A Novel Hybrid Approach for Stability Analysis of SMIB using GA and PSO

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Abstract— *Stability exploration has drawn more attention in contemporary research for huge interconnected power system. It is a complex frame to describe the behaviour of system, hence it can create an overhead for modern computer to analyse the power system stability (PSS).The preliminary design and optimization can be achieved by low order liner model. This paper presents a hybrid approach for the stability analysis of single machine infinite bus system using generic power system stabilizer (GPSS) and proportional-integral-derivative.*

Keywords— GPSS, PID, PSS.

I. INTRODUCTION

In the world always try to have good managements of any product regardless, because the challenges all economies and minimized losses. In what could and managed to better the power produced by a power plant, and improve the stability of the power system when it is put to a large defect (three-phase short circuit). This defect is either due to the increase of the load or due to fluctuations in power. Therefore it is inevitable to construct an additional power plant and transmission lines to replace a central damage by a defect. This additional line narrowed and conducts financial and environmental problems.

The use of FACTS (Flexible AC Transmission System) can now increase the capacity of the power transmission without considering the construction of the additional line in this manner by solving such problems. In the family of FACTS, we see Thyristor-Controlled Series Capacitors (TCSC), Static Synchronous Compensators (STATCOM) and Proportional-Integral-Derivative (PID). These contains the ability to increase the power control and system stability. The allocation of this unit aim to achieve the most effective stabilization system modes while this is a complex issue that requires consideration of several factors.

These considerations include the identification of nodes, branches, locate the controllers of the system and the choice of suitable reaction. Modern power systems are complex and large scale. Disturbances lead to change of the network topology and results in a non-linear response of the system.

II. SINGLE MACHINE INFINITE BUS SYSTEM (SMIB)

Algorithmic simplicity can be achieved by focusing on one machine. Therefore, the single machine infinite bus (SMIB) system came into existence instead of multi-machine power system. As shown in Figure 1, a single machine is connected to infinite bus system through a transmission line containing inductance$x_e$and resistancer_e.

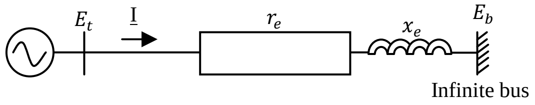

Fig.1: Single machine infinite bus system

The generator is demonstrated using transient model, as indicated by the accompanying equations.

Stator Winding Equations:

$$v_q = -r_s i_q - x_d^{'} i_d + E_q^{'} \quad (1)$$
$$v_d = -r_s i_d - x_q^{'} i_q + E_d^{'} \quad (2)$$

Where

$E_d^{'}$is the d-axis transient voltage.

$E_q^{'}$is the q-axis transient voltage

$x_q^{'}$is the q-axis transient resistance

$x_d^{'}$is the d-axis transient resistance

r_s is the stator winding resistance

Rotor Winding Equations:

$$T_{do}^{'} \frac{dE_q^{'}}{dt} + E_q^{'} = E_f - (x_d - x_d^{'}) i_d \quad (3)$$
$$T_{qo}^{'} \frac{dE_d^{'}}{dt} + E_d^{'} = E_f - (x_q - x_q^{'}) i_q \quad (4)$$

Where, $T_{do}^{'}$is the d-axis open circuit transient time constant.

$T_{qo}^{'}$is the q-axis open circuit transient time constant$E_f$is the field voltage.

Torque Equation:

$$T_{el} = E_q^{'} i_q + E_d^{'} i_d + (x_q^{'} - x_d^{'}) i_d i_q \quad (5)$$

Rotor Equation:

$$2H \frac{d\omega}{dt} = T_{mech} - T_{el} - T_{damp} \quad (6)$$

Then

$$T_{damp} = D\Delta\omega \quad (7)$$

Where,

$T_{el}$is the electrical torque.

$T_{damp}$is the damping torque and

D is the damping coefficient.

T_{mech}represents mechanical torque, which is constant in this model.

