

Comparison of Pole Placement Technique and Genetic Algorithm Technique for tuning stabilizers in Power system

P Pavan Kumar

M.Tech Student, EEE Department, Gitam University,
Visakhapatnam, Andhra Pradesh, India-533045,

C Srivalli Soujanya

M.Tech Student, EEE Department, Gitam University,
Visakhapatnam, Andhra Pradesh, India-533045

M Ravindra Babu

Assistant Professor, EEE Department, Gitam University,
Visakhapatnam, Andhra Pradesh, India-533045,

Abstract— The problem of damping low frequency oscillations in the range of 0.2 – 3 Hz observed in power systems has been the major concern these days. Power System Stabilizers (PSS) are commonly used to damp these low frequency oscillations. The parameters of the PSS (gain, phase lead time constant) are tuned by considering the single machine connected to infinite bus system (SMIB). Tuning of these parameters for the system considered can be done using various design techniques. In this paper mainly two types of PSS are used to damp these low frequency oscillations one is speed based lead-lag stabilizer and the other is derivative type power based stabilizer. Tuning of parameters for both these stabilizers are done using pole assignment technique and genetic algorithm over various operating conditions of power system and the results of both the techniques are compared. Genetic Algorithm toolbox is used along with MATLAB/SIMULINK for simulation.

Keywords—Power system stabilizer (PSS), power system oscillations, SMIB, Pole placement Technique, Genetic Algorithm.

I. INTRODUCTION

Power systems are usually large nonlinear systems, which are often subject to low frequency electro-mechanical oscillations, while the system can be operated even if it is transiently unstable, small signal stability is necessary at all time. Low frequency oscillations (LFOs) are generator rotor angle oscillations having a frequency between 0.1-3.0 Hz, and are defined by how they are created or where they are located in the power system. The use of high-gain AVRs and fast acting generator exciters, poorly tuned generation excitation, HVDC converters or static VAR compensators may create LFOs with negative damping. These low frequency oscillations are related to the small signal stability of a power system. The mitigation of these oscillations is commonly

performed with power system stabilizers (PSSs). LFOs include local plant modes, control modes, torsional modes induced by the interaction between the mechanical and electrical modes of a turbine-generator system, and inter-area modes, which may be caused by either high-gain exciters or heavy power transfers across weak tie-lines [1]. When present in a power system, this type of oscillation limits the amount of power transfer on the tie-lines between the regions containing the groups of coherent generators. Hence there is prerequisite for controlling these low frequency oscillations.

The control method investigated in this paper will focus on the use of a power system stabilizer (PSS) in conjunction with the automatic voltage regulators (AVRs) of the generators in the test system. Damping of the LFOs contributes to the enhancement of the stability limits of the system, signifying greater power transfer through the system. The application of PSSs with speed ($\Delta\omega$) and electrical power (ΔP_e) input signals for this particular control problem is discussed in this paper [4]. Often a PSS that is expected to damp oscillations over a broad range of frequencies is not able to sufficiently damp every oscillatory mode that might be excited in the system.

In this paper the optimal parameter of the PSS are evaluated using pole placement technique and genetic algorithm technique. In pole placement technique the characteristic equation of the system including PSS is used to carry out the eigen value analysis and to determine the stabilizer parameters, while in genetic algorithm technique the state matrix A of the system including PSS is considered in designing fitness/objective function with mild constraints on the PSS parameters. These parameters are obtained using genetic algorithm toolbox considering few specifications which is shown in Appendix. Eigen value analysis and simulation results have been carried out to assess the effectiveness and robustness of both the techniques to damp out the electromechanical modes of oscillations and enhance

the dynamic stability of power systems. The simulation results and PSS parameters obtained are shown below in section V.

II. SYSTEM CONSIDERED

A single machine-infinite bus (SMIB) system is considered for the present investigations. A machine connected to a large system through a transmission line may be approximated to a SMIB system, by using Thevenin's equivalent of the transmission network external to the machine.

