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Design of PSS and SVC Controller Using PSO Algorithm to Enhancing Power System Stability

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Abstract: *This paper presents simultaneous tuning of power system stabilizer (PSS) and static var compensator (SVC) based controller to enhance power system stability. The design problem is converted into an optimization problem with a time domain simulation based objective function and particle swarm optimization (PSO) is employed to find optimal parameters of controller. The proposed controller is tested with different disturbance like balance fault, unbalance fault, small disturbance over a weakly connected power system. The nonlinear simulation results show that the proposed control schemes effectiveness and ruggedness over a broad range of different disturbances. Further, the proposed design approach is found to be robust and improves stability efficiently.*

Keywords: *EHV, LFO, PSS, PSO, SMIB, SVC.*

I. Introduction

Many blackouts reported due to damping so power system stability is major concern. Power system stability means the ability of system to retrieve at its original condition after a disturbance present in a system. Voltage instability occurs when system gets various disturbances, growth in load or abnormal operating conditions. In the industry to damp out power system oscillations use of Power System Stabilizers (PSS) are now normal. Some operating conditions this device does not perform effectively and is not able to provide adequate damping. Therefore other effective options are required apart from PSS. When a SVC is present in a Power system to support the bus voltage, a additional damping controller could be designed for the regulation of the SVC bus voltage so as to improve system oscillations damping.

II. Power System

The power system model is represented by single machine infinity bus system (SMIB). The generated power of Synchronous machine is fed to the infinite bus via transmission line. The synchronous machine terminal voltage is shown by E_t while infinite bus voltage shown by E_b. Resistance & reactance of the transmission line R_e & X_e.

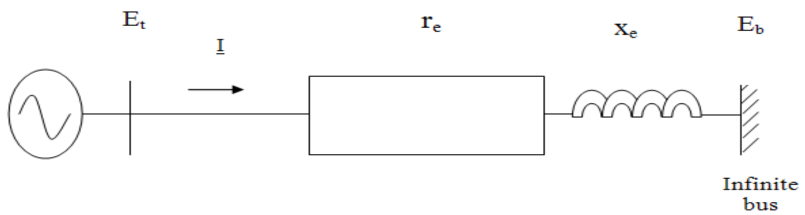

Fig.1: power system.

The synchronous generator model 1.1(with field circuit and one equivalent damper winding on q axis) is used to present the impact of PSS on power system stability. The Phillips-Haffron model of single machine infinity bus system is developed using MATLAB/SIMULINK, which can be further incorporated for explaining the power system stability phenomena and also for research works including the development of generator controllers via advanced technologies. The non-linear simulation results are offered to validate the effectiveness of the proposed approach. The below equations and notations for the variables and parameters described are standard.

$$\frac{d\delta}{dt} = w_B\,(S_m - S_{mo}) \tag{1}$$

$$\frac{dS_m}{dt} = \frac{1}{2H}\,[-D\,(S_m - S_{mo}) + T_m - T_e] \tag{2}$$

$$\frac{dE'_q}{dt} = \frac{1}{T'_{do}}\left[-E'_q + (x_d - x'_d)\, i_d + E_{fd}\right] \tag{3}$$

$$\frac{dE'_d}{dt} = \frac{1}{T'_{do}}\left[-E'_d + (x_q - x'_q)\, i_q\right] \tag{4}$$

The electrical torque T_e is expressed in terms of variables E'_d , E'_q , i_d and i_q as:

$$T_e = E'_d\, i_d + E'_q\, i_q + (x'_d + x'_q)\, i_d\, i_q \tag{5}$$

For a lossless network, the stator algebraic equations and the network equations are expressed as:

$$E'_q + x'_d\, i_d = V_q \tag{6}$$

$$E'_d - x'_q\, i_q = V_d \tag{7}$$

$$V_q = -x_e i_d + E_b \cos\delta \tag{8}$$

$$V_d = x_e i_q - E_b \sin\delta \tag{9}$$

Solving the above equations, the variables i_d and i_q can be obtained as:

$$i_d = \frac{E_b \cos\delta - E'_q}{X_e + X'_d} \tag{10}$$

$$i_q = \frac{E_b \sin\delta + E'_d}{X_e + X'_q} \tag{11}$$

III. Power System Stabilizer (PSS)

The PSS is used to add damping to rotor oscillations by varying field excitation using additional stabilizing signal. The stabilizer produces an electrical torque component in phase with the rotor speed deviation to provide adequate damping. Maintaining steady state and transient stability of modern synchronous generators especially demands fast control of the terminal voltage & high performance excitation systems. It is find that fast acting exciters with high gain automatic voltage regulator (AVR) also contribute for oscillatory instability in power systems. The low frequency (0.2 to 2.0 Hz) oscillations which are exist or even grow in magnitude without any apparent reason. An effective and satisfactory solution to oscillatory instability is to provide damping to rotor oscillations. Generally this damping is providing by Power System Stabilizer (PSS) which is supplementary controllers in the excitation systems. The PSS add damping to the rotor oscillations by controlling field excitation using additional stabilizing signal.

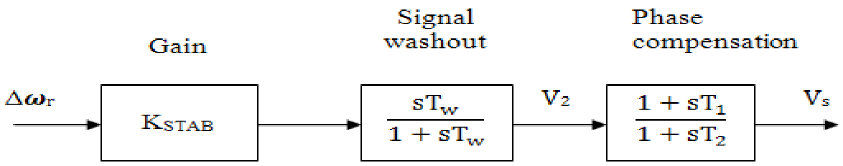

Fig. 2: Power System Stabilizer

Preturbed value from above figure, we can write:

$$\Delta V_2 = \frac{pT_w}{1+pT_w}\left(K_{STAB}\,\Delta\omega_r\right) \tag{12}$$

Hence

$$p\Delta V_2 = K_{STAB}\, p\Delta\omega_r - \frac{1}{T_w}\Delta V_2 \tag{13}$$

Taking state variables for $p\Delta\boldsymbol{\omega}_r$ in equation (13) we can rewrite above equation in state variables.

$$p\Delta V_2 = K_{STAB}\left[a_{11}\Delta\omega_r + a_{12}\Delta\delta + a_{13}\Delta\psi_{fd} + \frac{1}{2H}\Delta T_m\right] - \frac{1}{T_w}\Delta V_2 \tag{14}$$

$$p\Delta V_2 = a_{51}\Delta\omega_r + a_{52}\Delta\delta + a_{53}\Delta\psi_{fd} + \frac{K_{STAB}}{2H}\Delta T_m \tag{15}$$

Where

$$a_{51} = K_{STAB}\, a_{11}, \qquad a_{52} = K_{STAB}\, a_{12}, \qquad a_{53} = K_{STAB}\, a_{13}, \qquad a_{55} = \frac{1}{T_w}, \qquad a_{54} = a_{56} = 0$$

$$\Delta V_s = \Delta V_2 \frac{1+pT_1}{1+pT_2} \tag{16}$$

$$p\Delta V_s = \frac{T_1}{T_2} p\Delta V_2 + \frac{1}{T_2}\Delta V_2 - \frac{1}{T_2}\Delta V_s \tag{17}$$

Substituting value $p\Delta V_2$ from equation (15) we get

$$p\Delta V_s = a_{61}\Delta\omega\omega_r + a_{62}\Delta\delta + a_{63}\Delta\psi_{fd} + a_{64}\Delta V_c + a_{65}\Delta V_2 + a_{66}\Delta V_s + \frac{T_1}{T_2}\frac{K_{STAB}}{2H}\Delta T_m \tag{18}$$

Where

$$a_{61} = \frac{T_1}{T_2}a_{51}, \quad a_{62} = \frac{T_1}{T_2}a_{52}, \quad a_{63} = \frac{T_1}{T_2}a_{53}, \quad a_{65} = \frac{T_1}{T_2}a_{55} + \frac{1}{T_2}, \quad a_{66} = -\frac{1}{T_2}$$

IV. Static VAR Compensator (SVC)

The SVC is an important Shunt FACTS reactive compensation device. It is placed at the mid section of transmission line. By controlling the amount of reactive power injected into or absorbed from the power system SVC modulate the voltage at its terminal. SVC generates the reactive power (capacitive mode), when the system voltage is lower and it absorbs reactive power (inductive mode), when the voltage is higher.