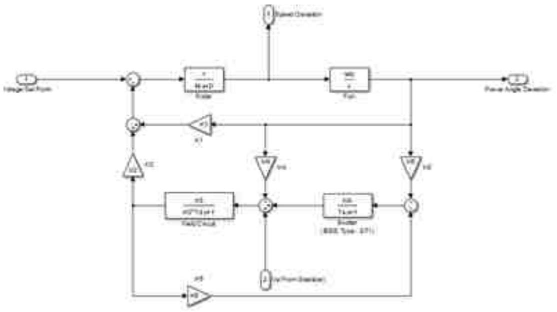

Fig.2: Heffron-Phillips model – SMIB

For the study of single machine infinite bus system a Heffron-Phillips model can be obtained by linearizing the system equations around an operating condition. The obtained Heffron model is as in figure 2 and essential mathematical equations related with SMIB framework are:

$$\frac{d}{dt}\delta = \omega_b S_m \tag{8}$$

$$\frac{d}{dt}S_m = \frac{1}{2H}[T_{mech} - T_{elec} - DS_m] \tag{9}$$

$$\frac{d}{dt}E_q^{'} = \frac{1}{T_{do}^{'}}[E_{fd} - E_q^{'} + (X_d - X_d^{'})i_d] \tag{10}$$

$$\frac{d}{dt}E_{fd} = \frac{1}{T_e}[K_e(V_{ref} + V_{pss} - V_t) - E_{fd}] \tag{11}$$

$$T_{elec} = E_q^{'}i_q + (X_d^{'} - X_q^{'})i_d i_q \tag{12}$$

$$S_m = \frac{\omega - \omega_b}{\omega_b} \tag{13}$$

Where,

δ =Rotor angle.

S_m= Slip speed.

T_{mech} and T_{elec}= Mechanical and Electrical torques respectively.

D= Damping coefficient.

$E_q^{'}$ = Transient EMF due to field flux linkage.

i_d= d-axis component of stator current.

i_q=q-axis component of stator current.

$T_{do}^{'}$ = d-axis open circuit time constant.

$X_d, X_d^{'}$ - d-axis reactance.

$X_q, X_q^{'}$= q-axis reactance.

E_{fd}= Field voltage.

K_e, T_e: Exciter gain and time constant.

V_t = Voltage measured at the generator terminal.

V_{ref}= Reference voltage.

Linearized equations are:

$$\Delta\delta^{'} = \omega_b \Delta S_m \tag{14}$$

$$\Delta S_m^{'} = \frac{1}{2H}[\Delta T_m - \Delta T_e - D\Delta S_m] \tag{15}$$

$$\Delta T_e = K_1 \Delta\delta + K_2 \Delta E_q^{'} \tag{16}$$

$$\frac{d}{dt}\Delta E_q^{'} = \frac{[K_3(\Delta E_{fd} - K_4\Delta\delta - \Delta E_q^{'})]}{K_3 T_{do}^{'}} \tag{17}$$

$$\Delta V_t = K_5\Delta\delta + K_4\Delta E_q^{'} \tag{18}$$

$$\frac{d}{dt}\Delta E_{fd}^{'} = \frac{1}{T_A}[K_A(\Delta V_{ref} + \Delta V_{pss} - \Delta V_t) - \Delta E_{fd}^{'}] \tag{19}$$

Where, Heffron-Phillip's constants are explained as:

$$K_1 = \frac{E_b E_{qo}\cos\delta_0}{X_q + X_e} + \frac{X_q - X_d^{'}}{X_e + X_d^{'}} E_b \sin\delta_0$$

$$K_2 = \frac{X_q + X_e}{X_e + X_d^{'}} i_{q_0}$$

$$K_3 = \frac{X_e + X_d^{'}}{X_d + X_e}$$

$$K_4 = \frac{X_d - X_d^{'}}{X_e + X_d^{'}} E_b \sin\delta_0$$

$$K_5 = -\frac{X_q V_{d0} E_b \cos\delta_0}{(X_q + X_e)V_{to}} - \frac{X_d^{'} V_{qo}\sin\delta_0}{(X_e + X_d^{'})V_{to}}$$

$$K_5 = \frac{X_e}{X_e + X_d^{'}}\frac{V_{qo}}{V_{to}}$$

Where $E_{qo} = E_{qo}^{'} - (X_q - X_d^{'})i_{do}$

δ_0, $E_{qo}^{'}$ and V_{to}represents the values at the initial operating condition.