The synchronous machine is described as the fourth order model. The two-axis synchronous machine representation with a field circuit in the direct axis but without damper windings is considered for the analysis. The equations describing the steady state operation of a synchronous generator connected to an infinite bus through an external reactance can be linearized about any particular operating point as follows (eq.1-4):

$$\Delta T_m - \Delta P = M \frac{d^2 \Delta \delta}{dt^2} \quad (1)$$

$$\Delta P = K_1 \Delta \delta + K_2 \Delta E'_q \quad (2)$$

$$\Delta E'_q = \frac{K_3}{1+sT'_{do}K_3} \Delta E_{fd} - \frac{K_3 K_4}{1+sT'_{do}K_3} \Delta \delta \quad (3)$$

$$\Delta V_t = K_5 \Delta \delta + K_6 \Delta E'_q \quad (4)$$

The constants (K_1 - K_6) can be computed using the equations given in Appendix.

The system data considered is:

$$\begin{aligned} x_d &= 0.973 & x'_d &= 0.19 \\ x_q &= 0.55 & T'_{do} &= 7.765s \\ D &= 0 & H &= 5 & f &= 60\text{Hz} \end{aligned} \quad (5)$$

$$\begin{aligned} \text{Transmission line (p.u):} \\ R_e &= 0 & X_e &= 0.4 \end{aligned} \quad (6)$$

$$\begin{aligned} \text{Exciter:} \\ K_E &= 200 & T_E &= 0.05s \end{aligned} \quad (7)$$

$$\begin{aligned} \text{Operating point:} \\ V_{to} &= 1.0 & P_0 &= 1.0 \\ Q_0 &= 0.2 & \delta_0 &= 28.26^\circ \end{aligned} \quad (8)$$

The interaction between the speed and voltage control equations of the machine is expressed in terms of six constants k_1 - k_6 which is termed as Heffron-Phillips constants. They are dependent on the machine parameters and the operating conditions. Generally K_1 , K_2 , K_3 and K_6 are positive. K_4 is mostly positive except for cases where R_e 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 loadings [7]. The overall linearized block diagram of the SMIB system is shown in Fig.1 below.

From the linearized block diagram, the following state variables are chosen for single machine system [7]. The linearized differential equations can be written in the state space form as,

$$\dot{X}(t) = A \cdot x(t) + B \cdot u(t) \quad (9)$$

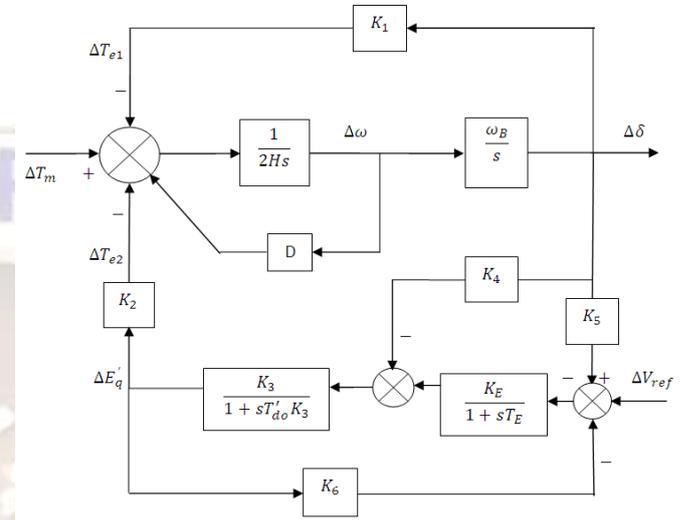


Fig. 1 Overall block diagram of SMIB system

Where,

$$X(t) = [\Delta \delta \quad \Delta \omega \quad \Delta E'_q \quad \Delta E'_{fd}]^T \quad (10)$$

$$A = \begin{bmatrix} 0 & \omega_B & 0 & 0 \\ \frac{-K_1}{2H} & \frac{-D}{2H} & \frac{-K_2}{2H} & 0 \\ \frac{-K_4}{T'_{do}} & 0 & \frac{-1}{T'_{do}K_3} & \frac{1}{T'_{do}} \\ \frac{-K_E K_5}{T_E} & 0 & \frac{-K_E K_6}{T_E} & \frac{-1}{T_E} \end{bmatrix} \quad (11)$$

$$B = \begin{bmatrix} 0 & 0 & 0 & \frac{K_E}{T_E} \end{bmatrix}^T \quad (12)$$

System state matrix A is a function of the system parameters, which depend on operating conditions. Control matrix B depends on system parameters only. Control signal U is the PSS output. From the operating conditions and the corresponding parameters of the system considered, the system eigen values are obtained. This system without including PSS is considered as open loop system whose transfer function G(s) is to be computed using the state equations and matrices.