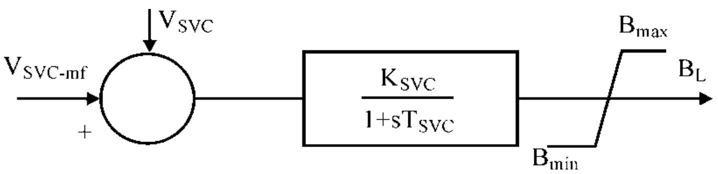

Figure 3.14: Block diagram of the SVC controller.

$w = 2\pi f$, α is the getting delay angle and σ is the conduction angle: $\sigma = 2(\pi - \alpha)$. The fundamental component of the instantaneous current $i_{TCR}(t)$ is given by is found by Fourier analysis:

$$I_{TCR} = V_m . B_L(\alpha) \tag{3.27}$$

The relationship between the firing angle α and the steady state value of B_{TCR} is given as follows:

$$B_L(\alpha) = \frac{2(\pi-\alpha)+\sin(2\alpha)}{\pi X_L}\ ;\ \frac{\pi}{2} \ll \alpha \leq \pi \tag{19}$$

The equivalent susceptance of the SVC, B_{SVC} is given by

$$B_{SVC}(\alpha) = \frac{1}{X_C} - B_L(\alpha) \tag{20}$$

The major role of static VAC compensator is adjusting and the voltage at its terminals. SVS is usually modeled by the block diagram shown in fig. 3.14. The main controller of the tension can be proportional integral or a combination of both actions.

The SVC dynamic regulator can be written as follows

$$\dot{B}_L = \frac{1}{T_{SVC}}(-B_L(t) + B_{LO} + K_{SVC}U_B(t)) \tag{21}$$

Where $B_L(t)$ is the susceptance of the inductor in SVC; B_{LO} is the initial susceptance of the TCR; T_{SVC} the time constant of the SVC regulator, K_{SVC} the gain of the SVC regulator and $U_s(t)$ is the input of the SVC regulator.

The mathematical model of SIMB system with SVC on the transmission line may be presented by the classic third order model as given by equation (1) and the svc model represented by fourth one

$$\begin{cases} \delta = \dot{\omega} \\ \dot{\omega} = -\frac{D}{H}\omega + \frac{\omega_s}{H}(P_m - P_e) \end{cases} \tag{22}$$

$$\dot{E}'_q = \frac{1}{T'_{do}}\left(E_f - E_q\right) \tag{23}$$

$$\dot{B}_L = \frac{1}{T_{SVC}}(-B_L(t) + B_{LO} + K_{SVC}U_B(t) \tag{24}$$

V. Particle Swarm Optimization

Particle swarm optimization has become a common heuristic technique in the optimization community, with many researchers exploring the concepts, issues, and applications of the algorithms. The coordinated search for food which lets a swarm of birds land at a certain place where food can be found was modeled with simple rules for information sharing between the individuals of the swarm. A PSO algorithm maintains a population of particles (the swarm), where each particle represents a location in a multidimensional search space (also called problem space). The particles start at random locations and search for the minimum (or maximum) of a given objective function by moving through the search space. The movements of a particle depend only on its velocity and the locations where good solutions have already been found by the particle itself or other (neighboring) particles in the swarm. PSO algorithm each particle keeps track of the coordinates in the search space which are associated with the best solution it has found so far. The corresponding value of the objective function (fitness value) is also stored. Another "best" value that is tracked by each particle is the best value obtained so far by any particle in its topological neighborhood. When a particle takes the whole population as its neighbors, the best value is a global best. At each iteration of the PSO algorithm the velocity of each particle is changed towards the

Personal and global best (or neighborhood best) locations. But also some random component is incorporated into the velocity update.

Integral time absolute error of the speed deviations is taken as the objective function. The expression of objective function is as follows:

$$J = \int_{t=0}^{t=t_{sim}} |\Delta\omega| . t . dt \qquad (25)$$

Where, $\Delta\omega$ is the speed deviation and t_{sim} is the time range of simulation.

