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Dynamic Stability Analysis of Generator with Power System Stabilizers Using Matlab Simulink

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Abstract

The dynamics in single machine been connected to an infinite power system bus is analyzed in this paper. This analysis requires certain amount of system modeling level. The main components of the system models are excitation system, synchronous machine and the Power System Stabilizer. The Simulink /Matlab are used as the programming tool for analyzing this system performance. Design optimization arobust PSS based on genetic algorithm (GA) approach has been improvement. A proper design is required for this power system stabilizer (PSS) performance using the particle swarm optimization (PSO) to archieve this. Then the implemented of the model and response of the dynamic system is been analyzed. The designed without PSS showed an unacceptable system response since as shown in the simulation results, system response with PSS proven to have improvements and PSS succeeding in stabilizing an unstable system. Therefore this leads to stability of the performance of the generator.

Keywords: *dynamic stability, power system stabilizer, genetic algorithm (GA), particle swarm optimization*

1. Introduction

Power system stabilizers has been commonly used to provide additional supplementary control signals into the AVR damping out the oscillations of electromechanical of generators in the power systems. The CPSS (conventional PSS) is generally designed based on “linear model of system” for specific operating point. Though, most power systems are fundamentally nonlinear and changes at operating point much during a “daily cycle”. Hence, the CPSS performance may be significantly degraded under variations caused by vibrant time characteristics and nonlinear of the power system elements. To obtain a high-performing PSS for wide ranges of conditions of operating, some control strategies are been introduced. The application of adaptive control techniques and robust control methods and have been mentioned for PSS design. Due to the requirement of information on system states or the function transfer form in the PSS designing, it is rather difficult finding a dynamic linearized model for the system. Furthermore, in real systems of electric power whose time parameters vary, the online application of identifier for the techniques of adaption in which the system parameters are been estimated, might be difficult and the fixed controller being more feasible and proper for the practical implementations. Low frequency and small magnitude oscillations often remained for an extensive time in power systems. These types of oscillations were controlled by controlling the excitation signal of automatic voltage regulator of the generator. The tuning and location of PSS were found to be important parameters to suppress low frequency oscillations [1],[2]. Automatic voltage regulators have been utilized in power systems since 1960’s.Oscillation at low frequencies of 0.2 to 2.5 Hz may occur in the system due to large disturbances like phase-to-ground faults in a transmission line. Power system stabilizers are used in the addition of damp to the system through modulation of excitation system by adding a component to the electrical torque that phases with the speed deviation [3].

The PSS being a device that provides added supplementary loops control to the automatic voltage regulators system and/or that of the system of turbine governing generating unit. This is considered the most common methods of enhancing for both the small signal stability (“steady-state”) and the large-signal stability (“transient”). PSS are oftenly used as economic and effective damping means of such oscillations [4]. The PSS is connected directly

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to the AVR for synchronous generators in addition; the fundermental aim of the PSS-AVR control excitation configuration is providing voltage regulation and damping. Some techniques are been proposed in order tune and design schemes of PSS–AVR properly [5]. Basically the function of power system stabilizer is extending the stability limits of generator excitation by modulating to provide damping for oscillations of the machine rotors synchronous in relation to another. Furthermore the advancement in the bio-inspired and evolution techniques like Particle-Swarm Optimization (PSO) and Genetic Algorithms (GA) have lead to a new approach in solvingcomplex optimization problems. The advantage of using GA techniques is that it is independent of the complexity of the performance index considered. Typically these oscillations concern arise approximately in the frequency ranges of 0.2 to 2.5 Hz, also these oscillations might limit the transmition ability for the power inadequate damping [6]. The added signals are generally derived from deviation excitation system, speed of deviation or the power acceleration. This is archeived by inserting the “stabilizing signal into the excitation system voltage reference summing point junction. The device arrangement is to provide the signal is called power system stabilizer”. Furthermore, tuning of scaling factors is very important because a change of scaling factors can affect the stability, oscillation and damping of the system [7,[8].The parameter tuning of the PSS has been know to be a complex exercise becoming the subject of many researches [5]. In conventional PSS tuning for large power systems the methodologies are inadequate, since they produce occasionally adverse effects on other oscillatory modes for the damping, especially the once associated with exciters and the oscillations shaft torsional. Using reduced order models of the power system could significantly speed-up the process of PSS tuning [9].