III. POWER SYSTEM STABILIZERS

A cost efficient and satisfactory solution of the problem of oscillatory instability is to provide damping for generator rotor oscillation. This is conveniently done by providing Power System Stabilizers (PSS) which are supplementary controllers

in the excitation systems [3]. The input V_s to the exciter is the output from PSS which has input signal derived from rotor velocity, frequency, electrical power or a combination of these variables.

A. Structure of PSS

The basic block diagram of PSS used in power system is shown in Fig.2. It consists of washout circuit, dynamic compensator, torsional filter and limiter. The function and role of each of these blocks to damp the low frequency oscillations is discussed in detail below [7].

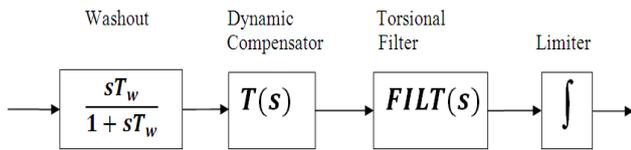


Fig 2: Basic Structure of PSS

1) *Washout Circuit*: The washout circuit is used to eliminate steady state bias in the output of PSS which will modify the generator terminal voltage [7]. The PSS is expected to respond only to transient variations in the input signal and not to the dc offsets in the signal. This is done by subtracting from input signal the low frequency components of the signal obtained by passing the signal through a low pass filter. The washout circuit acts essentially as a high pass filter and it must pass all frequencies that are of interest. For local modes the T_w can be chosen in the range of 1 to 2 and for inter area modes it must be chosen in the range of 10 to 20.

2) *Dynamic Compensator*: The dynamic compensator used in industry is made up of lead-lag stages and has the following transfer function,

$$T(s) = K \frac{(1+sT_1)(1+sT_3)}{(1+sT_2)(1+sT_4)} \quad (13)$$

Where K is the gain of PSS and the time constants, T_1 to T_4 are chosen to provide a phase lead for the input signal in the range of frequencies that are of interest (0.1 to 3.0Hz)[7].

3) *Torsional Filter*: The torsional filter in the PSS is a band reject or a low pass filter to attenuate the first torsional mode frequency. It is used to avoid the adverse interaction of PSS with the torsional oscillations. This can lead to shaft damage, particularly at light generator loads when the inherent mechanical damping is small.

4) *Limiter*: The output of the PSS must be limited to prevent the PSS acting to counter the action of AVR. At load rejections it is desired to trip the PSS, since AVR acts to reduce the terminal voltage to nominal value.

B. Types of PSS considered

Power system stabilizers are classified based on the type of input signal used. The input signals include deviations in the rotor speed ($\Delta\omega = \omega_{mech} - \omega_o$), the frequency (Δf), the electrical power (ΔP_e) and the accelerating power (ΔP_a) [3].

As mentioned above in this paper two types of PSS are considered to damp the low frequency oscillations they are,

1) *Speed based lead-lag PSS*: These stabilizers employ the direct measurement of shaft speed ($\Delta\omega$) and employ it as input signal for it. The stabilizer, while damping the rotor oscillations, could reduce the damping of the lower-frequency torsional modes if adequate filtering measures were not taken [3]. In addition to careful pickup placement at a location along the shaft where low-frequency shaft torsionals were at a minimum electronic filters called torsional filters should be used for adequate damping of low frequency oscillations.

