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Improved Step Response of Power System Stabilizer using Fuzzy Logic Controller

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Abstract

As every power system is constantly being subjected to disturbances, we should see that these disturbances do not make the system unstable. Therefor additional signals derived from speed deviation, excitation deviation and accelerating power are injected into voltage regulators. The device to provide these signals is referred as power system stabilizer. The use of power system stabilizers has become very common in operation of large electric power systems. The conventional PSS which uses lead-lag compensation, where gain settings designed for specific operating conditions, is giving poor performance under different loading conditions. Therefore, it is very difficult to design a stabilizer that could present good performance in all operating points of electric power systems. In an attempt to cover a wide range of operating conditions, Fuzzy logic control has been suggested as a possible solution to overcome this problem. In this paper, a systematic approach to fuzzy logic control design is proposed. The study of fuzzy logic power system stabilizer for stability enhancement of a single machine infinite bus system is presented. In order to accomplish the stability enhancement, speed deviation and acceleration of the rotor synchronous generator are taken as the inputs to the fuzzy logic controller. These variables take significant effects on damping the generator shaft mechanical oscillations. The stabilizing signals were computed using the fuzzy membership function depending on these variables. The performance of the system with fuzzy logic based power system stabilizer is compared with the system having conventional power system stabilizer and system without power system stabilizer

Keywords: *Power System Stabilizer, Conventional Power System Stabilizer, Fuzzy Logic Controller, Lead-Lag Compensator*

1. Introduction

The power system is a dynamic system. It is constantly being subjected to disturbances, which cause the generator voltage angle to change. When these disturbances die out, a new acceptable steady state operating condition is reached. It is important that these disturbances do not drive the system to unstable condition. The disturbances may be of local mode having frequency range of 0.7 to 2 Hz or of inter area modes having frequency range in 01 to 0.8 Hz, these swings are due to the poor damping characteristics caused by modern voltage regulators with high gain. A high gain regulator through excitation control has an important effect of eliminating synchronizing torque but it effects the damping torque negatively. To compensate the unwanted effect of these voltage regulators, additional signals are introduced in feedback loop of voltage regulators. The additional signals are mostly derived from speed deviation, excitation deviation or accelerating power. This is achieved by injecting a stabilizing signal into the excitation system voltage reference summing point junction. The device set up to provide this signal is called "power system stabilizer". Excitation control is well known as one of the effective means to enhance the overall stability of electrical power systems. Present day excitation systems predominantly constitute the fast acting AVRs. A high response exciter is beneficial in increasing the synchronizing torque, thus enhancing the transient stability i.e. to hold the generator in synchronism with power system during large transient fault condition. However, it produces a negative damping especially at high values of external system reactance and high generator outputs.

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Stability of synchronous generators depends upon number of factors such as setting of automatic voltage regulators (AVR). AVR and generator field dynamics introduces a phase lag so that resulting torque is out of phase with both rotor angle and speed deviation. Positive synchronizing torque and negative damping torque often result, which can cancel the small inherent positive damping torque available, leading to instability.

Generator excitation controls have been installed and made faster to improve stability. PSS have been added to the excitation systems to improve the oscillatory instability it is used to provide a supplementary signal to excitation system. The basic function of PSS is to extend the stability limit by modulating generator excitation to provide the positive damping torque to power swing modes.

The application of power system stabilizer (PSS) is to generate a supplementary signal, which is applied to control loop of the generating unit to produce a positive damping. The most widely used conventional PSS is lead-lag PSS where the gain settings are fixed under certain value which are determined under particular operating conditions to result in optimal performance for a specific condition. However, they give poor performance under different synchronous generator loading conditions.

A typical PSS consists of phase compensation stage, a signal washout stage and gain block. To provide damping, PSS must provide a component of electrical torque on the rotor in phase with speed deviations. PSS input signal includes generator speed, frequency and power. For any input signal, the transfer function of PSS must compensate for gain and phase characteristics of the excitation system, the generator and the power system. These collectively determine the transfer function from the stabilizer output to the component of electrical torque which can be modulated via excitation control.

The PSS, while damping the rotor oscillations can cause instability of turbine generator shaft torsional modes. Selection of shaft speed pick-up location and torsional notch filters are used to attenuate the torsional mode frequency signals. The PSS gain and torsional filter however, adversely affect the exciter mode damping ratio. The use of accelerating power as input signal for PSS attenuates the shaft torsional modes inherently and mitigates the requirements of the filtering in main stabilizing path.

The various techniques used in power system stabilizer are classical [1]-[4], fuzzy logic [5]-[8], neural network [9]-[13], genetic algorithm [14]-[18], hybrid [19]-[22], swarm intelligence [23]-[27].