2. Research Method

In this work, the research methodology will be discussed in depth in the following sub-sections.

2.1. Stabilizing Signal

Signal washout becoming a filter high-pass preventing the steady change in speed from being modified by the voltage field. The washout time value of the “constant T_w” should always be high enough allowing associated “signals with oscillations speed” in rotor passing unchanged. The T_w value may not critical and can be anywhere within the range 1 to 20 seconds from the "washout function," viewpoint. The main concern is that, it should be made long enough in order to pass the “stabilizing signals at frequencies of relatively unchanged interest”, but again not so long that could result to undesirable voltage generator excursions due to stabilizer actions during the conditions of system-islanding. Ideally, the stabilizer should not respond to the system-wide frequency variations. For “the local mode oscillations” within the ranges 0.8 to 2.0 Hz, the washout of 1.5 seconds is considered satisfactory. From low-frequency viewpoint of oscillations inter area, a “constant washout time of 10 seconds or higher” is considered desirable, since the constants lower-time result in the significant phase lead at lower frequencies. Unless this is compensated for elsewhere, it will reduce the torque component synchronizing at the frequencies of inter area. The effect of desynchronizing is harmful to transient stability of inter area as it causes the areas swinging further apart following the disturbance[10],[11].

2.2. Infinite Bus to Single Machine Connection

The synchronous generator experience and the period of oscillatory could be classified into the period of transient and dynamic period or steady state. From the assumption this stator voltage linear “equation of $(E^{'}q)$” that is proportional to the main linkage flux winding could be found [4, 7].

$$\Delta E^{'}q = \frac{K_3}{1 + K_3\tau^{'}_{d0^s}}\Delta E_{FD} - \frac{K_3K_4}{1 + K_3\tau^{'}_{d0^s}}\Delta\delta \tag{1}$$

$$\Delta T_e \;=\; K_1 \;\; \Delta\delta + K_2\,\Delta E^{'}q \tag{2}$$

$$E^{'}q = E + (x_d - x'_d) \tag{3}$$

Where the E is gap stator air RMS voltage, synchronous generator “linearized terminal voltage” ΔV_t is given by:

$$\Delta V_t = k_5 \Delta \delta + k_6 \Delta E' \tag{4}$$

Note that the constants *K₁*, *K₂*, *K₃*, *K₄*, *K₅* and *K₆* are been dependent on the system operation conditions and parameter. *G*enerally, K_1, K_2, K_3 and K_6 are been positive, whereas K_4 is always positive except R_e is high. Nonetheless, K_5 is a positive for *the* low and the medium loading and the external impedance. Nevertheless, if loading and external impedance becomes high K_5 will become Negative.

$$\Delta E'q = \frac{K_3}{1 + K_3 \tau'_{0^s}} \Delta E_{FD} - \frac{K_3 K_4}{1 + K_3 \tau_{do^s}} \Delta\delta \tag{5}$$

$$\Delta\omega_m = \frac{1}{2Hs}[\Delta T_M - \Delta T_e - D\Delta\omega_m] \tag{6}$$

$$\Delta\delta = {}^{\omega B}_{S}\Delta\omega_{m=} {}^{\omega B}_{S}\Delta\varpi \tag{7}$$

where the S is Laplace Operator. The system of excitation representation is shown in Figure1 [4, 7, 10]

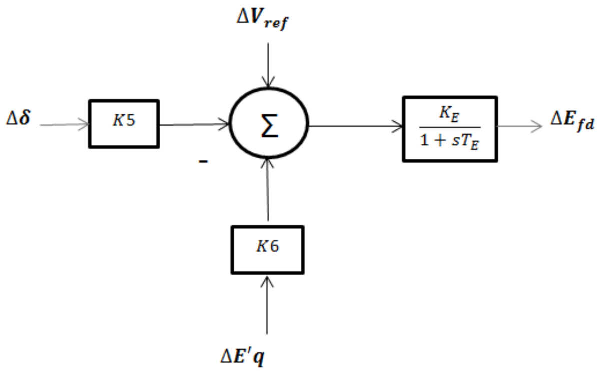

Figure 1. Simple excitation system model

The linearized equation of the excitation system is given by the following equation [4]:

$$\Delta E_{fd=} \frac{K_e}{1+sT_E}(\Delta V_{ref} - \Delta V_t) \tag{8}$$

2.2.1. Synchronous Machine Model

The Synchronous machine models, which are consisting of decay loop flux, and torque angle loop are being implemented in Matlab/ Simulink as shown in Figure 2 [4, 7].