The structure of this PSS is in the form as shown below [4], for which the parameter such as stabilizer gain K_c , lead lag time constants T_1 and T_2 are to be computed such that the overall closed loop system will be stable when the PSS is included in the feedback loop.

$$H(s) = \frac{K_c s T_w (1+sT_1)}{(1+sT_w)(1+sT_2)} \quad (14)$$

2) *Power based derivative PSS*: Due to the simplicity of measuring electrical power and its relationship to shaft speed, it was considered to be a natural candidate as an input signal to early stabilizers. The equation of motion for the rotor can be written as follows [3]:

$$\frac{\partial}{\partial t} \Delta\omega = \frac{1}{2H} (\Delta P_m - \Delta P_e) \quad (15)$$

Where, H = inertia constant

ΔP_m = change in mechanical power input

ΔP_e = change in electric power output

$\Delta\omega$ = speed deviation

As previously mentioned this type of stabilizer uses electrical power (ΔP_e) as input and is of derivative type whose structure is as shown below [4], and the optimal stabilizer parameter K and T are to be computed which ensure closed loop stability of the system.

$$H(s) = \frac{K_s}{(s + \frac{1}{T})^2} \quad (16)$$

When PSS of structure described above is used in feedback of open loop system it forms a closed loop system. Here two additional state variables ΔV_1 and ΔV_2 are used for both PSS to form the state matrices which are described in Appendix. In both the types of PSS the optimal stabilizer parameters are obtained using pole placement technique and genetic algorithm technique.

IV. GENETIC ALGORITHM

Genetic Algorithms are a family of computational models inspired by evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome-like data structure and apply recombination operators to these structures as to preserve critical information.

The most common operators handled in genetic algorithm are described in detail below, which in whole called as breeding cycle.

1) *Selection (Reproduction)*: Selection is the process of choosing two parents from the population for crossing. The purpose of selection is to emphasize fitter individuals in the population in hopes that their off springs have higher fitness[9]. Chromosomes are selected from the initial population to be parents for reproduction.

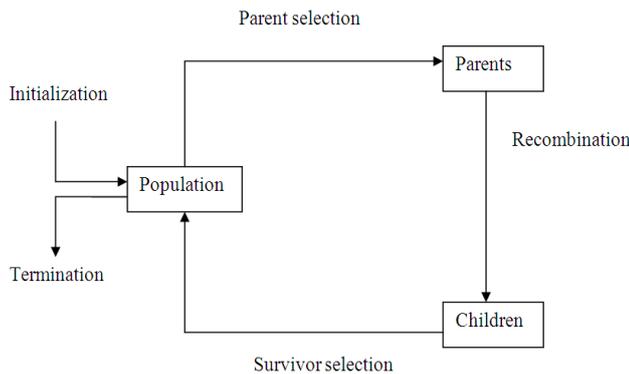


Fig. 3 General Scheme of Genetic Algorithm

2) *Crossover (Recombination)*: Crossover is the process of taking two parent solutions and producing from them a child. After the selection (reproduction) process, the population is enriched with better individuals [9]. Reproduction makes clones of good strings but does not create new ones. Crossover operator is applied to the mating pool with the hope that it creates a better offspring.

3) *Mutation*: After crossover, the strings are subjected to mutation. Mutation prevents the algorithm to be trapped in a local minimum. Mutation plays the role of recovering the lost genetic materials as well as for randomly disturbing genetic information. Mutation has traditionally considered as a simple search operator [9]. If crossover is supposed to exploit the current solution to find better ones, mutation is supposed to help for the exploration of the whole search space.

4) *Replacement*: Replacement is the last stage of any breeding cycle. Two parents are drawn from a fixed size population, they breed two children, but not all four can return to the population, so two must be replaced i.e., once off springs are produced, a method must determine which of the current members of the population, if any, should be replaced by the new solutions[9].

All these operation are carried out in Genetic Algorithm toolbox in which the following fitness function has to be defined. The problem of computing optimal parameters of a single power system stabilizer for different operating points implies that power system stabilizer must stabilize the family of N plants:

$$\dot{X} = A_k X + B_k U, k=1,2,3,\dots,N \quad (17)$$

Where $X(t)$ is the state vector and $U(t)$ is the input stabilizing signal. A necessary and sufficient condition for the set of plants in the system to be simultaneously stabilizable with stabilizing signal is that Eigen values of the closed-loop system lie in the left-hand side of the complex s-plane. This condition motivates the following approach for determining the parameters K, T1 and T2 of the power system stabilizer. Selection of K, T1 and T2 to minimize the following fitness function,

$$J = \text{Remax}(\lambda_{i,k}), i=1,2,\dots,N, k=1,2,\dots,N \quad (18)$$

Where $\lambda_{i,k}$ is the k th closed-loop eigen value of the i th plant[4]. If a solution is found such that $J < 0$, then the resulting K, T1 and T2 stabilize the collection of plants.

