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MATLAB/Simlink Based Power System Stabilizer with PID controller

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ABSTRACT

The power system network is coming more disturbed and its power transfer capacity reduces gradually. The disturbance is mainly caused due to increase in number of load, losses in the transmission line. It is very difficult to control the stability of such system. Researchers have been conducted in this field with aim of incorporating power electronics device with electric power system. In the bulk power transmission system these problems can be overcomes with the help of power electronic devices. In the large power system power electronic based controllers called as FACTS (Flexible Ac Transmission systems) plays a vital role in controlling the stability. The main purpose of this paper is to compare various FACTS devices such as SVC, TSCS, SSSC, STATCOM, UPFC, IPFC, and DPFC. The survey is conducted by placing various facts devices in the power system.

Keywords--- SSSC, DVR, TSCS, STATCOM, UPFC, IPFC and DPFC

I. INTRODUCTION

The PSS uses auxiliary stabilizing signals to control the excitation system so as to improve power system dynamic performance. The application of PSS can help in damping out rotor oscillations and improve the system stability. If no adequate damping is available, the oscillation can increase and cause system separation. PSS is installed in power generator to help the damping of power system oscillations. There are many approaches to enhance damping of power stability limit. To improve PSS design problem include adaptive and self-tuning control, obtain the output of power system stabilizer with different load conditions. In the late 1950's and early 1960's most electrical power system used automatic voltage regulators and the proved useful for the small signal stability of the power system lower frequency oscillation 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. Low frequency oscillation can be created by small disturbance in the system, such as changes in the load, and are normally analyzed through the small signal stability of the power system. These small disturbances head to a steady increase or decrease in generator rotor angle caused by the lack of synchronizing torque or to rotor oscillations of increasing amplitude due to a lack sufficient damping torque. The most typical instability is the lack of sufficient damping torque on the rotor's low frequency oscillation. The power system stabilizer is the most effective devices for stabilizing and damping low frequency oscillation while increasing the stability margin of power system [1]. A PSS prepares a supplementary input signals in phase with the synchronous rotor speed deviation to excitation systems resulting in generator stability. Robust controller based on the optimization of the H_∞ - norm of the transfer matrix between the system disturbance and its output, via linear matrix inequalities [2-3]. Modeling of a single machine connected to infinite bus introduce by DeMello and Concordia [4] which is used to analyze the nature of the low frequency electro mechanical oscillation in power system. PSS has been used by utilities in real power systems as it has been shown to be the most cost effective electromechanical damping control [5, 6]. Recently, many modern techniques can be used to design different power system stabilizer structures. Howe ever, utilities prefer to choose lead – lag structure due to its simple structure and reliability in applying with real power systems.

In the last two decades, various types of PSS have been designed. For example, Adaptive controller based PSS have been used in many applications [7]. Most of these controllers are based on system identifications and parameter estimations therefore from computational point of view they are time consuming. It is evident from the various publications that interest in application of Fuzzy logic based PSS (FLPSS) has also grown in recent years [8]. Low computation burden simplicity and robustness make FLPSS suitable for stabilization purposes. Different methods for designing such devices are proposed using genetic algorithm (GA) and artificial neural network [9-11].

In this paper, the PSS model is designed which considers various kind of load such as small oscillations of mechanical power input due to unstable regulation of turbine governors. Various fault conditions due to reactive power changes on certain buses in network and generator are observed. The PSS modeling is done by the functional block of simulink.

Modeling Of Synchronous Generator

In Fig. 1, the synchronous generator is connected with the infinite bus through the transmission line. The real power of the synchronous generator is governed by speed governor. The output of the rotor speed deviation governor is compared with reference power and given to turbine which is connected to the synchronous generator. The rotor speed deviation of synchronous generator is given to PSS as input whose output is used to get the stable voltage (Vpss). The stable voltage is given to synchronous generator through the voltage regulator and exciter. The output of voltage of the exciter is given to excitation system stabilizer and compared with reference terminal voltage. The output power from the synchronous generator is given to infinite bus through transmission voltage. To PSS will be doing no more work if the switch S1 is changed to zero position. Then the system will act as normal system without PSS and oscillation will not be damped out

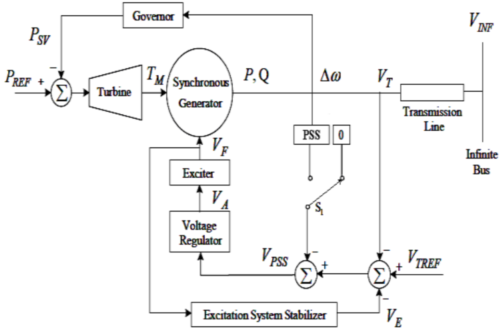


Fig. 1: system Model configuration.