Figure 3 showing the SIMULINK Implementation of Phillip-Heffron model stated above.

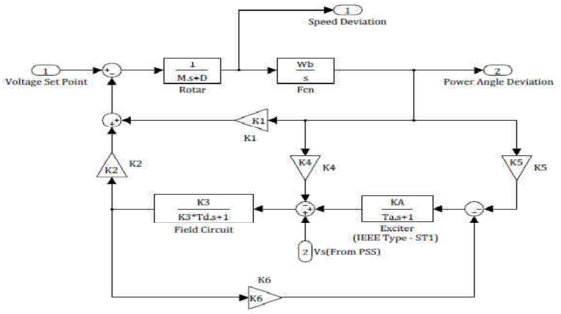

Fig.3: Simulink Implementation of SMIB

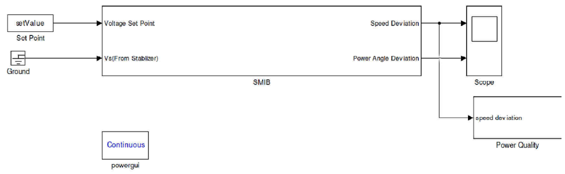

Fig.4: Simulink model for proposed SMIB

III. POWER SYSTEM STABILITY

Power system stability is a property that enable it to operate in its equilibrium state under normal operating condition and regain its normal state of equilibrium when disturbance occurs.

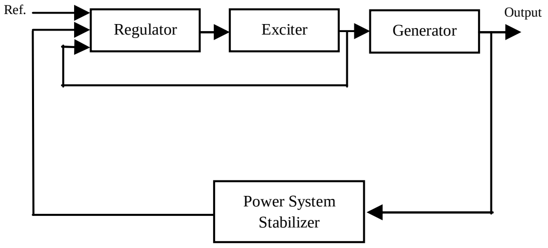

Fig.5: Basic block diagram of a synchronous generator excitation control system [5]

This paper concentrates electromechanical disturbance, which furthers causes for power fluctuations between electrical networks and generating units. In addition the electromechanical will also cause the instability of rotating part of power system [20]. Security of the power system relies on its ability to survive any disturbances which may occur without any disturbance in the services. A large synchronous generator of a typical excitation control system is shown in Figure5.

Power system stabilizers (PSS) are utilized on a synchronous generator to expand the damping of oscillations of the rotor/turbine shaft. The traditional PSS was initially proposed in the 1960s and traditional control hypothesis, characterized in transfer functions, was utilized for its structure. Later the progressive work of DeMello and Concordia [1] in 1969, control engineers, and additionally power system engineers, have shown incredible knowledge and made huge assistance with PSS outline and applications for both single and multi-machine power systems.

Optimal control hypothesis for stabilizing out SMIB power systems was created by Anderson [2] and also by Yu [3]. These controllers had linear property. Adaptive control methodologies have likewise been proposed for SMIB, the vast majority of which include linearization or model estimation.

Klein et al. [4, 5] demonstrated that the PSS area and the voltage characteristics of the system loads are huge component in the capacity of a PSS to expand the damping of inter-area oscillations. Currently, the traditional lead-lag power system stabilizer is broadly utilized by power system usages [6]. Additional types of PSS, for example, proportional-integral power system stabilizer (PI-PSS) and proportional-integral-derivative power system stabilizer (PID-PSS) have additionally been developed [7-8].

Certain methodologies have been connected to PSS design issue. These incorporate pole placement, H_∞, adaptive control, optimal control, variable structure control, and various artificial intelligence and optimization methodologies [9].