For running the GA toolbox the command **gatool** [10], is to be given in command window of MATLAB and in the tool the fitness function is to be defined in which the state matrix A including PSS is used and the unknown PSS parameters are taken as unknown variables which are to be optimized such that the eigen values of the matrix lie on the left half of s-plane i.e., in the stability region. This method of finding the parameter is applied for both the types of PSS's described in section III. The state matrices 'A' of both the cases and the specifications used for running GA toolbox is mentioned in Appendix.

V. POLE PLACEMENT TECHNIQUE

Pole placement is a method employed in feedback control system theory to place the closed-loop poles of a plant in pre-determined locations in the s-plane. This method is also known as Full State Feedback (FSF) technique. Placing poles is desirable because the location of the poles corresponds directly to the eigen values of the system, which control the characteristics of the response of the system.

Based on the system data considered and the operating condition, the Heppron-Phillips constants for the system are computed. The state equations are then considered using these constants to compute the state matrices and then the transfer function of the open loop system is computed in matlab using these state matrices. The open loop system transfer function is taken as G(s). Now in the feedback loop, the stabilizer is used for the control of low frequency speed oscillations whose transfer function is taken as H(s). The simple block diagram considered for pole placement technique is shown below.

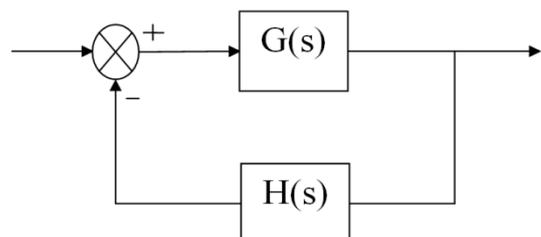


Fig.4 Closed loop system including PSS

Let the linearized equations of single machine, infinite bus system be expressed in the form,

$$sX(s) = AX(s) + BU(s) \quad (19)$$

$$Y(s) = CX(s) \quad (20)$$

The PSS with the following structure is used [5],

$$\frac{Y(s)}{U(s)} = GPSS(s) = H(s) \quad (21)$$

Where the PSS parameter are to determined such that system dominant eigen values are equal to desired eigen values. Using equations (19),(20) and (21), it can be readily shown that the closed loop system characteristic equation is given by[5],

$$1 - C(sI - A)^{-1}BH(s) = 0 \quad (22)$$

The above equation can be rewritten in the form,

$$H(s) = \frac{1}{C(sI - A)^{-1}B} \quad (23)$$

From eqn.(23) the required stabilizer parameters can be computed by replacing s by the desired eigen value λ and equating the real and imaginary terms on bothsides of the equation(21).

Using the state equations and state matrices mentioned in section II, the open loop transfer function G(s) of the system is obtained, and the PSS of structure shown in eqn.(14)& (16) is used as feedback H(s) for the open loop system and thus forming the closed loop system with unknown parameters K_c, T_1, T_2, K and T. These unknown parameters are computed using the pole placement technique,

$$1 \pm G(s)H(s) = 0$$

From this equation the required stabilizer parameters can be computed by replacing s by the desired eigenvalue λ and equating the real and imaginary terms on bothsides of the equation (21).

VI. APPENDIX

A. Computation of Heffron-Phillips constants

All the variables with subscript 0 are values of variables evaluated at their pre-disturbance steady-state operating point from the known values of P_0, Q_0 and V_{t0} .