VI. Simulation & Results

The power system model represented by SMIB as defined in equations above is simulated by using MATLAB. The oscillations are created by deviation in rotor speed of synchronous machine. The power system stabilizer (PSS) is introduced in system and performance is observed.

L-L-L-G FAULT

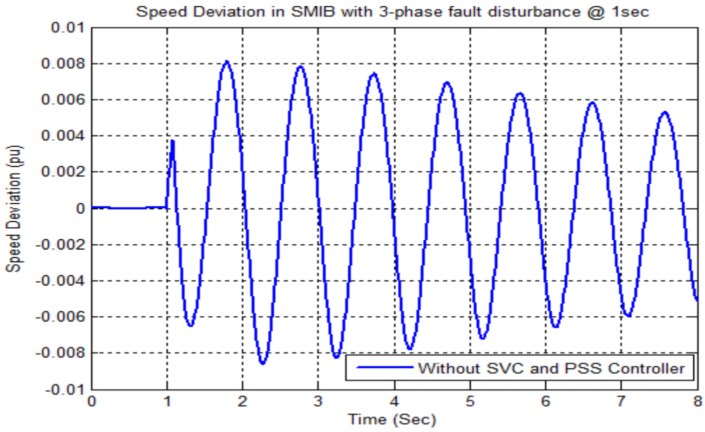

Fig.1: Speed deviation under a 3-phase fault without PSS and SVC.

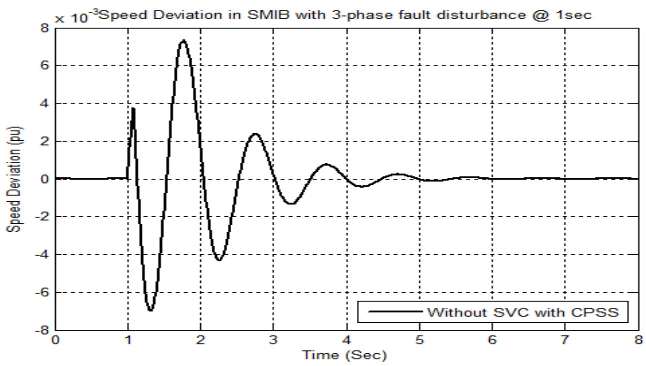

Fig.2: Speed deviation under a 3-phase fault with CPSS and without SVC.

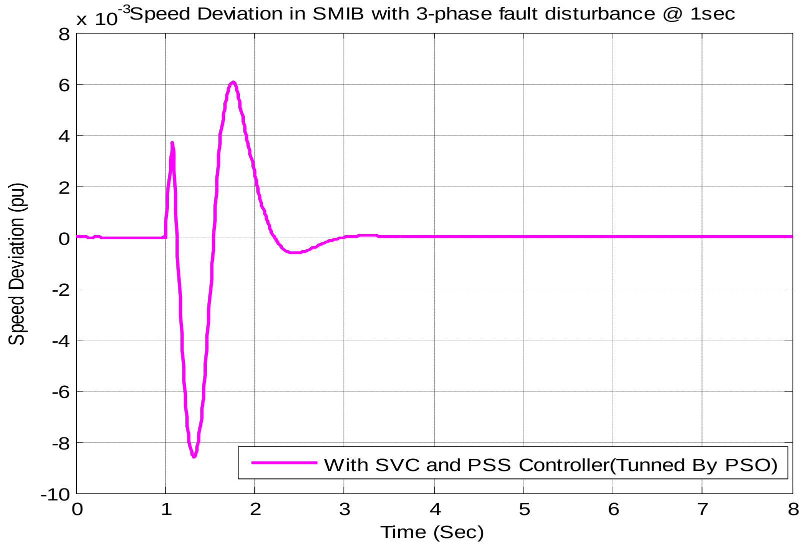

Fig.3: Speed deviation under a 3-phase fault with PSO tuned SVC and PSS.