3. Single Machines Infinite Bus Model [Smib]

An infinite bus is a source of constant frequency and voltage either in magnitude and angle [4] a schematic representation of this show in Fig. 2.

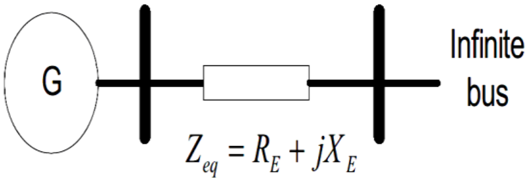


Fig. 2: Single machine connected to a large system through transmission line.

The theoretical basic for a PSS is illustrated with the aid of the block diagram shown in Fig. 3, since the purpose of a PSS is to introduce a damping torque component, a logical signal to use for controlling generator excitation is the speed deviation. If the exciter transfer function and generator transfer function between ΔE_{fd} and T_e were pure gains, a direct feedback of $\Delta\omega$ would results in a damping torque component. However, in practice both the generator and the exciter exhibit frequency dependent gain and phase characteristics. Therefore, the transfer function should have appropriate phase compensation circuits to compensate the phase lag between the exciter input and the electrical torque. In the ideal case, the phase characteristic of PSS being an exact inverse of the exciter and generator phase characteristics to be compensated, the PSS would result in a pure damping torque at all oscillating frequencies. The linear state space model of the system as given by the equation 1. Where X, A and b are given by the equations 2, 3 and 4 respectively.

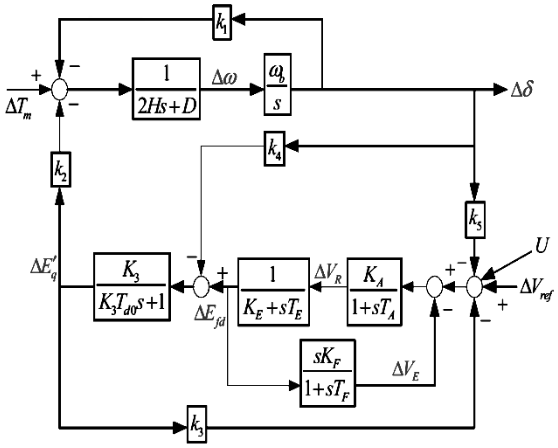


Fig.3: Block Diagram Representation of SMIB with Exciter and AVR.

$$\dot{x} = Ax + bu \tag{1}$$

$$x = \begin{bmatrix} \Delta\omega & \Delta\delta & \Delta E'_q & \Delta E_{fd} & \Delta V_R & \Delta V_E \end{bmatrix}^T \tag{2}$$

$$A = \begin{bmatrix} 0 & -\frac{K_1}{2H} & -\frac{K_2}{2H} & 0 & 0 & 0 \\ 2\pi f & 0 & 0 & 0 & 0 & 0 \\ 0 & -\frac{K_4}{T'_{d0}} & -\frac{1}{T'_{d0}K_3} & \frac{1}{T'_{d0}} & 0 & 0 \\ 0 & 0 & 0 & -\frac{K_E}{T_E} & \frac{1}{T_E} & 0 \\ 0 & -\frac{K_AK_5}{T_A} & -\frac{K_AK_6}{T_A} & 0 & -\frac{1}{T_A} & -\frac{K_A}{T_A} \\ 0 & 0 & 0 & -\frac{K_EK_F}{T_ET_F} & \frac{K_F}{T_ET_F} & -\frac{1}{T_F} \end{bmatrix}$$

$$b = \begin{bmatrix} 0 & 0 & 0 & 0 & \frac{K_A}{T_A} & 0 \end{bmatrix}^T \tag{4}$$