The linearized equations of GPSS are:

$$\frac{d\Delta X_{w(GPSS)}}{dt} = K_{GPSS}\frac{d\Delta\omega}{dt} - \frac{1}{T_w}\Delta X_{w(GPSS)} \qquad (20)$$

$$\frac{d\Delta X_{(GPSS)}}{dt} = \frac{T_1}{T_2}\frac{dX_{w(GPSS)}}{dt} + \frac{1}{T_2}\Delta X_{w(GPSS)} - \frac{1}{T_2}\Delta X_{(GPSS)} \qquad (21)$$

$$\frac{d\Delta V_{s(GPSS)}}{dt} = \frac{T_3}{T_4}\frac{dX_{(GPSS)}}{dt} + \frac{1}{T_4}\Delta X_{(GPSS)} - \frac{1}{T_4}\Delta V_{s(GPSS)} \qquad (22)$$

Figure 6 and Figure 7 show the Simulink model for Generic-PSS and SMIB system connected with GPSS respectively.

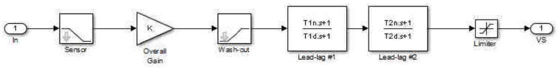

Fig.6: Simulink model for Generic-PSS

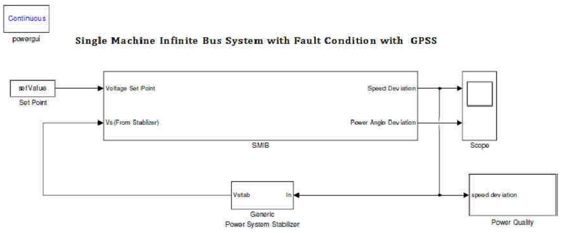

Fig.7: Simulink model for SMIB with GPSS

IV. PROPORTIONAL-INTEGRAL-DERIVATIVE (PID)

PID controllers give satisfactory performance for many of the control processes. Due to their simplicity and usefulness, PID controller has become a powerful solution to the control of a large number of industrial processes. The control systems performance is complicated by the numerator dynamics (presence of a zero) of the process. Several processes exhibit second order plus time delay system with a zero transfer function model.

PID controller contains Proportional Action, Integral Action and Derivative Action which is generally known as Ziegler-Nichols PID tuning parameters. PID controller's algorithm is generally utilized as a part of feedback loops. PID controllers can be realised in numerous structures. It can be realised as a stand-alone controller or as a component of Direct Digital Control (DDC) bundle or even Distributed Control System (DCS). It is fascinating to note that more than half of the industrial controllers being used today use PID based control techniques. Figure 8 shows a basic block diagram of the PID controller which is known as non-interacting form or parallel form.

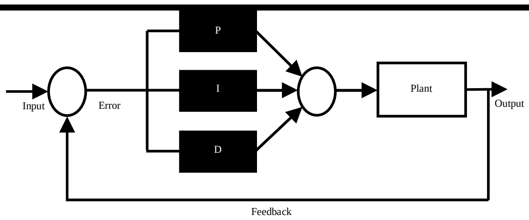

Fig.8: Schematic of the PID Controller- Non Interacting form

Mathematical expression for the output of PID controller is given by:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt} \quad (23)$$

Figure 9 and Figure 10showthe Simulink model for PID and SMIB system connected with PID respectively.

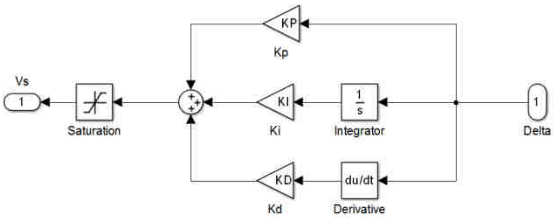

Fig.9: Simulink model for PID

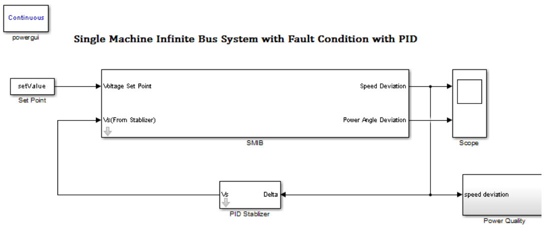

Fig.10: Simulink model for SMIB with PID

V. HYBRID APPROACH

Voltage stabilizer (GPSS) generates spikes during the speed deviation and the output of GPSS is generally positive. To decrease those spikes, this hybrid method uses PID along with the GPSS. This approach reduces the spikes generation. In hybrid approach, we have associated PID stabilizer with the GPSS connected SMIB as shown in Figure 11.