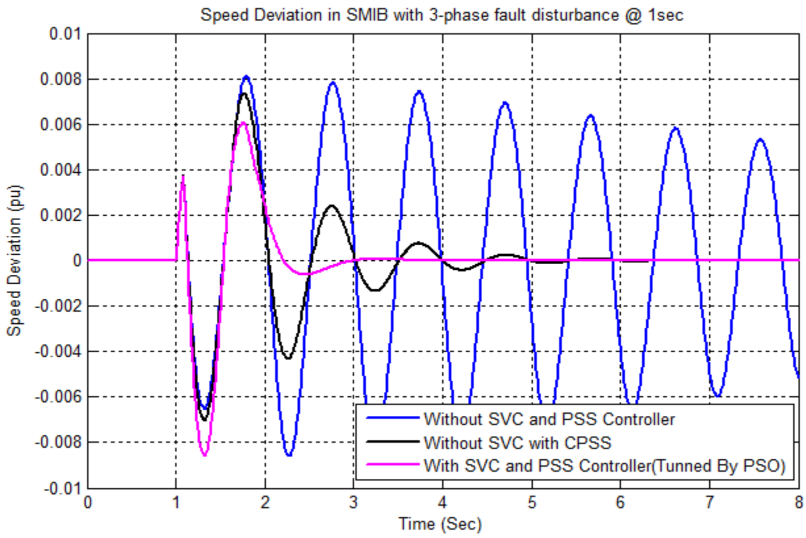

Fig.4: Speed deviation under a 3-phase fault with and without SVC and PSS controller

L-G FAULT:

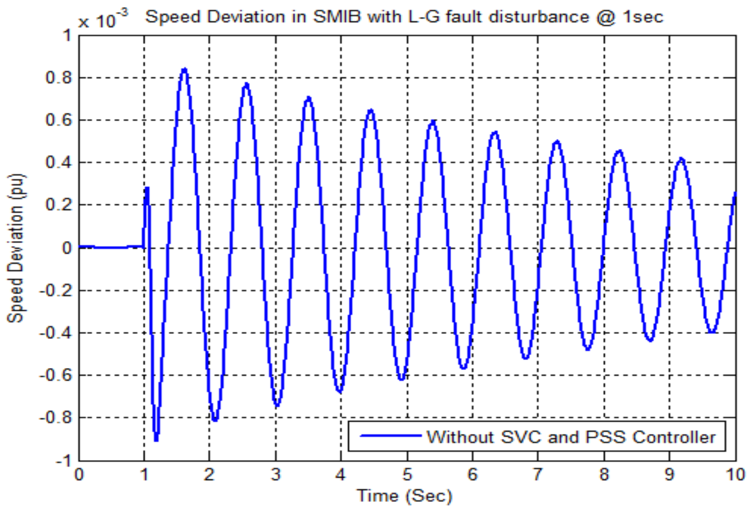

Fig.5: Speed deviation under an L-G Fault without PSS and SVC.

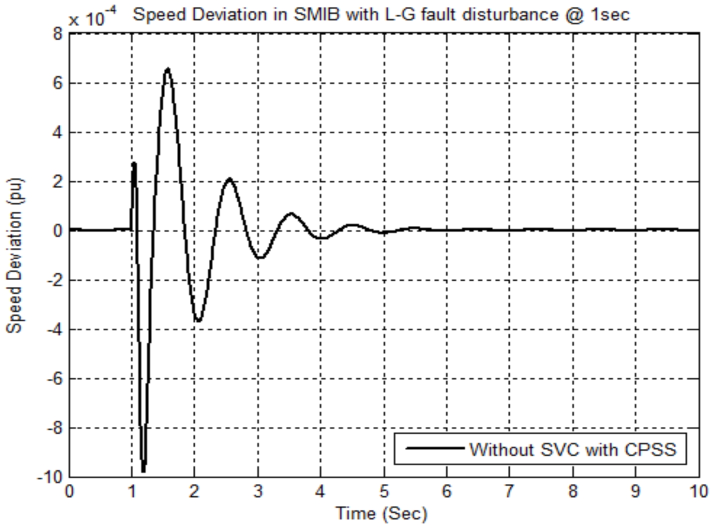

Fig.6: Speed deviation under an L-G Fault with CPSS and without SVC.