The operating condition is listed below [4], where K5 < 0 operating condition:
K1= 0.9831, K2= 1.092, K3= 0.3864 K4= 1.4746, K5= - 0.1103 K6= 0.4477, H=6 sec,
DT = 5 sec, TE = 0.25, KE = 0.075

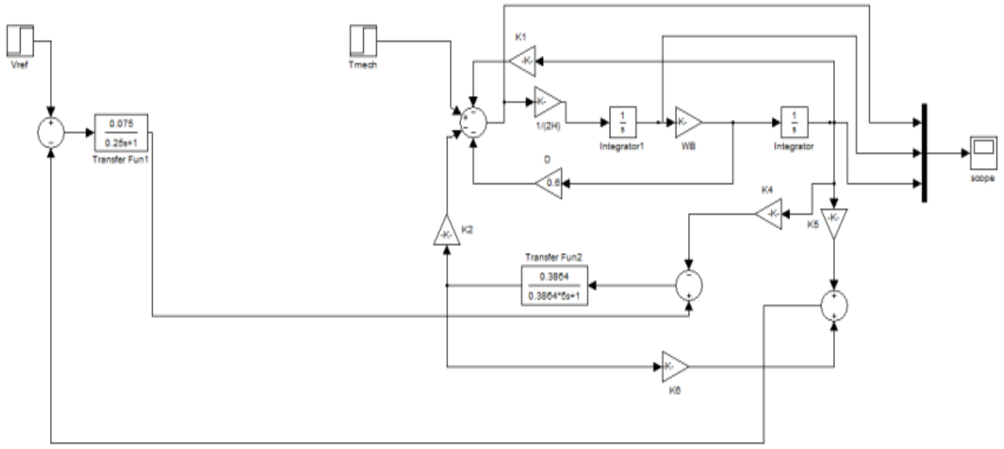

Figure 2. Matlab/Simulink model for Synchronous machine

2.2.2. Excitation System

Excitation system is described by Equation (4) and Equation (8). These implementented Equations are done in Matlab / Simulink as shown in Figure 3.

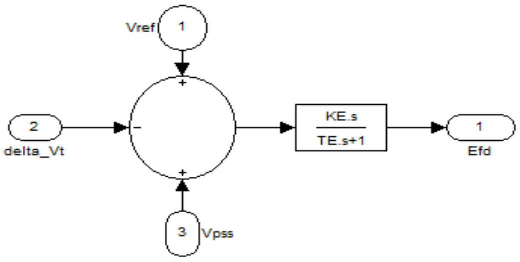

Figure 3. Excitation system of simulink layout [4]

2.3. Implementation of Power System Stabilizer

The PSS model presented in Equation (9) is implemented in Matlab / Simulink as shown in Figure 4, been the input signal of deviation to PSS speed and the VPSS output signal being the auxiliary signal for the excitation system.

$$\frac{Vpss^{(s)}}{Delta\ Speed^{(s)}} = K_S.\frac{10}{10S+1}.\frac{T1.\ s+1}{T2.\ s+1}.\ \frac{T3.\ s+1}{T4.\ s+1} \tag{9}$$

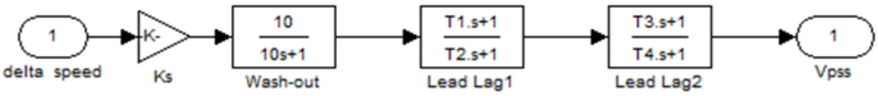

Figure 4. Implementation of PSS in simulink [4]

Table 1 shows PSS parameters been designed by the GA (Genetic Algorithm). A PSO is being used in this paper in order to tune parameters of PSS as described in previous sections, presenting the PSS parameters been designed by a PSO.