$$i_{q0} = \frac{P_0 Q_0}{\sqrt{(P_0 x_q)^2 + (V_{t0}^2 + Q_0 x_q)^2}}$$

$$v_{d0} = i_{q0} x_q$$

$$v_{q0} = \sqrt{V_{t0}^2 - v_{d0}^2}$$

$$i_{d0} = \frac{Q_0 + x_q i_{q0}^2}{v_{q0}}$$

$$E_{q0} = v_{q0} + i_{d0} x_q$$

$$E_o = \sqrt{(v_{d0} + x_e i_{q0})^2 - (v_{q0} - x_q i_{d0})^2}$$

$$\delta_o = \tan^{-1} \frac{(v_{d0} + x_e i_{q0})}{(v_{q0} - x_q i_{d0})}$$

$$K_1 = \frac{E_b E_{q0} \cos \delta_o}{(x_e + x_q)} + \frac{(x_q - x'_d)}{(x_e + x'_d)} E_b i_{q0} \sin \delta_o$$

$$K_2 = \frac{(x_e + x_q)}{(x_e + x'_d)} i_{q0} = \frac{E_b \sin \delta_o}{(x_e + x'_d)}$$

$$K_3 = \frac{(x_e + x'_d)}{(x_d + x_e)}$$

$$K_4 = \frac{(x_d - x'_d)}{(x'_d + x_e)} E_b \sin \delta_o$$

$$K_5 = \frac{-x_q v_{d0} E_b \cos \delta_o}{(x_e + x_q) V_{t0}} - \frac{x'_d v_{q0} E_b \sin \delta_o}{(x_e + x'_d) V_{t0}}$$

$$K_6 = \frac{x_e}{(x_e + x'_d)} \cdot \left(\frac{V_{q0}}{V_{t0}} \right)$$

B. State Space modelling of system including PSS

1) *System using Speed based PSS($\Delta\omega$):* When PSS of structure described in equation (14) is used as feedback of open loop system it forms a closed loop system. The state equations involved are,

$$\Delta \delta = \frac{\omega_B}{s} \Delta \omega$$

$$\Delta \omega = \frac{-K_1}{2Hs} \Delta \delta - \frac{K_2}{2Hs} \Delta E'_q - \frac{D}{2Hs} \Delta \omega$$

$$\Delta E'_q = (-K_4 \Delta \delta + \Delta E_{fd}) \frac{K_3}{1 + sK_3 T'_{do}}$$

$$\Delta E_{fd} = (-K_5 \Delta \delta - K_6 \Delta E'_q + \Delta v_2) \frac{K_E}{1 + sT_E}$$

$$\Delta v_1 = \frac{(1 + sT_1)}{(1 + sT_2)} \Delta v_1$$

$$\Delta v_2 = k \frac{sT_w}{(1 + sT_w)} \Delta v_1$$

$$A = \begin{bmatrix} 0 & \omega_B & 0 & 0 & 0 & 0 \\ \frac{-K_1}{2H} & 0 & \frac{-K_2}{2H} & 0 & 0 & 0 \\ \frac{-K_4}{T'_{do}} & 0 & \frac{-1}{K_3 T'_{do}} & \frac{1}{T'_{do}} & 0 & 0 \\ \frac{-K_E K_5}{T_5} & 0 & \frac{K_E K_6}{T_E} & \frac{-1}{T_E} & 0 & \frac{K_E}{T_E} \\ \frac{-K_c K_1}{2H} & 0 & \frac{-K_c K_2}{2H} & 0 & \frac{-1}{T_w} & 0 \\ \frac{K_1 K_c}{2HT_1} & 0 & \frac{-K_2 K_c}{2HT_2} & 0 & \frac{(T_w - T_1)}{T_w T_2} & \frac{-1}{T_2} \end{bmatrix}$$

Population size	50
Creation function	Use constraint dependent default
Scaling function	Rank
Selection function	Roulette
Crossover fraction	0.7
Mutation function	Use constraint dependent default
Crossover function	Single point
Migration direction	Forward
Number of generations	200

Table.1 Genetic Algorithm Specifications for Toolbox

2) System using Power based PSS (ΔP_c): When PSS of structure described in equation (16) is used as feedback of open loop system it forms a closed loop system. The state equations involved are,

$$\Delta \delta = \frac{\omega_B}{s} \Delta \omega$$

$$\Delta \omega = \frac{-K_1}{2Hs} \Delta \delta - \frac{K_2}{2Hs} \Delta E'_q - \frac{D}{2Hs} \Delta \omega$$

$$\Delta E'_q = (-K_4 \Delta \delta + \Delta E_{fd}) \frac{K_3}{1 + sK_3 T'_{do}}$$