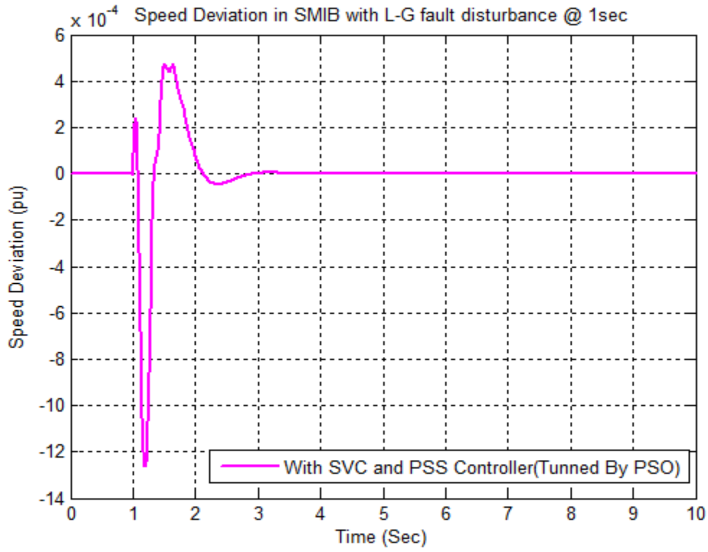

Fig.7: Speed deviation under an L-G Fault with PSO tuned SVC and PSS.

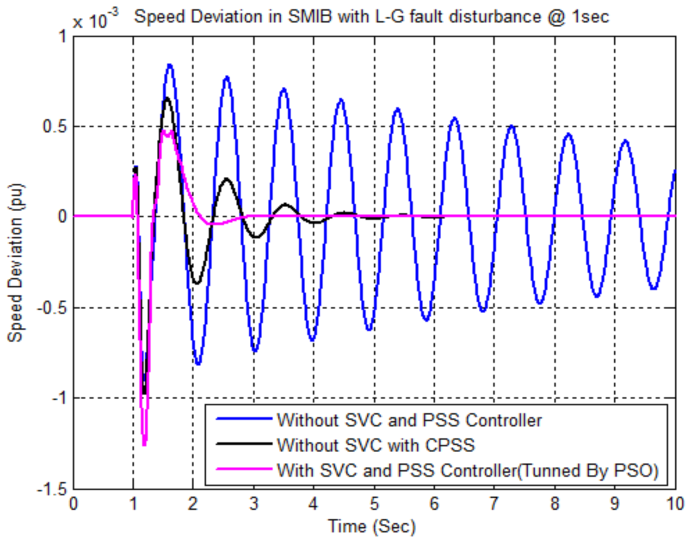

Fig.8: Speed deviation under an L-G Fault with and without SVC and PSS controller.

L-L-G FAULT:

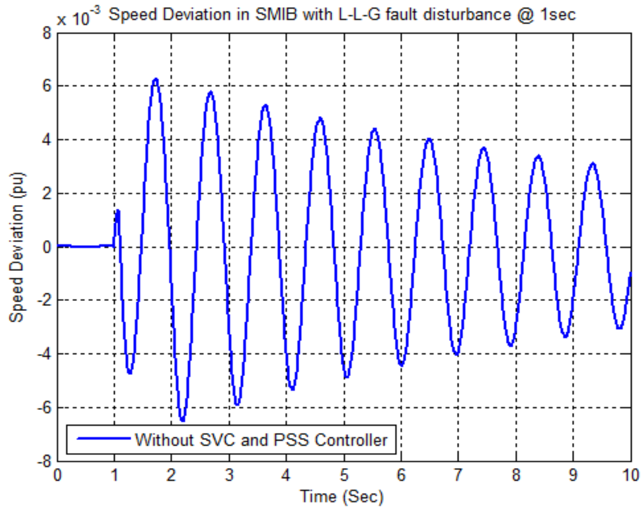

Fig.9: Speed deviation under an L L-G Fault without PSS and SVC.

