Effect of PID Power System Stabilizer for a Synchronous Machine in Simulink Environment

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Abstract. This paper presents the use of Proportional-Integral-Derivative (PID) Controller with power system stabilizer (PSS) in a single machine infinite bus system. A PSS is used to generate supplementary damping control signals for an excitation system in order to damp out low frequency oscillations (LFO) of an electric power system. The paper is modelled in the MATLAB Simulink Environment to analyze the performance of a synchronous machine under a wide range of operating conditions. The functional blocks of PID controller with PSS are generated and the simulation studies are conducted based on different test cases to observe the dynamic performance of the power system. Analysis in this paper reveals that the PID-PSS gives better dynamic performance as compared to that of conventional power system stabilizer and also the optimal gain settings of PID PSS obtained at normal operating condition works well to other operating condition without much deterioration of the dynamic responses.

1. Introduction
Considerable research effort has been done for solving the instability problem of power system caused by low frequency oscillation (LFO). To reduce the damping period of oscillations, power system stabilizers (PSS) are used to inject a supplementary control signal at the voltage reference input of the automatic voltage regulator (AVR). It operates by generating an electric torque in phase with the rotor speed. In most cases, the PSS works well in damping oscillations. However, its control has less flexibility because the parameters of PSS are tuned by the original system parameters, which means the control results, are far from ideal if the operating conditions and/or structures of the system is changed. PSS uses auxiliary stabilizing signals to control the excitation system so as to improve power system dynamic performance by the damping of system oscillations. Demello and Concordia [1] analyzed the phenomena of stability of synchronous machines under small perturbations and have provided a set of guidelines for stabilization through supplementary excitation control. Kundur et al. [2] presented a comprehensive approach for conventional tuning of PSS parameters and its effect on the dynamic performance of the power system. This paper presents the use of PID Controller with PSS for a synchronous machine in a MATLAB simulink model environment. The aim is to reduce the damping of low frequency oscillations (LFO) of an electric power system under several operating conditions. The PID controller together with PSS can guarantee to provide a better result to common stabilizer situations with the effectiveness in enhancing and improving the transient ability and dynamic performance of power system [3]. Dynamic responses are also simulated when the power system is subjected to a major disturbance that would result in a significant change in system operating condition. Several simulations have been carried out in order to generate various types of condition using a single machine infinite bus power system.

2. Power System Stabilizer

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Damping of low frequency oscillations in interconnected power system is essential for secure and stable operation of the system. Power System Stabilizer (PSS) is the most widely used device for overcoming oscillatory stability problems. PSS provides an electrical damping torque ($\Delta T_m$) in phase with the speed deviation ($\Delta \omega$) in order to improve damping of power system oscillations [4]. In this paper an optimal method based on the PID controller is considered to the tuning parameters of the PID type PSS. Power system stability is similar to the stability of any dynamic system, and has fundamental mathematical underpinnings. Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. The basic function of PSS is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signal(s). In order to provide damping, the stabilizer will produce electrical torque in phase with rotor speed deviations.

3. PID Controller

Proportional–integral–derivative (PID) controller is a generic control loop feedback mechanism that will correct the error between a measured process variable and the desired input by calculating and give an output of correction that will adjust the process accordingly. A PID controller has the general form: $u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de}{dt}$ where $K_p$ is proportional gain, $K_i$ is the integral gain, and $K_d$ is the derivative gain. The calculation (algorithm) involves three separate parameters; the Proportional, the Integral and Derivative values. The weighted sum of these three actions is used to adjust the process for obtaining the desired output.

![Figure 1. Block Diagram of a PID controller.](image)

4. Modeling of PID Controller with PSS

For the performance analysis of Power System Stabilizer (PSS), a simulation model was developed in Simulink block set using MATLAB software. The effectiveness of PID Controller with PSS is observed for various operating conditions [6]. The functional block diagram of PID with PSS in Simulink environment is shown below. The generator speed deviation $\Delta \omega$ is as the input signal of the proposed stabilizer. The objective of using PID controller together with PSS is to provide a better answer to stability problem with the effectiveness much superior to power systems utilizing. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set-point and the degree of system oscillation. The various blocks involved in modeling the synchronous machine are as shown below:

![Figure 2. Block diagram of a synchronous generator excitation controller with PID PSS](image)

5. Simulation Results and Discussion

In order to investigate the effect of the synchronous machine on proposed power system stabilizer, numeral simulations were carried out for several scenarios under different operating conditions on the single machine infinite bus power system. In the interest of brevity, we considered a system with the following three typical cases: normal load without vulnerable (fault) condition, normal load subjected a three phase fault condition and heavy load subjected to three phase fault condition.