Table 1. PSS parameters design [4]

parameters	T_1	T_2	T_3	T_4	K_{PSS}	T_R
GA	1.4557	0.6143	1.0083	0.1005	2.1783	0.02
PSO	0.3730	0.1096	0.7910	0.0819	7.1144	0.02

2.3.1. Simulation Model for Synchronous Machine

The simulation of dynamic stability analysis is based on reference [4]. Figure 5(a) shows Synchronous Machine Model with Excitation System Automatic Voltage Regulator (AVR) without connected PSS to show Angular Speed, Angular Position, Torque Variation and Voltage Variation when connected to Single Machine Infinite Bus (SMIB).

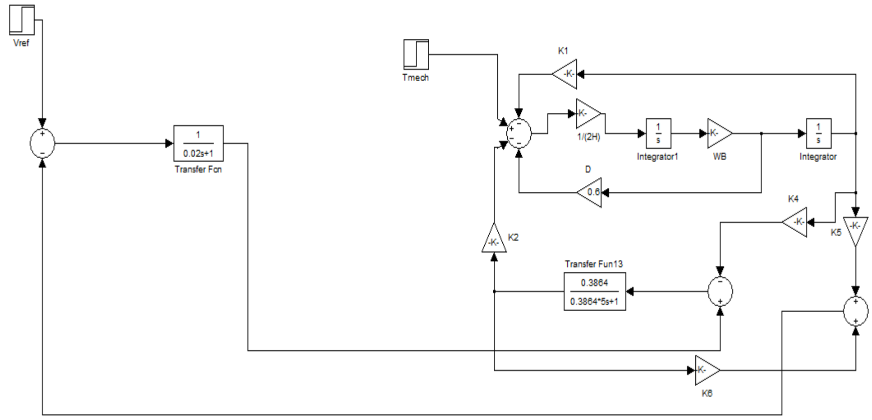

Figure 5(a). Simulink model for synchronous machine with excitation system automatic voltage regulator (AVR) without PSS

Figure 5(b) shows Synchronous Machine Model connected with PSS designed by Genetic Algorithm (GA) for simulation test of Angular Speed, Angular Position, Torque Variation and Voltage Variation when connected to Single Machine Infinite Bus (SMIB).

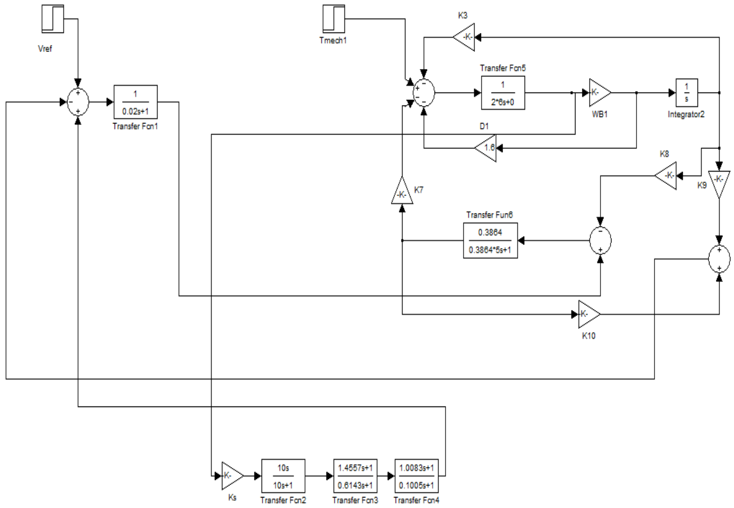

Figure 5 (b). Simulink model for synchronous machine model connected with PSS and GA

Figure 5(c) shows Synchronous Machine Model with connected PSS designed by Particle Swarm Optimization (PSO) to show Angular Speed, Angular Position, Torque Variation and Voltage Variation when connected to Single Machine Infinite Bus (SMIB).