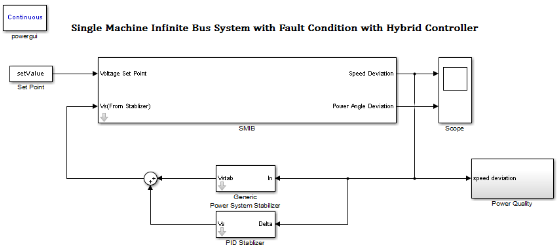

Fig.11:Simulink model for hybrid approach

VI. SIMULATION RESULTS

The performance of proposed algorithms has been studied by means of MATLAB simulation.

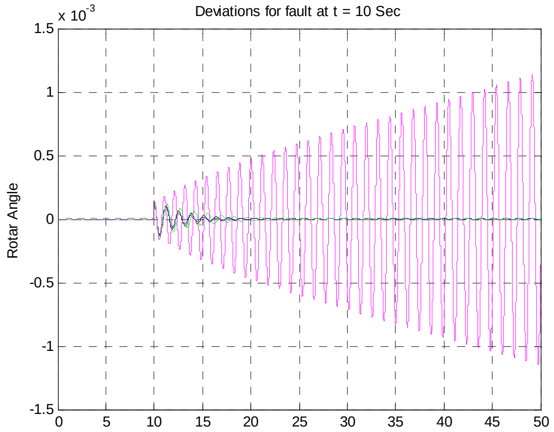

Fig. 12: Rotor angle deviations for fault at t=10 sec

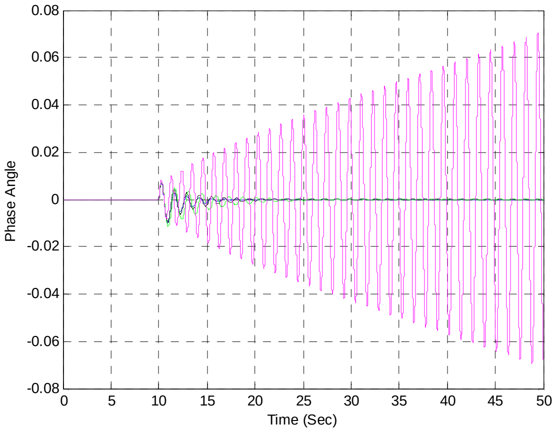

Fig.13: Phase angle deviations for fault at t=10 sec

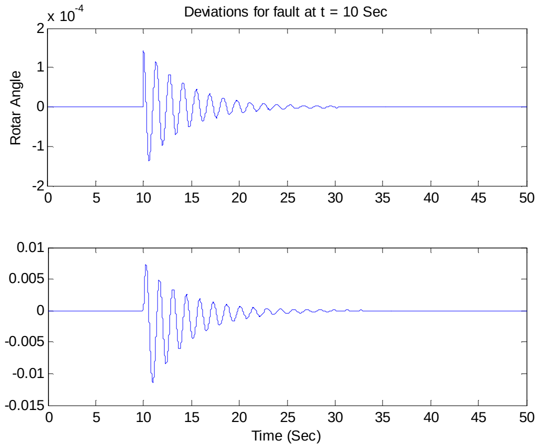

Fig.14: Rotor and Phase angle deviations of GPSS for fault at t=10 sec