$$\Delta E_{fd} = (-K_5 \Delta \delta - K_6 \Delta E'_q - \Delta v_2) \frac{K_E}{1 + sT_E}$$

$$\Delta v_1 = \frac{KT}{(1 + sKT)} (K_1 \Delta \delta + K_2 E'_q)$$

$$\Delta v_2 = \frac{s}{(s + \frac{1}{T})^2} \Delta v_1$$

$$A = \begin{bmatrix} 0 & \omega_B & 0 & 0 & 0 & 0 \\ \frac{-K_1}{2H} & 0 & \frac{-K_2}{2H} & 0 & 0 & 0 \\ \frac{-K_4}{T'_{do}} & 0 & \frac{-1}{K_3 T'_{do}} & \frac{1}{T'_{do}} & 0 & 0 \\ \frac{-K_E K_5}{T_5} & 0 & \frac{K_E K_6}{T_E} & \frac{-1}{T_E} & 0 & \frac{-K_E}{T_E} \\ K_1 K & 0 & K_2 K & 0 & \frac{-1}{T} & 0 \\ K_1 K & 0 & K_2 K & 0 & \frac{-1}{T} & \frac{1}{T} \end{bmatrix}$$

For the application of GA tool box for optimization of parameters of both speed based and power based PSS, the following constraints on the parameters has to be considered, for speed based PSS,

$$10 \leq K_c \leq 50; 0.01 \leq T_1 \leq 1; 0.01 \leq T_2 \leq 0.1$$

For power based PSS,

$$0.1 \leq K \leq 10; 0.01 \leq T \leq 1$$

VII. RESULTS

The obtained parameters of speed based PSS using Pole placement technique are,

$$K_c = 9.6763, T_1 = 0.285, T_2 = 0.05$$

Parameter obtained using Genetic Algorithm is,

$$K_c = 10.541, T_1 = 0.498, T_2 = 0.1$$

The state matrix A when PSS is included as feedback of open loop system, forming closed loop system is computed using equations in Appendix (B.1),

$$A = \begin{bmatrix} 0 & 377 & 0 & 0 & 0 & 0 \\ -0.1113 & 0 & -0.0657 & 0 & 0 & 0 \\ -0.14028 & 0 & -0.463 & 0.166 & 0 & 0 \\ 1833.6 & 0 & -2058.64 & -20 & 0 & 4000 \\ -1.077 & 0 & -0.6362 & 0 & -0.5 & 0 \\ 3.78 & 0 & -12.72 & 0 & 17.15 & -20 \end{bmatrix}$$

C. Genetic Algorithm Specifications:

For using GA toolbox to optimize the PSS parameters the following specifications are used,

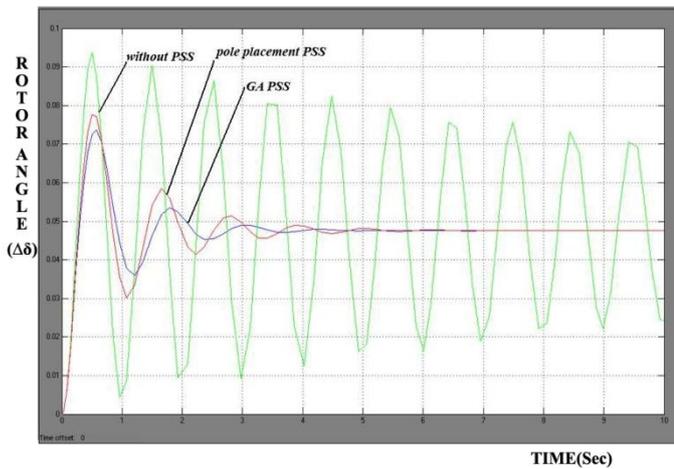


Fig.5 Simulation output of Speed based PSS

The obtained parameters of speed based PSS using Pole placement technique are,

$$K=0.8954, T=0.3104$$

Parameters obtained using Genetic Algorithm is,

$$K=3.4, T=0.498$$

The state matrix A when PSS is included as feedback of open loop system, forming closed loop system is computed using equations in Appendix (B.2),

$$A = \begin{bmatrix} 0 & 377 & 0 & 0 & 0 & 0 \\ -0.1113 & 0 & -0.0657 & 0 & 0 & 0 \\ -0.14028 & 0 & -0.463 & 0.166 & 0 & 0 \\ 1833.6 & 0 & -2058.64 & -20 & 0 & 4000 \\ 0.9973 & 0 & 0.5891 & 0 & -3.221 & 0 \\ 0.9973 & 0 & 0.5891 & 0 & -3.221 & 3.221 \end{bmatrix}$$

