nominal operating point to give good performance, however, the system dynamic performance may deteriorate when the operating point changes to some extent. Again, in many cases it is observed that, the PSS designed for damping local mode of oscillation, are practically unsuitable for the inter-area mode of oscillation. To fulfill the above requirements of an excitation control system and to avoid the growing difficulties faced by conventional control schemes, artificial intelligence (AI) technique were widely used [1], this work presents enhancement in power system stability by using the artificial neural network instead of the power system stabilizer (PSS) and automatic voltage regulator (AVR) for the single machine infinite bus. A comparison is done between performance of the system with AVR & PSS and the system with ANN by using MATLAB simulation package.

II. SINGLE MACHINE INFINITE BUS (SMIB)

In this work, a single machine infinite bus power system is considered (SMIB). It is defined by a set of machines given in power station which is connected through a transmission line to a large transmission network (called infinite bus) and this system is reduced to a linearized SMIB system, by using thevenin's equivalence of the external transmission network [9]. The general single line diagram of the system configuration is shown in fig .1[9] the mathematical models in state space form for small signal analysis are derived by several steps for SMIB as follow [9]:

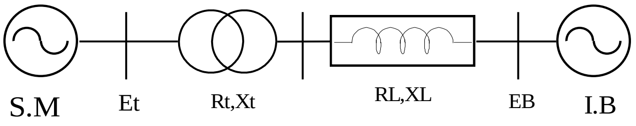

Fig .1 Synchronous machine connected to infinite bus

A. System Classical Model

The classical model of the generator neglecting all resistances is as shown in fig .2 [9], were (E') is the voltage behind ($\acute{X}d$) & its magnitude is assumed to remain constant at the pre-disturbance value.(δ) the angle by which (E') leads the infinite bus voltage(E_B). The line current is expressed as:

$$\acute{I}_t = \frac{E'\angle 0^\circ - E_B\angle -\delta}{jX_T} = \frac{E' - E_B(\cos\delta - j\sin\delta)}{jX_T} \qquad (1)$$

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

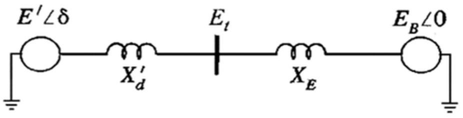

Fig.2 Classical model of generator

Equation represent in the classical model of the generator can be linearized and presented as follows:[9]

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

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

From above, the state equation of the system is as below:

$$\frac{d}{dt}\begin{bmatrix}\Delta\omega_r\\ \Delta\delta\end{bmatrix} = \begin{bmatrix}-\frac{K_D}{2H} & -\frac{K_s}{2H}\\ \omega_0 & 0\end{bmatrix}\begin{bmatrix}\Delta\omega_r\\ \Delta\delta\end{bmatrix} + \begin{bmatrix}\frac{1}{2H}\\ 0\end{bmatrix}\Delta T_m \qquad (5)$$

By using the information in appendix, the state equation of the system are become:

$$A = \begin{bmatrix}0 & -0.1089\\ 376.991 & 0\end{bmatrix}, B = \begin{bmatrix}0.1429\\ 0\end{bmatrix} \qquad (6)$$

and its block diagram is as shown in fig.3 [9]:

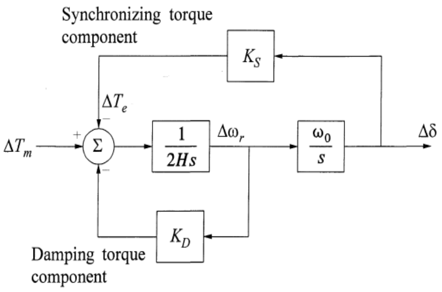

Fig.3 Block diagram of classical model of generator

III. THE SYSTEM WITH FIELD VOLTAGE

To develop the model of the system, consider the system performance including the effect of field flux variation with neglecting the amortissur effects and assuming field voltage constant, therefore, the developed state space model of the system as is follow [9]:

$$\begin{bmatrix}\Delta\dot{\omega}_r\\ \Delta\dot{\delta}\\ \Delta\dot{\psi}_{fd}\end{bmatrix} = \begin{bmatrix}a_{11} & a_{12} & a_{13}\\ a_{21} & 0 & 0\\ 0 & a_{32} & a_{33}\end{bmatrix}\begin{bmatrix}\Delta\omega_r\\ \Delta\delta\\ \Delta\psi_{fd}\end{bmatrix} + \begin{bmatrix}b_{11} & 0\\ 0 & 0\\ 0 & b_{32}\end{bmatrix}\begin{bmatrix}\Delta T_m\\ \Delta E_{fd}\end{bmatrix} \qquad (7)$$