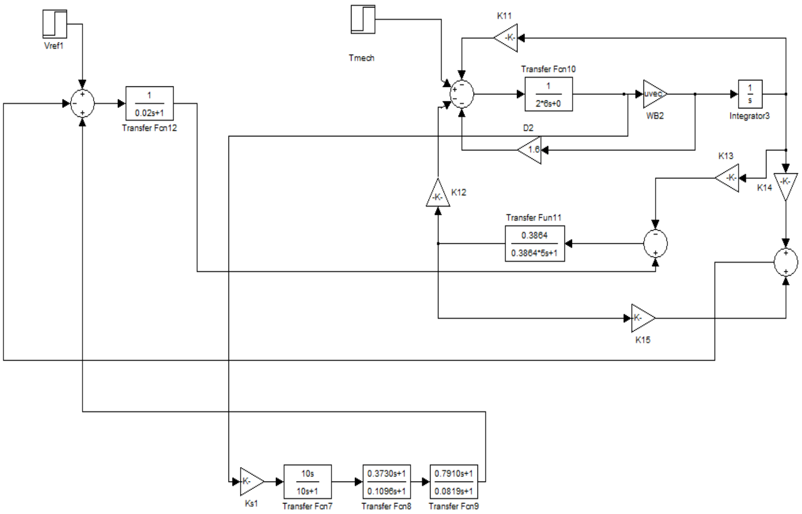

Figure 5(c). Simulink model for synchronous machine model connected with PSS and PSO

3. Results and Analysis

Figure 6 shows variation of the angular position and the angular speed increasing the torque for negative of K5. This system has become unstable; however, the transients have also become more with the negative K5 whereas the position of the higher angular is attained without the PSS “Power System Stabilizer”.

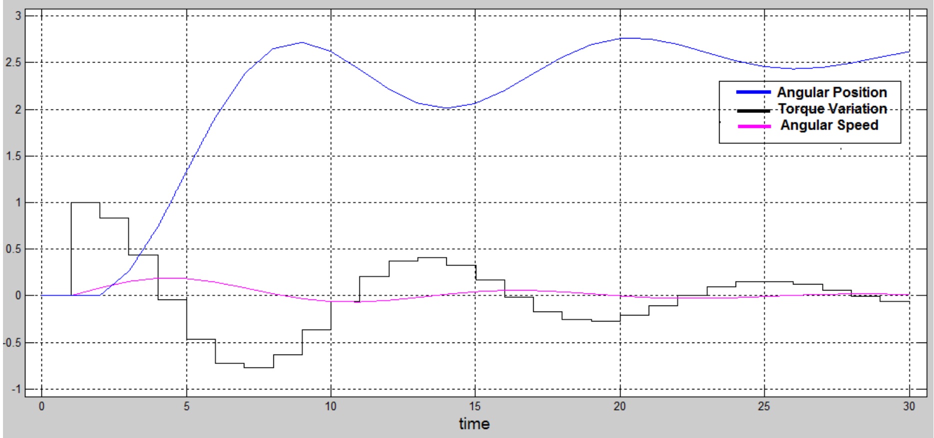

Figure 6. Simulation result of angular speed, angular position and torque for the system without PSS for 10% change in step input

Figure 7 Shows the comparison of angular speed in three cases without PSS, with PSS designed by GA and with PSS designed by PSO with WB=3.14.

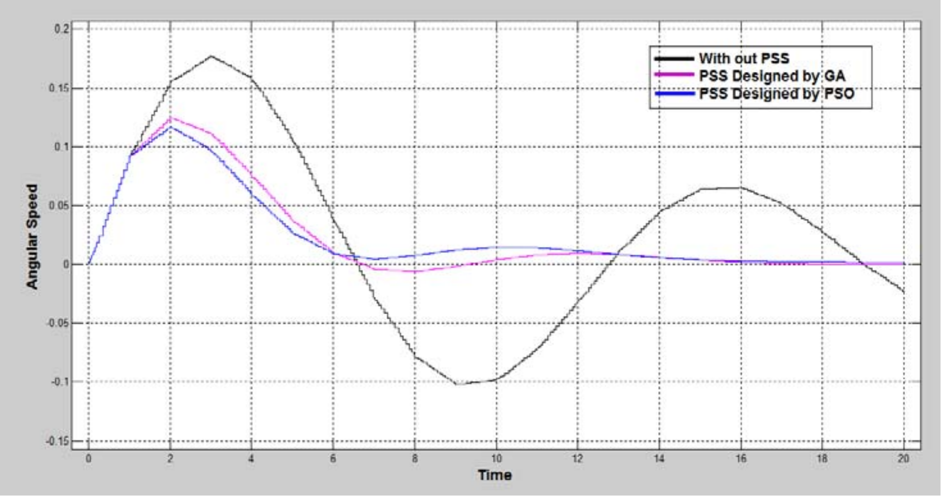

Figure 7. Simulation result angular speed for 10% change in step input

Figure 8. Shows the comparison of angular position in three cases without PSS, with PSS designed by GA and with PSS designed by PSO with WB=3.14.