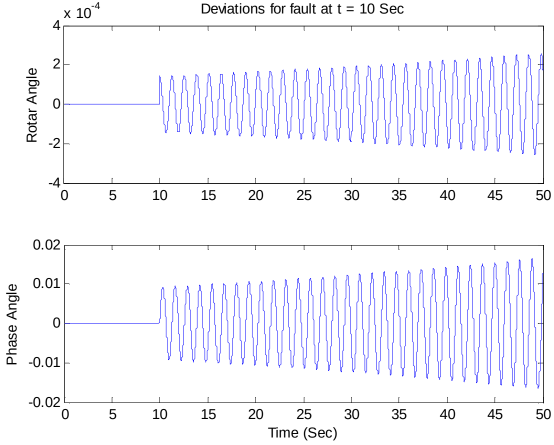

Fig.15: Rotor and Phase angle deviations of SMIB for fault at t=10 sec

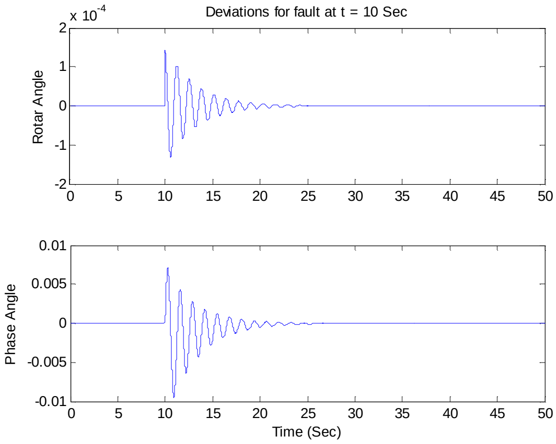

Fig.16: Rotor and Phase angle deviations of PID for fault at t=10 sec

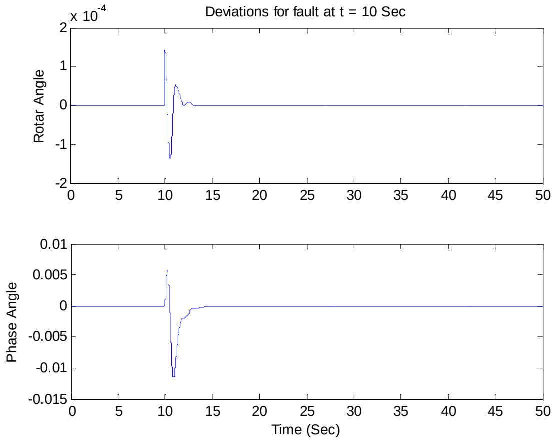

Fig.17: Rotor angle and Phase angle deviations for fault at t=10 sec (PSObased hybrid approach)

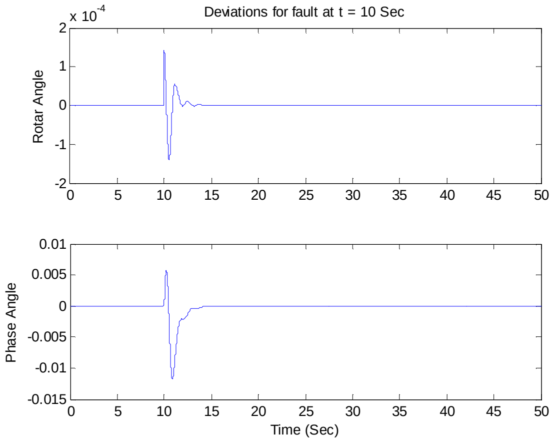

Fig.18: Rotor angle and Phase angle deviations for fault at t=10 sec (GA based hybrid approach)