Whre

V_t- Generator terminal voltage

Vd,Vq - d-q axis machine voltage (pu)
ω- Synchronous speed (rad/sec)
T_1 T_2 T_3 T_4- Lead-lag and lag lead network parameters (Sec)
T_w-Washout network parameters
V_{ref}- Reference input voltage
V_{pss}- Stabilizer output
P_M- Mechanical input
δ- Torque angle
Pω-Active power (pu)
Qω-Reactive power (pu)
T_e-Electro magnetic torque
H - Inertia constant
Δ_ω- Speed deviation (pu)
Δδ - Angle deviation

Simulink Model Of Power System Stabilizer

The PSS representation in Fig. 4, consists of three blocks namely phase compensation block, washout block and gain block. The gain block used here to determine the amount of damping introduced by the PSS. It corresponds to the maximum damping. Wash out block serves as high pass filter with time (T_w). Critical value and may be range 1 to 20 seconds. Frequency of interest will be unchanged and it The combination of PSS with excitation system is shown in Fig. 5. The PSS output, terminal voltage and reference terminal voltage are added and the output of the summer is connected to the excitation system. The output of the exciter is field voltage which is connected to the synchronous generator

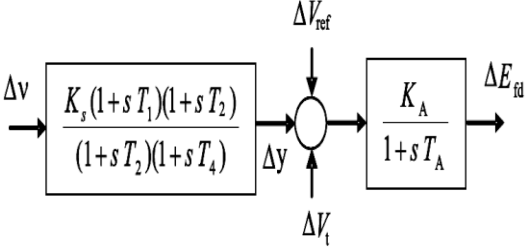


Fig. 5: Exciter with power system stabilizer

Simulink Diagram

To analyse the performance PSS, model is developed in simulink block set of MATLAB. The functional block set of PSS is developed in simulink environment which is given in Fig. 6. The design parameters of PSS are given in Appendix I.

6. Simulation Results:

The following three case studies were carried out in the Simulink environment to illustrate the performance of PSS through simulation. Case i: The variation of rotor speed, load angle, terminal voltage and real power were analyzed with and without PSS.

be long enough to pass stabilizing signals. The phase compensation block provides the appropriate phase lead characteristic for compensation the phase lag between the exciter input and generator electrical torque, the frequency range if unrests are 0.1 to 2.0 Hz phase lead network should provide compensation over the entire system condition two first order blocks using here. The equivalent transfer function of the block in Fig. 4, is the equation (5)

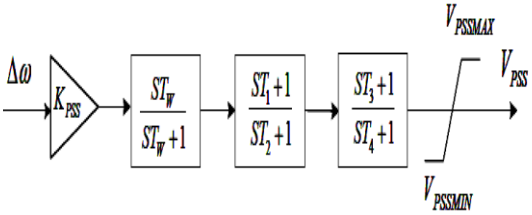
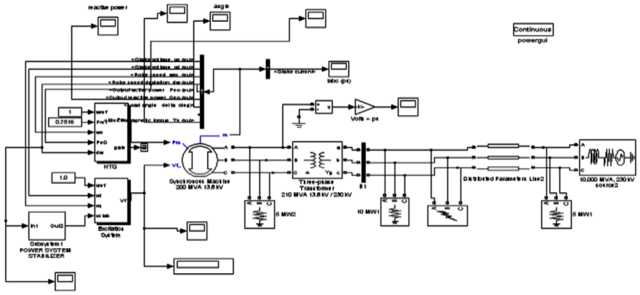


Fig. 4: Block diagram of the power system stabilizer.

$$PSS_w(s) = K_s \frac{T_w s}{1+T_w s} \frac{(1+sT_1)(1+sT_3)}{(1+sT_2)(1+sT_4)} \qquad (5)$$

Case ii: System was subjected to the different load conditions and it's variations were compared.



Case iii: System is vulnerable (fault) condition subjected.
Case iv: The variation of rotor speed, load angle, terminal voltage and real and reactive power were analyzed with PSS and PSS with PID
The inference of the simulation results for above cases are illustrated as follows:

Case 1:
Effect Of Power System Stabilizer

The simulation results of the system after the inclusion of PSS are illustrated from the Fig. 7 through Fig. 11. The illustrations describe the variations of speed, real power, field voltage and load angle of the system. From the figures, it is inferred that the oscillations are damped out quickly after the inclusion of PSS. By this effect, the field voltage will be stable and in turn it ensures the system stability. In Fig.9, it is inferred that the load angle varies between 10 degrees to 45 degrees. It is also ensured that system is completely stable after the inclusion of PSS however the level of damping oscillation is low.