When:

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

By using the information and equation in appendix we obtained:

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

and the block diagram will be describes this case is[9]:

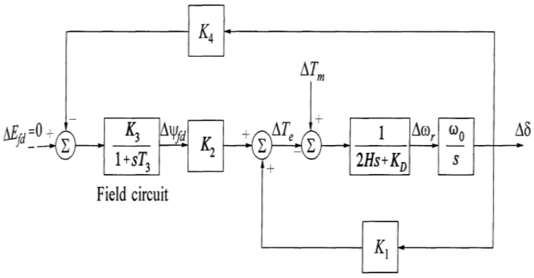

Fig.4, Block diagram representation with constant field (Efd)

IV. EXCITATION SYSTEM

The system developed by adding the excitation system, the excitation system used here is a static excitation system (type-STIA), it will be represented by a simplified form that includes necessary element for modeling a high exciter gain, without transient gain reduction or derivative feedback is used and also includes the terminal voltage transducer with time constant (T_R) and (K_A) which represent again of automatic voltage regulator as shown in fig 5.

V.AUTOMATIC VOLTAGE REGULATOR (AVR)

The aim of this control is to maintain the system voltage within prescribed limits by adjusting the excitation of the machines. The input signals for voltage control are error of terminal voltage and its derivative. Whenever the reactive power load changes a drop in the terminal voltage magnitude appears. The voltage magnitude is sensed through a potential transformer on one phase rectified and compared to a d.c reference signal. The amplified error signal controls the exciter and increases the exciter terminal voltage. Thus, the generator field current is increased, which result in an increase in the generated emf. The reactive power generation is increased to a new equilibrium, raising the terminal voltage to the desired value [10]. The state equation of the system (with and without AVR) is:

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

By using the information's & equations given in the appendix, The following matrices are obtained:

1) System matrices without AVR:

$$A = \begin{bmatrix} 0 & -0.1089 & -0.1250 & 0\\ 376.991 & 0 & 0 & 0\\ 0 & -0.1967 & -0.4133 & -0.13708\\ 0 & -7.2968 & 20.9090 & -50\end{bmatrix}, B = \begin{bmatrix}0.1429\\ 0\\ 0\\ 0\end{bmatrix} \qquad (11)$$

2) System matrices With AVR:

$$A = \begin{bmatrix} 0 & -0.1089 & -0.1250 & 0\\ 376.991 & 0 & 0 & 0\\ 0 & -0.1967 & -0.4133 & -27.4175\\ 0 & -7.2968 & 20.9090 & -50\end{bmatrix}, B = \begin{bmatrix}0.1429\\ 0\\ 0\\ 0\end{bmatrix} \qquad (12)$$

The system block diagram in this cases is as shown on fig 5 [9]:

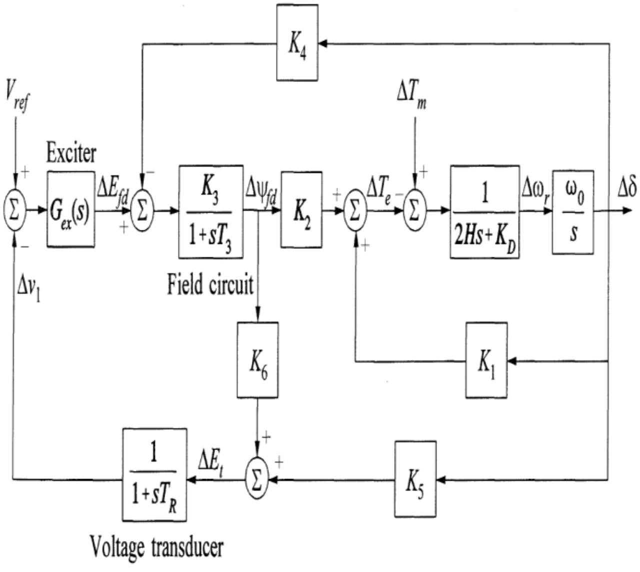

Fig.5 The block diagram of the system with excitator

VI. POWER SYSTEM STABILIZER (PSS)

Power system stabilizer (PSS) is used to improve the small signal stability properties of the system [11]. The basic function of power system stabilizer is to add damping to the generator rotor oscillation by controlling its excitation using auxiliary stabilizing signals in order to provide damping signals the stabilizer must produce a component of electrical torque in phase with rotor speed deviation when the voltage regulator creates a negative damping torque and give rise to oscillation and instability.