5.1 Dynamic Performance of the system with PID-PSS
The performance of PID Power System Stabilizer (PID-PSS) was studied in the Simulink environment for different operating conditions. In order to review the significance and robustness of proposed technique, simulation studies are carried out for three phases fault disturbances and fault clearing sequence. The performance of proposed controller under transient and dynamic condition is verified using the PID and PSS. It is recognized that the highest magnitude of power system disturbance is caused by three phase fault. The use of PID PSS is able to track the system operating conditions, and thus, as seen from the results in Figure 3-6, it is able to adjust and provide a uniformly good performance over a wide range of operating conditions and disturbances.

5.1.1 Speed Deviation. Figure 3 shows the dynamic response of speed deviation with different loading conditions. Examining Figure 3, it can be observed that, PID PSS is giving a better response at nominal loading condition, both in terms of peak deviation and settling time. Further, with fault conditions, PID PSS is giving virtually similar response to that of the dynamic response of the system at nominal and also heavy loading conditions. The response with PID PSS is better in terms of settling time which means the system reached steady state faster.

Table 1 shows the comparison results for the speed deviation under different loading condition based on the output obtained in Figure 3. It can be clearly seen that the settling time for normal load without fault condition is the shortest. This is because for normal loading, the speed remains constant when transmission occurs. Besides that, PID with PSS supports the synchronous generator to maintain synchronous speed even at severe fault conditions. It can also provide better damping characteristics than the PSS even at the loading condition. The damping characteristic of PID PSS is insensitive to load change while that of PSS will deteriorate as the load changes.

5.1.2 Rotor Angle Deviation. For the rotor angle deviation with different loading condition, the simulation results are shown in Figure 4. It is seen that the acceleration of rotor increases due to fault condition. However, the rotor angle maintained at normal level with the help of PID PSS and also settled down faster compared to PSS. PID PSS improves the rotor angle to the maximum extent by reaching the settling time before 3 seconds.

5.1.3 Load Angle. According to Figure 5, the load angle is maintained at 8 degree for all the three cases after they reached steady state. The settling time for normal load is much shorter than nominal and heavy loads with fault conditions. For this case, it is inferred that PID with PSS supports the synchronous generator to maintain synchronous speed even at severe fault conditions.
5.1.4 Field Voltage. Figure 6 illustrates the result of field voltage. It is observed that the normal load produce less overshoot and settle faster compare to the other two cases. By this effect, the field voltage will be stable and in turn it ensures the system stability. We can also conclude that the combination of PID with PSS provides better solution for damping of oscillations. The dynamic performance of the system with PID PSS is better, both in terms of peak deviation and settling time. The performance of the system with PID PSS is also quite robust in wide variations of loading conditions.

6. Conclusions
In this study, the proportional-integral-derivative power system stabilizer (PID-PSS) has been proposed for the enhancement of the dynamic stability of single machine infinite bus. Results from this study indicate that PID PSS gives much better dynamic performance as compare to that of conventional PSS. An excellent improvement in the damping over a wide range of operating conditions has been achieved with PID PSS being used in the excitation control of synchronous machine. Modeling of proposed controller in Simulink environment provides an accurate result when compared to mathematical design approach. Simulation studies described in the paper show that the dynamic performance of the system with PID-PSS is quite robust to wide variations in loading conditions. This results from the fact that, during the faulted period, there will be drastic change in the operating condition. Therefore the proposed PID PSS are relatively simpler than the other controllers to provide better optimal solution and also for practical implementation.

7. Acknowledgements
I would like to express my gratitude to all those who provided me to possibility to complete my paper. Thanks to my dean of faculty and my family members for giving me support and my supervisor for always give me inspirational supervising throughout the research and paper writing process.

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