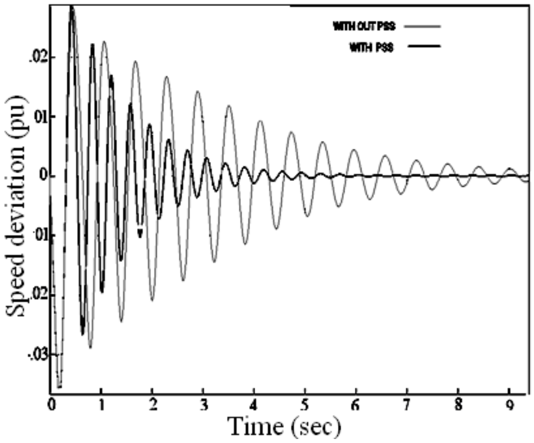


Fig.7: Rotor speed deviation

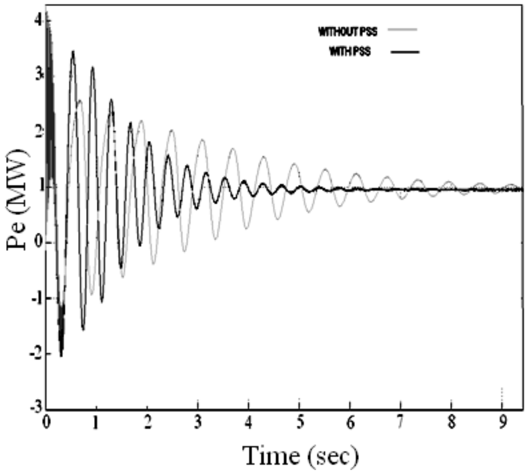


Fig.8: Real power

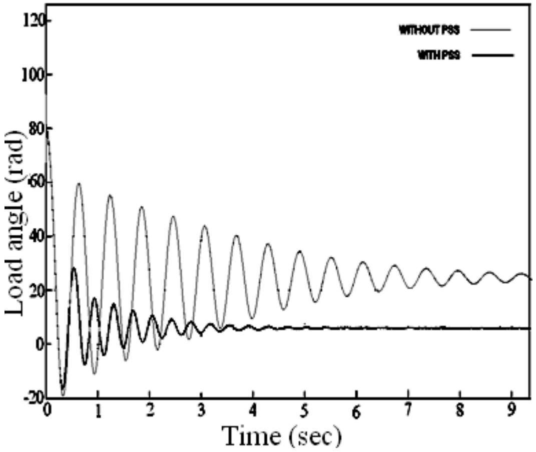


Fig.9: Load angle

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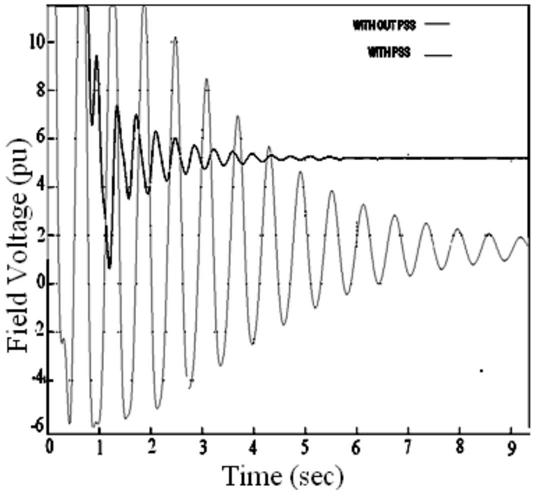


Fig.10: Field voltage

Case 2: Different Load Conditions

The synchronous generator is subjected to light nominal and heavy load conditions. The performance characteristic of the system with PSS is illustrated from Fig. 11 to Fig. 15. From the Fig. 11, it is inferred that the acceleration of rotor increases with respect to load condition. The rotor angles are with system limits for the above case studies. The variation of real power, field voltage and load angle also within permissible limits during the different load conditions.