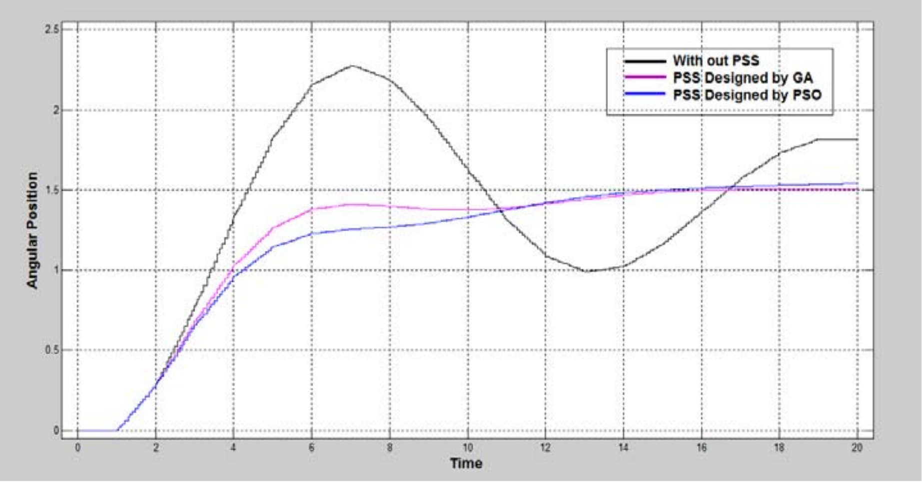

Figure 8. Simulation result angular position for 10% change in step input

Figure 9 Shows the comparison of torque variation in three cases without PSS, with PSS designed by GA and with PSS designed by PSO with WB=3.14.

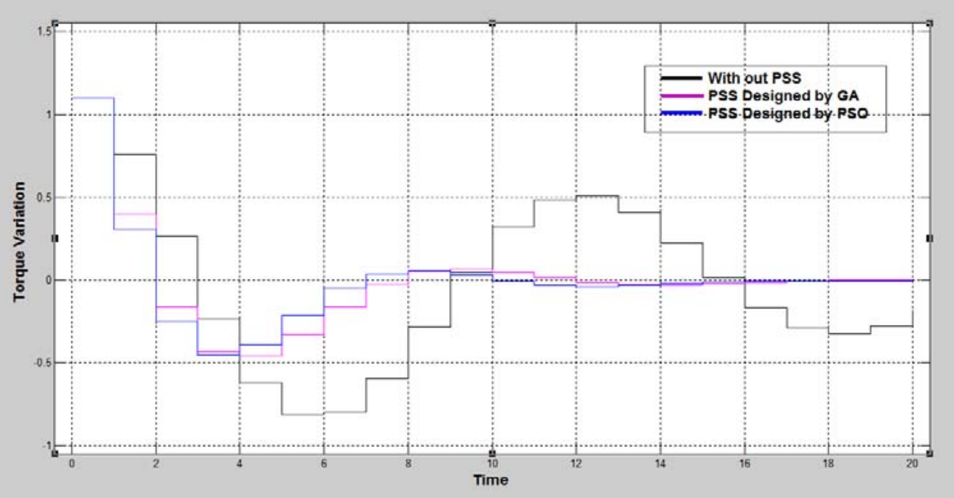

Figure 9. Simulation result torque variation for 10% change in step input

Figure 10. Shows the comparison of voltage variation in three cases without PSS, with PSS designed by GA and with PSS designed by PSO with WB=3.14.