2. Power System Stabilizer Model

The basic function of power system stabilizer is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signals. To provide damping, the stabilizer must produce a component of electrical torque in phase with rotor speed deviations. The theoretical basis for PSS may be illustrated with the aid of block diagram as shown in Figure 1.

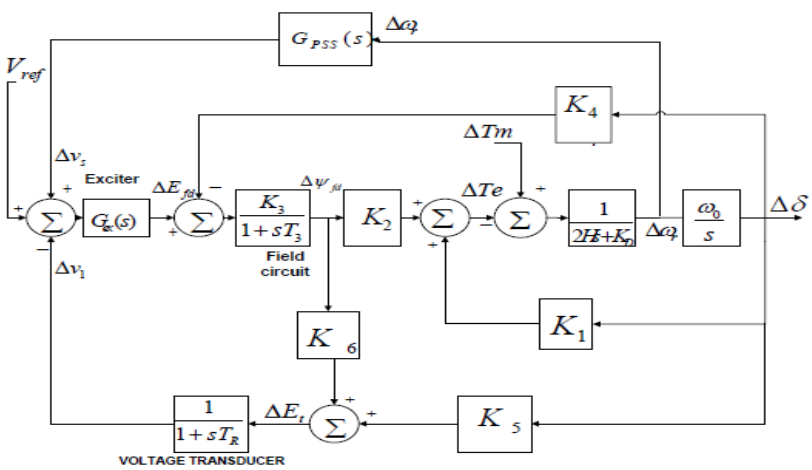

Figure 1. Block diagram representation with AVR and PSS

Since the purpose of PSS is to introduce a damping torque component. A logical signal to use for controlling generator excitation is the speed deviation $\Delta\omega_r$. The PSS transfer function, $G_{PSS}(s)$, should have appropriate phase compensation circuits to compensate for the phase lag between exciter input and electrical torque.

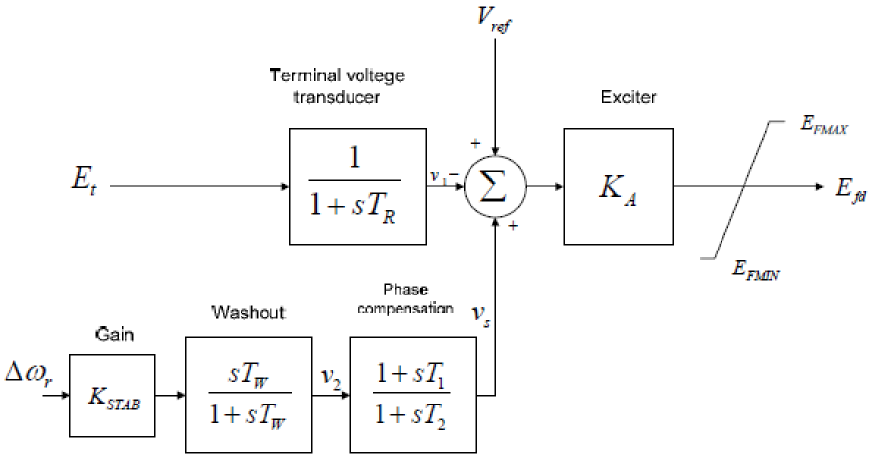

Figure 2. Thyristor excitation system with AVR and PSS

The phase compensation block provides the appropriate phase lead characteristics to compensate for the phase lag between exciter input and generator electrical torque. The phase compensation may be a single first order block as shown in Figure 2 or having two or more first order blocks or second order blocks with complex roots.

The signal washout block serves as high pass filter, with time constant T_w high enough to allow signals associated with oscillations in ω_r to pass unchanged, which removes d.c. signals. Without it, steady changes in speed would modify the terminal voltage. It allows PSS to respond only to changes in speed.

The stabilizer gain K_{STAB} determines the amount of damping introduced by PSS. Ideally, the gain should be set at a value corresponding to maximum damping;

The PSS parameters should be such that the control system results into the following-

- Maximize the damping of local plant mode as well as inter-area mode oscillations without compromising stability of other modes;
- Enhance system transient stability;
- Not adversely affect system performance during major system upsets which cause large frequency excursions; and
- Minimize the consequences of excitation system malfunction due to component failure.

3. Fuzzy Logic Based Power System Stabilizer

The block diagram representation of fuzzy logic controller implemented on single machine infinite bus system is shown in the Figure 3. The only difference in application of fuzzy controller to single machine infinite bus and conventional power system stabilizer is that in former case the PSS block is replaced by the fuzzy logic controller block.