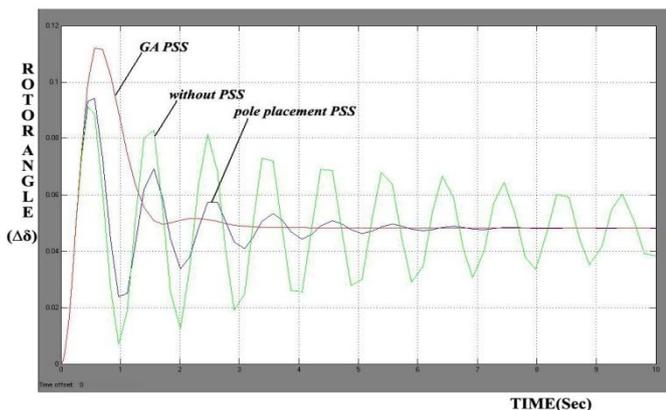


Fig.6 Simulation output of Power based PSS

The settling time of the simulation response for both the techniques are compared in table shown below,

Settling Time	Speed based PSS	Power based PSS
Without PSS	26.43sec	26.43sec
Pole placement PSS	4.14sec	5.79sec
GA PSS	3.29sec	1.93sec

Table.2 Comparison of Settling time

VIII.CONCLUSION

The low frequency oscillations occurring in the system are damped using Speed based and Power based PSS. The optimal parameters of both PSS are evaluated using Pole Placement technique & Genetic Algorithm and are compared.

In Pole placement technique taking suitable s value the dominant eigen values are shifted to left half of s-plane.

The objective function used in Genetic Algorithm toolbox consists, the state matrix of system including PSS in which shifting and assigning the eigenvalues associated with the electromechanical modes, to the left side of the s – plane.

The pole placement technique of computing parameters becomes complex with the increase in number of machines where as the technique of Genetic Algorithm can be used to compute optimal parameters of PSS for wide range of operating conditions in power system and also can be implemented for multi-machine system.

REFERENCES

- [1]. E.V Larsen and D.A. Swann, "Applying Power System Stabilizers, Parts I, II and III", IEEE Trans., Vol. PAS-100, June 1981, pp. 3017- 3046
- [2]. Joe H. Chow, George E. Boukarim, and Alexander Murdoch, "Power System Stabilizers as Undergraduate Control Design Projects", IEEE transactions on power systems, vol. 19, no. 1, February 2004. pp. 144-151
- [3]. G.R. Bérubé, L.M. Hajagos, Members Kestrel Power Engineering Ltd. Accelerating-Power Based Power System Stabilizers
- [4]. "Tuning of Power System Stabilizers via Genetic Algorithm for Stabilization of power Systems" by MehranRashidi, FarzanRashidi, Hamid Moaavar, 0-7803-7952-7/03/\$17.00 © 2003 IEEE
- [5]. "Efficient pole-assignment method for designing stabilisers in multimachine power systems" by S. Elangovan and CM. Lim, IEE PROCEEDINGS, Vol. 134, Pt. C, No. 6, NOVEMBER 1987
- [6]. P. M. Anderson and A.A Fouad "Power system control and stability", Iowa state university Press 1977
- [7]. K.R.Padiyar, "Power system Dynamics Stability and Control". John Wiley; Interline Publishing, 1996
- [8]. P.Kundur, "Power system stability and control". McGraw-Hill, New York 1994.
- [9]. S.N.Sivanandam, S.N .Deepa "Introduction to Genetic Algorithms".Springer-Verlag Berlin Heidelberg 2008
- [10]. A. J. Chipperfield and P. J. Fleming "The MATLAB Genetic Algorithm Toolbox" From IEE Colloquium on Applied Control Techniques Using MATLAB, Digest No. 1995/014, 26/01/95