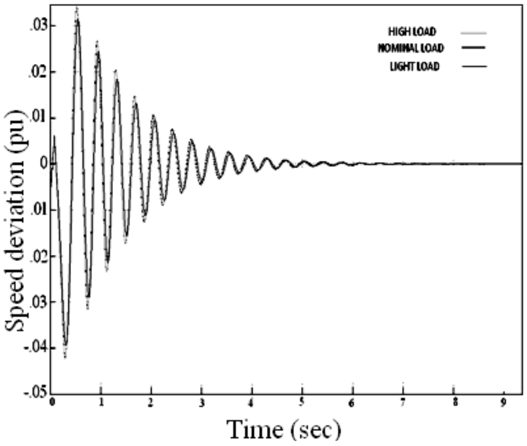


Fig. 11: Speed devia

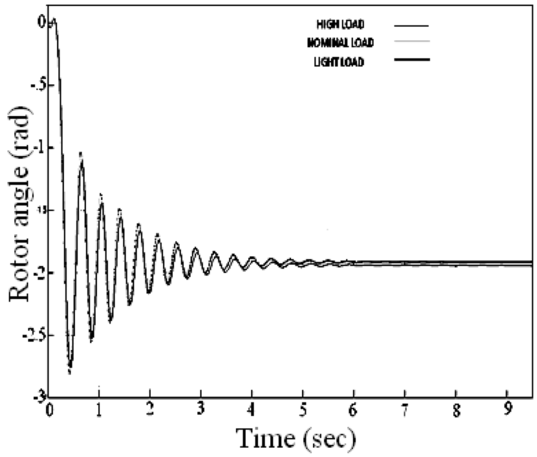


Fig.12: Rotor angle

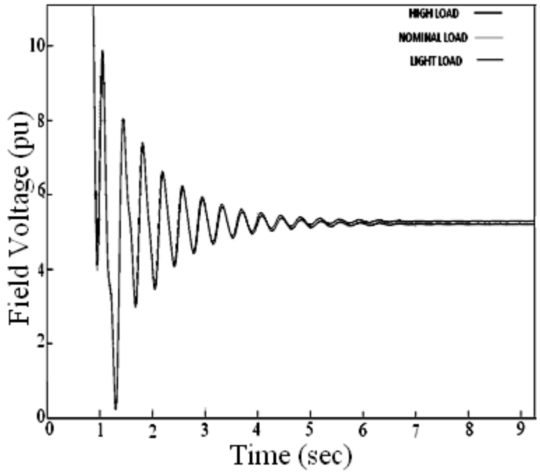


Fig. 13: Field voltage

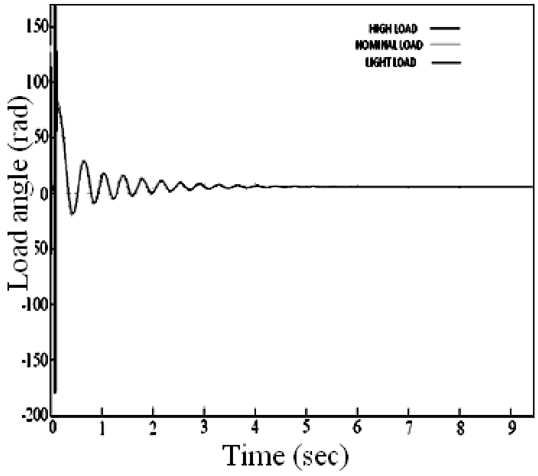


Fig. 14: Load angle

Case 3: Fault Condition

The illustrate the stability of the system during vulnerable condition, a three phase fault is assumed to happen at the transmission line. The fault persists in the system for 0.3 sec and it is cleared after 0.9 sec. The parameters of the system during fault condition, are illustrated in Fig.16 to Fig. 19. It is observed that when PSS is connected to the system, the overshoot and settling time of the system are minimized and stability is achieved.