VII. STRUCTURE AND TUNING OF PSS [4]

The general power system stabilizer (PSS) block is used to add damping to the rotor oscillation of the synchronous machine by controlling its excitation. The disturbances occurring in a power system induce electromechanical oscillation in the electrical generators. These oscillations are also called power swing. It must be effectively damped to maintain the system stability. The output signal of the PSS is used as an additional input (V-stab) to the excitation system block. The PSS input signal can be either the machine speed deviation or its acceleration power (difference between the mechanical power and the electrical power).

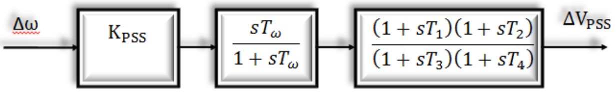

Fig.6 Structure of power system stabilizer

To ensure a robust damping, the PSS should provide a moderate phase advance at frequencies of interest in order to compensate the inherent lag between the field excitation and electrical torque induced by the PSS action. The model given in fig.6 consists of low pass filter, general gain, a washout (high pass filter) and phase compensation system. The function of each element is as follows:

- **Gain:** the overall gain of the generic power system stabilizer. The gain k determines the amount of damping produced by the stabilizer. gain k can be chosen in the range of (20-200).
- **Wash-out time constant:** the time constant, in seconds (s), of the first order high pass filter used by the washout system of the model. The washout high pass filter eliminates low frequencies that are present in the speed deviation signal and allows the PSS respond only to speed changes. The time constant (T_w) is normally chosen in the range of (1-2) for local modes of oscillation, however, if inter area modes are also to be damped then (T_w) must be chosen in the range of (10-20).
- **Lead –lag time constants (phase compensation system):** The time constant (T1,T2) in seconds(s), of the phase compensation system is to compensate the phase lag between the excitation voltage and electrical torque of the synchronous machine.

The final state equation of the system with addition of power system stabilizer as follow:

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

By using the information’s and equation given in appendix, one can obtain system matrices as follows:

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

$$\mathbf{B}=\begin{bmatrix} 0.14286 \\ 0 \\ 0 \\ 0 \\ 1.357143 \\ 1.357143 \\ 1.357143 \end{bmatrix} \qquad (14)$$

and the block diagram describes this case is given in the following fig.7 [9]:

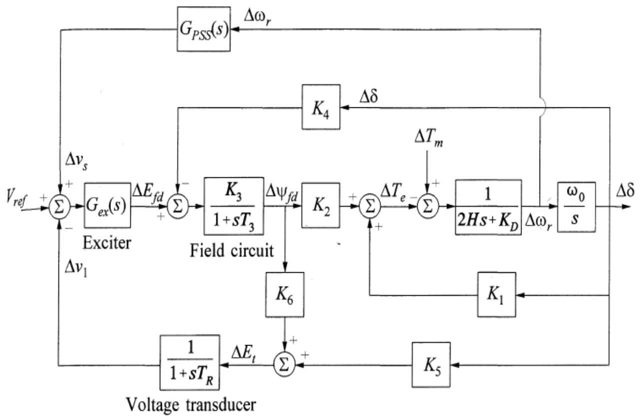

Fig.7 Block diagram of the system with AVR & PSS

There are six constants (K_1-K_6) that describe the relation between the rotor speed and voltage control equations of the machine which are termed as Heffron Phillip's constants. They depend on the machine parameters and the operating conditions. Generally (K_1, K_2, . K_3, K_6) are positive. K_4 is mostly expected positive to be for cases where RE is high. K_5 Can be either positive or negative, K_5 is positive for low to medium external impedances (R_E+jX_E) and low to medium loadings. K_5 is usually negative for moderate to high external impedances and heavy loading [9,12]. The constants (K_1-K_6) shown as Heffron Phillip's constants are computed using the following expression [9]:

$$K_1 = n_1\left(\psi_{ad0} + L_{aqs} i_{d0}\right) - m_1\left(\psi_{aq0} + L'_{ads} i_{q0}\right) \qquad (15)$$

$$K_2 = n_2\left(\psi_{ad0} + L_{aqs} i_{d0}\right) - m_2\left(\psi_{aq0} + L'_{ads} i_{q0}\right) + \frac{L'_{ads}}{L_{fd}} i_{q0} \qquad (16)$$

$$K_3 = \frac{B}{a_{33}} \quad , \qquad (17)$$

$$K_4 = \frac{a_{32}}{B} \qquad (18)$$

$$K_5 = \frac{e_{d0}}{E_{t0}}\left[-R_a m_1 + L_l n_1 + L_{aqs} n_1\right] + \frac{e_{q0}}{E_{t0}}\left[-R_a n_1 + L_l m_1 + L'_{ads} m_1\right] \qquad (19)$$

$$K_6 = \frac{e_{d0}}{E_{t0}}\left[-R_a m_2 + L_l n_2 + L_{aqs} n_2\right] + \frac{e_{q0}}{E_{t0}}\left[-R_a n_2 + L_l m_2 + L'_{ads}\left(\frac{1}{L_{fd}} m_2\right)\right] \qquad (20)$$

VIII. ARTIFITIAL NEURAL NETWORK (ANN)

ANN is an imitated network of neurons which interact with each other to process and transfer information [13]. It is a network of inter connected elements and these elements were inspired from the studies of biological nervous systems. In other words, neural network are an attempt at creating machines that work in a similar way to the human brain by building these machines using components that behave like biological neurons [14]. The basic ANN model has an input layer with any number of neurons, a number of hidden layers can be there with any number of neurons supported by the system for a particular operation and then there is an output layer which takes the weighted sum of all the hidden layer neurons and give a certain output [13]. The ability of ANN to model complex relationships makes them superior to conventional controller system. Conventional controllers require a good knowledge about mathematical model of controlled system, which may not be available. Most ANN controllers on the other hand do not need such requirements and can handle complex systems efficiently. They learn to map input-output relationships by training process. The ANN are trained to identify a process either off-line or on-line during the real time operation of the system [14-16]. ANN can easily handle complicated problems and can identify and learn correlated patterns between sets of input data and corresponding target values. After training, these networks can be used to predict the outcome from new input data. Being universal function approximates, they are capable of approximating any continuous nonlinear function to arbitrary accuracy [14]. From advance adaptive neural network have a built-in capability to adapt their synaptic weights to changes in the surrounding environment in particular, a neural network trained to operate in a specific environment can be easily retrained to deal with minor changes in the operating environmental conditions. Moreover, when it is operating in a non-stationary environment a neural network can be designed to change its synaptic weight in real time. The neural architecture of a neural network for pattern classification, signal processing and control applications, coupled with adaptive capability of the network, makes it an ideal tool for use in adaptive pattern classification, adaptive signal processing and adaptive control [17]. In this work, the information about the artificial neural network is shown below:

1) The type of the user artificial neural network is the feed forward type.

2) It has one hidden layer with 80 neurons.

3) It has one input and two outputs.

IX. SIMULATION RESULTS

For the simulation results, MATLAB (R 2010 a), Simulink version 7.10& Artificial neural network software (m-file) as been utilized. The simulation of the system with constant field in MATLAB program is as in fig.8 as shown below:

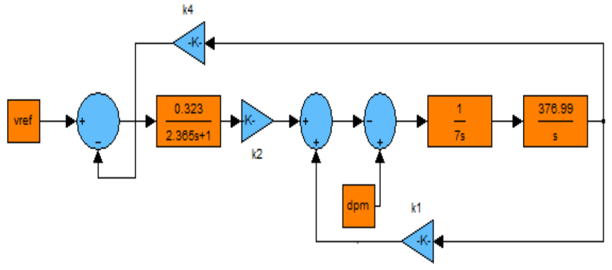

Fig.8 Simulation of SMIB with constant field in MATLAB

And the responses from the circuit are shown in fig.9 below:

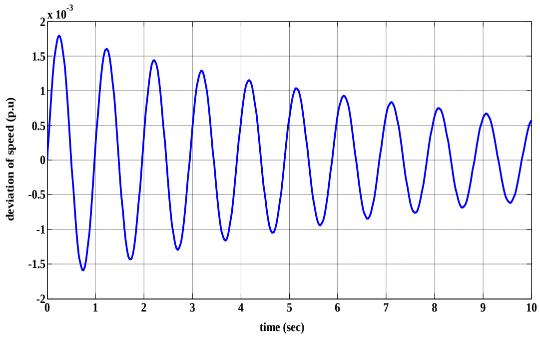

Fig.9 speed deviation response with dpm (8)%

& The simulation of SMIB circuit with AVR and PSS in MATLAB program as shown in fig.10 below:

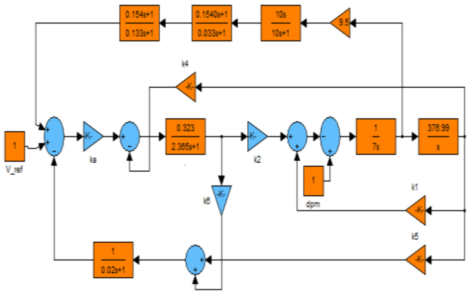

Fig.10 Simulation of SMIB with AVR &PSS in MATLAB

& the simulation of SMIB circuit with ANN in MATLAB program is shown in fig.11 below:

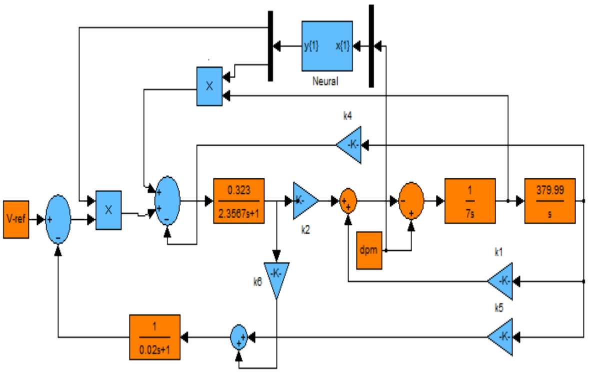

Fig.11Simulation of SMIB with ANN in MATLAB

and the results:

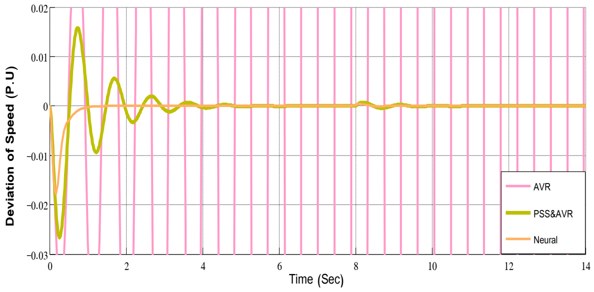

Fig.12 Rotor speed deviation response with dpm (0,5)% at T=(0,8)s

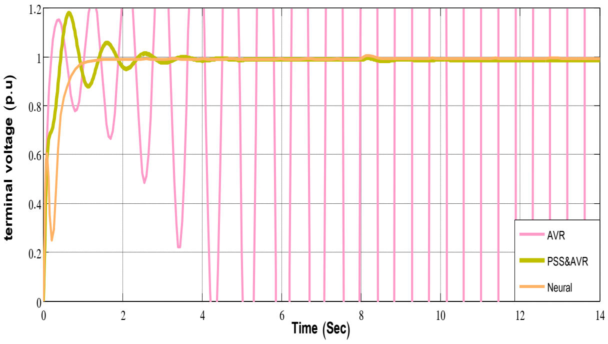

Fig.13 Terminal voltage response with dpm (0,5)% at T=(0,8)sec

To compare the performance of SMIB with different types of controllers by observing step response in the fig.12,fig.13, one can note:

1) By using the artificial neural network (ANN), the rise time & settling time of the system decreases, compared to conventional controllers (AVR+PSS) and automatic voltage regulator (AVR).

2) the oscillations reduces much faster with the application of the artificial neural network (ANN), compared to the conventional controller (AVR+PSS) and automatic voltage controller (AVR).