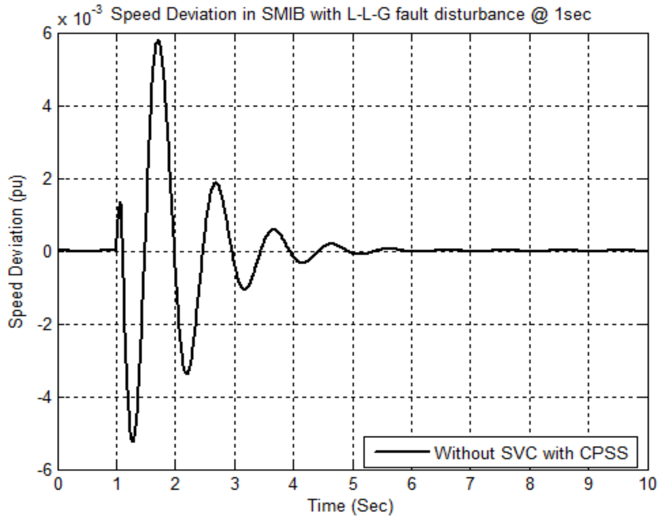

Fig.10: Speed deviation under an L-L-G Fault with CPSS and without SVC.

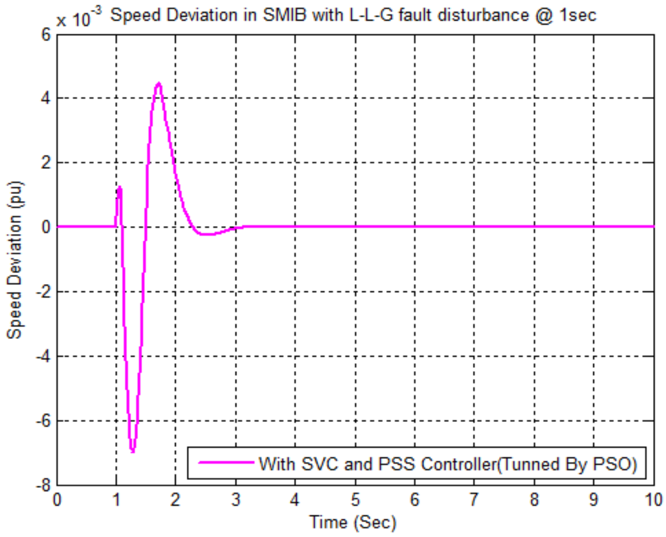

Fig.11: Speed deviation under an L-L-G Fault with PSO tuned SVC and PSS.

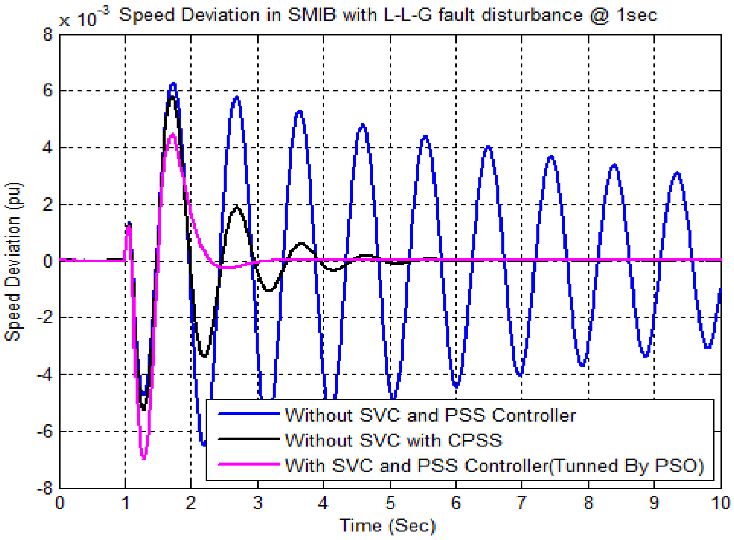

Fig.12: Speed deviation under an L-L-G Fault with and without SVC and PSS controller.