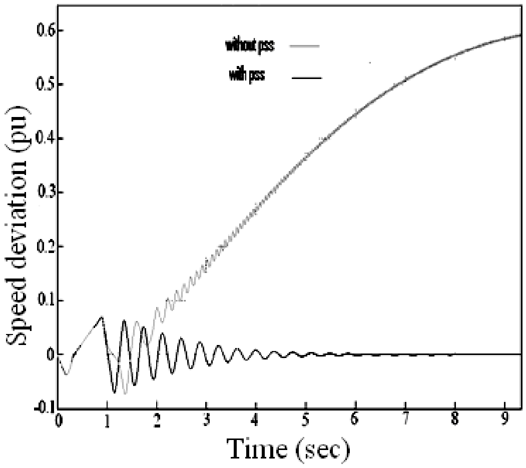


Fig.15: Speed Deviation fault at 0.3 and the fault line cut off after 0.9

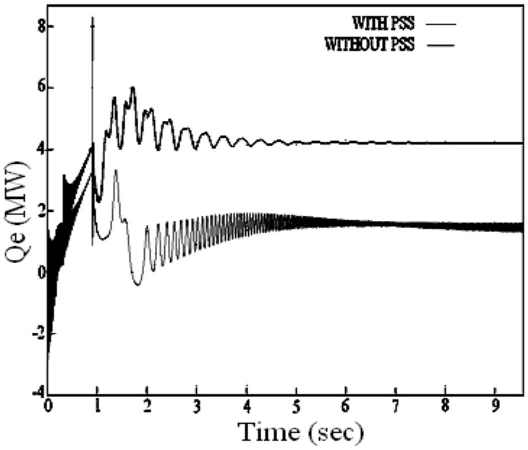


Fig.16: Reactive power fault

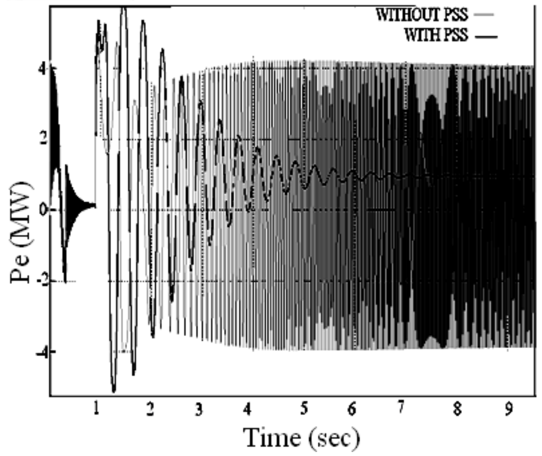


Fig. 17: Real power.

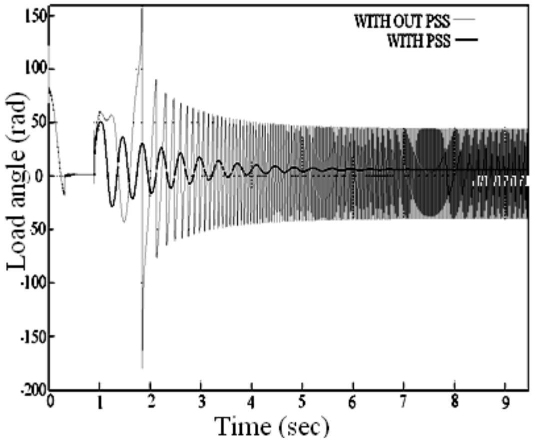


Fig.17: Load angle fault at 0.3 and the fault line cut off after 0.9

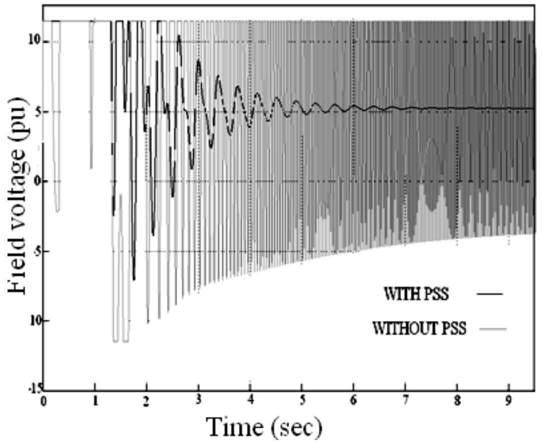


Fig.18: Field voltage V_f fault at 0.3 and the fault line cut off after 0.9

Case 4:

Effect Of Pid With Pss

The simulation results of the system after the inclusion of PID with PSS are illustrated from the Fig. 19 through Fig. 22. The illustrations describe the variations of speed, real power, field voltage and load angle of the system. From the figures, it is inferred that the oscillations are damped out quickly after the inclusion of PID with PSS. By this effect, the field voltage will be stable and in turn it ensures the system stability. Introducing of PID with PSS produces better result when compared to with PSS. Here the overshoot and settling time can be reduced to the better way the overshoot of response is reduced to 0.04 from 0.17 and the settling time reduced to 4 seconds from 7 seconds. Therefore PID with PSS gives better optimal solution for controlling the stability. From the Fig.21, the PID with PSS provides better solution by reducing overshoot to 75% and the settling time to 5 seconds even in heavy load condition. By this effect the field voltage will be stable and in turns maintain the system stability.

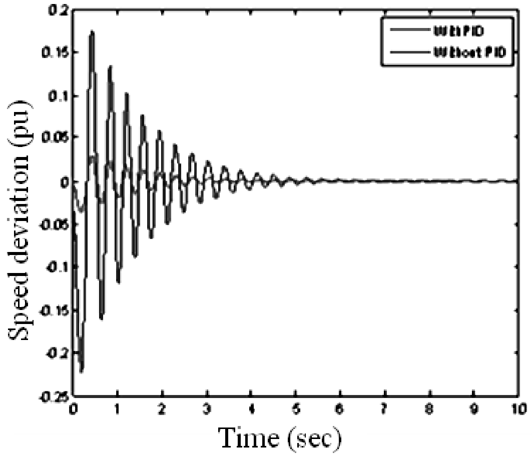


Fig. 19: speed deviation

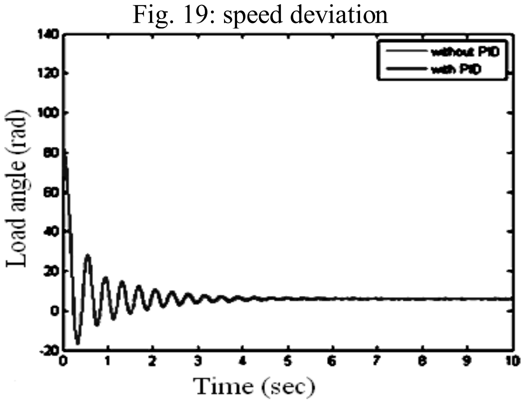


Fig. 20: Load angle

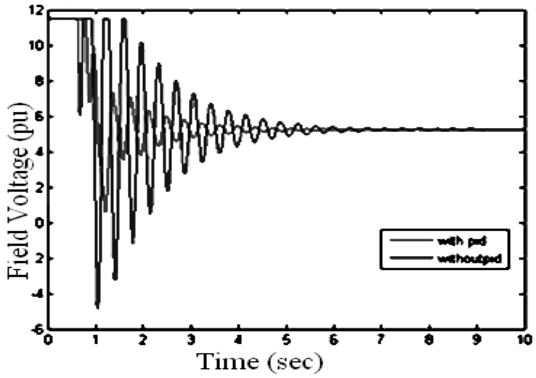
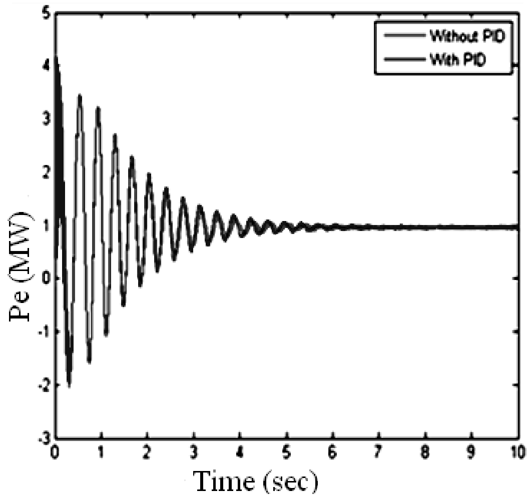


Fig. 21: field voltage



Conclusion

A novel simulink based design of system parameter with PSS is described with different case studies such as various load and vulnerable condition. The synchronization parameter such as speed deviation, field voltage, rotor angle is illustrated for the above mentioned cases. It is illustrated that the performance of PSS improves the system performance and stability.

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