X. CONCLUSION

The paper highlights a systemic approach for designing an artificial neural network (ANN) based Automatic voltage regulator and power system stabilizer. This ANN based AVR and PSS overcome the limitation of a conventional AVR and PSS which are over-dependent on human intuition. So the ANN based AVR and PSS achieves more flexibility and more suitability in operation with wider range and various types of disturbances at different times occur as in case of power system. The result show that the proposed (ANN) controller has promising, satisfactory generalization applicability, a good dynamic performance, fast acting, setting as well as accuracy and suitability. Therefore, the proposed controller (ANN) is more suitable for small signal stability of power system.

XI. FUTURE WORKE

- Application of proposed control method to multiple machines in a single machine unit (Multi Machine Single Plant).
- Application of proposed control method using multiple machines and multi-plant units.
- Implementation of the proposed operation on the electrical grid.

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APPENDIX

Constants:

K1=0.7643, k2=0.8649, k3=0.323, k4=1.4187, k5=-0.1463, k6=0.4168

Pss:

T1=0.154, T2=0.154, T3=0.033, T4=0.133, KPSS=9.5, Tw=10

AVR: Ka=200

Parameters:

F=60HZ, Xd=1.81, Xq=1.76, X1=0.16, X'd=0.3, Ra=0.003, RE=0,KD=0

Ladu=1.65,Laqu=1.6,L1=0.16,H=3.5,Rfd=0.0006,Lfd=0.153,Asat=0.031, Bsat=6.93, XE=0,T'do=8s, $\Psi_{TI} = 0.8$, TR=0.02, S=2220MVA,V=24KV

Equations:

$a_{12} = -\frac{K_1}{2H}$, $a_{13} = -\frac{K_2}{2H}$, $a_{21} = 2\pi f_0$, $a_{32} = \frac{\omega_0 R_{fd}}{L_{fd}} m_1 L'_{ads}$

$$a_{33} = -\frac{\omega_o R_{fd}}{L_{fd}}\left[1 - \frac{L'_{ads}}{L_{fd}} + m_2 L'_{ads}\right] \; , a_{34} = -\frac{\omega_o R_{fd}}{L_{adu}} K_A$$

$$a_{37} = K_A \frac{\omega_o R_{fd}}{L_{adu}}$$

$$a_{42} = \frac{K_5}{T_R} \; , \; a_{43} = \frac{K_6}{T_R} , \quad a_{44} = -\frac{1}{T_R} , \; a_{52} = K_{PSS} a_{12}$$

$$a_{53} = K_{PSS} a_{13} \; , \quad a_{55} = -\frac{1}{T_w} \; , \; a_{61} = a_{51}\frac{T_1}{T_2} \; , \quad a_{62} = a_{52}\frac{T_1}{T_2}$$

$$a_{63} = a_{53}\frac{T_1}{T_2} \; , \; a_{66} = -\frac{1}{T_2} \; , \; a_{71} = a_{61}\frac{T_3}{T_4} , \quad a_{72} = a_{62}\frac{T_3}{T_4}$$

$$a_{73} = a_{63}\frac{T_3}{T_4} \; , \quad a_{75} = a_{65}\frac{T_3}{T_4} \; , \quad a_{76} = a_{66}\frac{T_3}{T_4} + \frac{1}{T_4} , \; a_{77} = -\frac{1}{T_4}$$

$$b_{11} = \frac{1}{2H} \; , \; b_{51} = b_{61} = b_{71} = \frac{K_{PSS}}{2H} , b_{32} = \frac{\omega_o R_{fd}}{L_{adu}}$$

$$R_T = R_a + R_E \; , \quad X_{Tq} = X_E + \left(L_{aqs} + L_l\right) = X_E + X_{qs}$$
$$X_{Td} = X_E + (L'_{ads} + L_l) = X_E + X'_{ds},$$
$$D = R_T^2 + X_{Tq} X_{Td}$$
$$m_1 = \frac{E_B(X_{Tq}\sin\delta_o - R_T\cos\delta_o)}{D} , \; n_1 = \frac{E_B(R_T\sin\delta_o - X_{Td}\cos\delta_o)}{D}$$
$$m_2 = \frac{X_{Tq}}{D}\frac{L_{ads}}{(L_{ads} + L_{fd})} \; , n_2 = \frac{R_T}{D}\frac{L_{ads}}{(L_{ads} + L_{fd})}$$

Note: for more information, you can back to reference no.(9)

AUTHOR BIOGRAPHY

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