10% Step Increase In Mechanical Torque Input

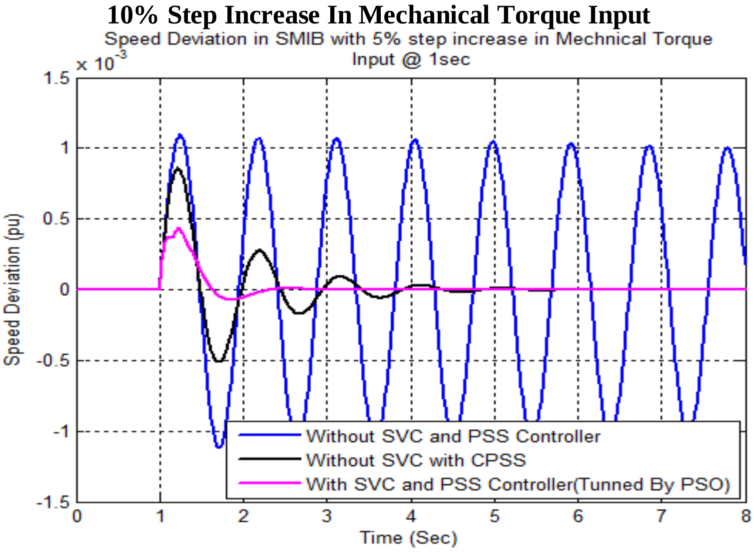

Fig.13: Speed deviation with 10% step increase in mechanical torque input

10% Step Increase In Reference Voltage Setting

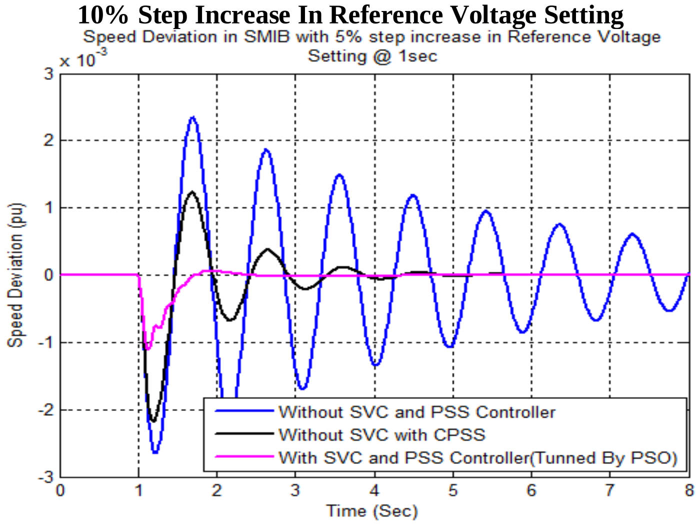

Fig.14: Speed deviation with 10% step increase in reference voltage setting.

VII. Conclusion

The effectiveness of the proposed controller is demonstrated to show power system stability improvement subjected to various disturbances as balance fault, unbalance fault and small disturbances. PSO tuned controller improves stability performance of power system with effectively damp out of various disturbances. Results show that proposed PSS and SVC Controller is suitable for stability analysis of power system. Also the parameters of this system are studied for the maximum efficiency.

References

[1] Salma Keskes, Wissem Bahloul and Mohamed Ben Ali Kammoun, "Improvement of Power System Stability by Static Var Compensator and Tuning Employing Genetic Algorithm", International Journal of Modern Nonlinear Theory and Application, Vol. 3, pp-113-123, 2014.

[2] Rajendra prasad Narne and P. C. Panda, "PSS with Multiple FACTS Controllers Coordinated Design and Real-Time Implementation Using Advanced Adaptive PSO", International Science Index International Journal of Electrical, Robotics, Electronics and Communications Engineering, Vol:8 No: 1, pp-144-154, 2014.

[3] Saeid Jalilzadeh, Reza Noroozian, Mahdi Sabouri and Saeid Behzadpoor , "PSS and SVC Controller Design Using Chaos, PSO and SFL Algorithms to Enhancing the Power System Stability", Energy and Power Engineering, Vol. no. 3 ,pp-87-95, 2011.

[4] A.Jalilvand, S. Behzadpoor and M. Hashemi , "Imperialist Competitive Algorithm-Based Design of PSS to Improve the Power System", IEEE, 2010.

[5] R. Grondin, I. Kamwa, G. Trudel and L. Gerin-Lajoie, "Modeling and closed-loop validation of a new PSS concept, the multi-band PSS", IEEE Power Engineering Society, General Meeting, July 2003.