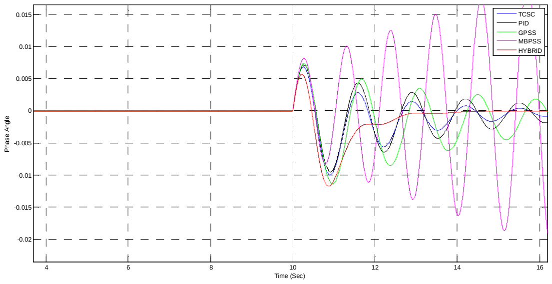

Fig.19: Comparative analysis of phase angle deviations for different methods

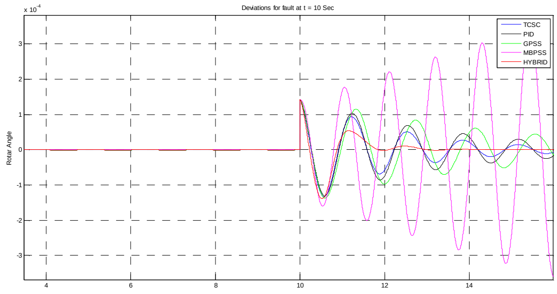

Fig.20: Comparative analysis of rotor angle deviations for different methods

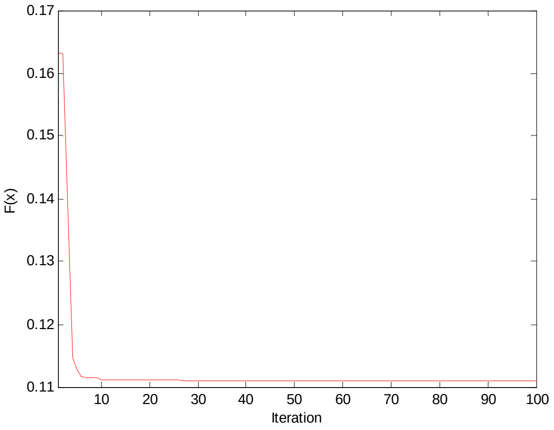

Fig.21: Convergence graph for PSO

VII. CONCLUSION

This paper proposes a hybrid approach for stability analysis using GA and PSO. The effectiveness of the proposed hybrid approach is demonstrated on a SMIB power system. Performance of the proposed approach is recorded on the basis of evaluation parameters i.e. Phase angle and rotor angle deviations. Figure 19 and Figure 20 show the comparative analysis for proposed approach and the techniques developed earlier and it can be said that the proposed hybrid approach outperforms than other techniques.

REFERENCE

[1] F. P. Demello and C. Concordia, “Concepts of Synchronous Machine Stability as Affected by Excitation Control,” IEEE Trans.on Power Apparatusand Systems, vol. PAS-88, no. 4, April 1969.

[2] Angeline J. H, “The control of a synchronous machine using optimal control theory,” Proceedings of the IEEE, vol. 1, pp. 25–35, 1971.

[3] Yu YN and Moussa HAM, “Optimal stabilization of a multi-machine system,” IEEE Transactions on Power Apparatus and Systems, vol. 91,no. 3, pp. 1174–1182,1972.

[4] Klein, M.; Rogers, G.J.; Kundur, P., “A fundamental study of inter-area oscillations in power systems,” IEEE Transactions on Power Systems, Volume: 6 Issue: 3, Aug. 1991, Page(s): 914 -921.

[5] Klein, M., Rogers G.J., Moorty S., and Kundur, P., “Analytical investigation of factors influencing power system stabilizers performance”, IEEE Transactions on Energy Conversion, Volume: 7 Issue: 3, Sept. 1992, Page(s): 382 -390.

[6] G. T. Tse and S. K. Tso, "Refinement of Conventional PSS Design in Multimachine System by Modal Analysis," IEEE Trans. PWRS, Vol. 8, No. 2, 1993, pp. 598-605.

[7] Y.Y. Hsu and C.Y. Hsu, “Design of a Proportional-Integral Power System Stabilizer,” IEEE Trans. PWRS, Vol. 1, No. 2, pp. 46-53, 1986.

[8] Y.Y. Hsu and K.L. Liou, “Design of Self-Tuning PID Power System Stabilizers for Synchronous Generators,” IEEE Trans. on Energy Conversion, Vol. 2, No. 3, pp. 343-348, 1987.

[9] V. Samarasinghe and N. Pahalawaththa, “Damping of Multimodal Oscillations in Power Systems Using Variable Structure Control Techniques”, IEEE Proc. Genet.Transm. Distrib. Vol. 144, No. 3, Jan. 1997,pp. 323-331.