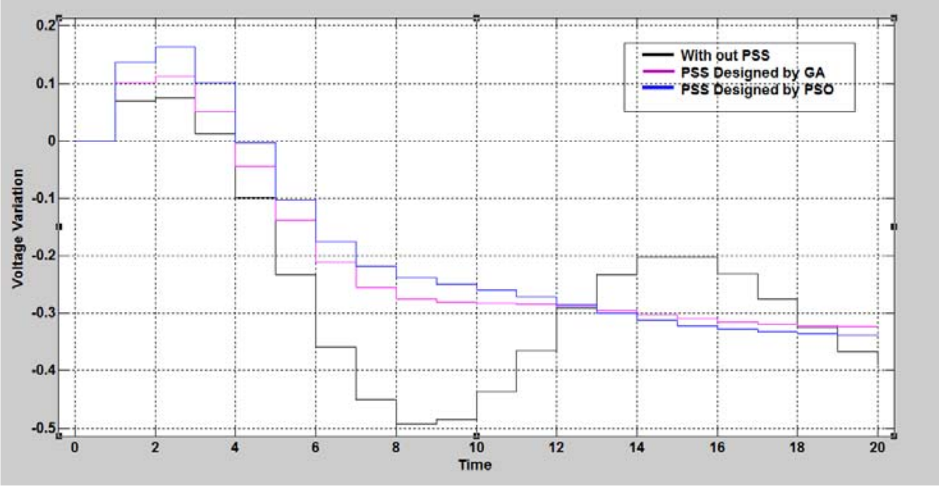

Figure 10. Simulation result voltage variation for 10% change in step input

4. Conclusion

Power systems are been subjected to a variety of disturbances existing such as slight load changes that could be of effect to the efficiency mostly leading to unstablilityof the entire system. The disturbances can could as a result of low frequencies of undesired oscillations since this mostly affects the quantity of the power been transferred through the lines of transmission leading to external tensions to the mechanical shaft. In order to avoid this situation the PSS is added to AVR enhancing the stability of the dynamic ranges and disturbance of the first few cycles. The control of signal input to the PSS is been selected becoming the speed deviation of generator (Δω). The result for the analysis shows that adding the PSS has given an additional damping for the oscillatory of the system bringing back the normal stable operation. This PSS proposed design enhances the response time of system while providing a better result in damping for oscillation when comparing to similar designs by the Genetic Algorithm (GA). The main contribution to design an optimal PSS. Particle Swarm optimization (PSO) is used to design the PSS parameters.

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References

[1] MR Tavakoli, V Rasouli, HR Nasajpour and M Shaarbafchizadeh. “A new simultaneous coordinated design of STATCOM controller and power system stabilizer for power systems using cultural algorithm”. *2014 IEEE Int. Energy Conf.* 2014: 446–450.

[2] CR Makkar. “Simultaneous Coordination of Power System Stabilizer and UPFC for Improving Dynamic Stability of Multimachine System”. *IEEE*. 2014.

[3] A Kharrazi. “Tuning of Power System Stabilizer in Single Machine Infinite Bus (SMIB) using Genetic Algorithm and Power Factory Modal Analysis”. *IEEE*. 2015.

[4] M and SMAH AS Al-Hinai. “Dynamic Stability Enhancement using Particle Swarm Optimization Power System Stabilizer”. *IEEE*. 2009: 0–4.

[5] B Selvabala. “Co-Ordinated Tuning Of AVR-PSS Using Differential Evolution Algorithm”. *IEEE*. 2010: 439–444.

[6] AH Ahmad, D Ph, and AA Abdelqader. “Power System Stabilizer Design Using Real-Coded Genetic Algorithm”. *2nd Int. Conf. Control. Instrum. Autom.* 2011.

[7] M Kushwaha. “Dynamic Stability Enhancement of Power System using Fuzzy Logic Based Power System Stabilizer”. *Int. Conf. Power, Energy Control*. 2013: 213–219.

[8] M Sulaiman, Z Salleh and R Omar. “Effects of Parameters Variation in Fuzzy based Induction Motor Drives”. *TELKOMNIKA Indones. J. Electr. Eng.* 2015; 16(2): 701–711.

[9] S Ghosh, N Senroy and S Mishra. “Fast Power System Stabilizer Tuning in Large Power Systems”. *IEEE*. 2015: 1–5.

[10] P Kundur. “Power-System-Stability-and-Control”. Mc Graw-Hill, Inc.1994.

[11] M Rasheed, R Omar and M Sulaiman. “Harmonic Reduction in Multilevel Inverter Based on Super Capacitor as a Storage”. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2015; 16(3): 520–530.