The fuzzy module has two inputs namely the angular velocity and its derivative i.e. angular acceleration and output parameter as voltage. These are normalized by gains K_{in1}, K_{in2} and K_{out} respectively in order to match the range on which the membership functions are defined. Seven fuzzy subsets are defined for each input and output. The main problem that was faced now is the tuning of these fuzzy logic parameters K_{in1}, K_{in2} and K_{out}.

These parameters were tuned using the following procedure. Initially set the value of K_{in1} and K_{in2} equal to unity and study the effect of variation of third parameter on the response of the system and among them select the most suitable value then vary other variables keeping two parameter constant. Follow this procedure to investigate the effect of all three constants on the system.

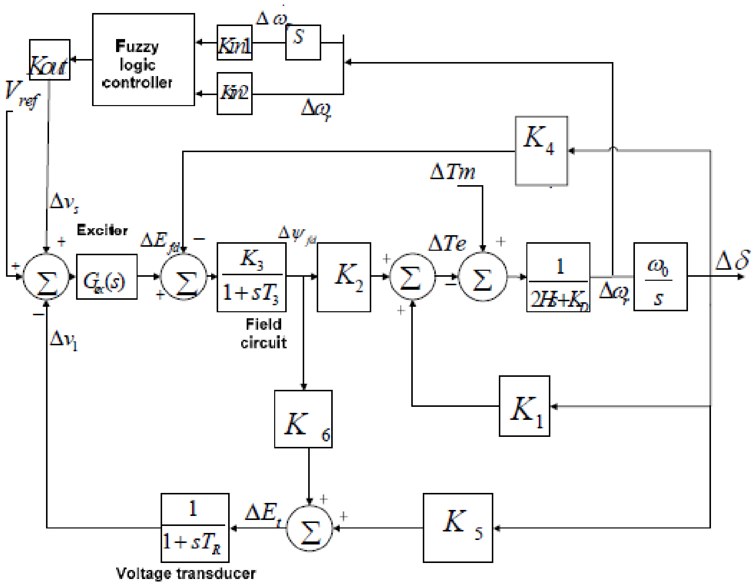

Figure 3. Implementation of fuzzy logic controller

4. Simulation Results

The simulink model of lead-lag power system stabilizer is shown in Figure 4.

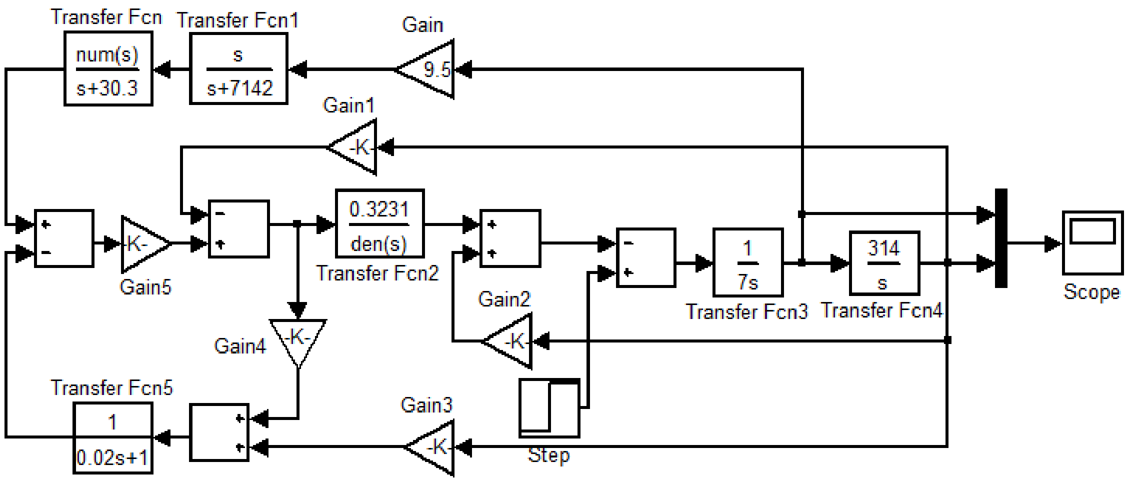

Figure 4. Simulink model with AVR and PSS

The parameters of PSS are:-

$T_1 = 0.154$, $T_2 = 0.033$, $T_W = 1.4$, $K_{STAB} = 9.5$

The Model used in Simulink/Matlab to analyze the effect of fuzzy logic controller in damping small signal oscillations when implemented on single machine infinite bus system is shown below in Figure 5. The performance of fuzzy logic controller is studied for the scaling factors having the values as Kin1=1.6, Kin2=29.56, Kout=1.06.

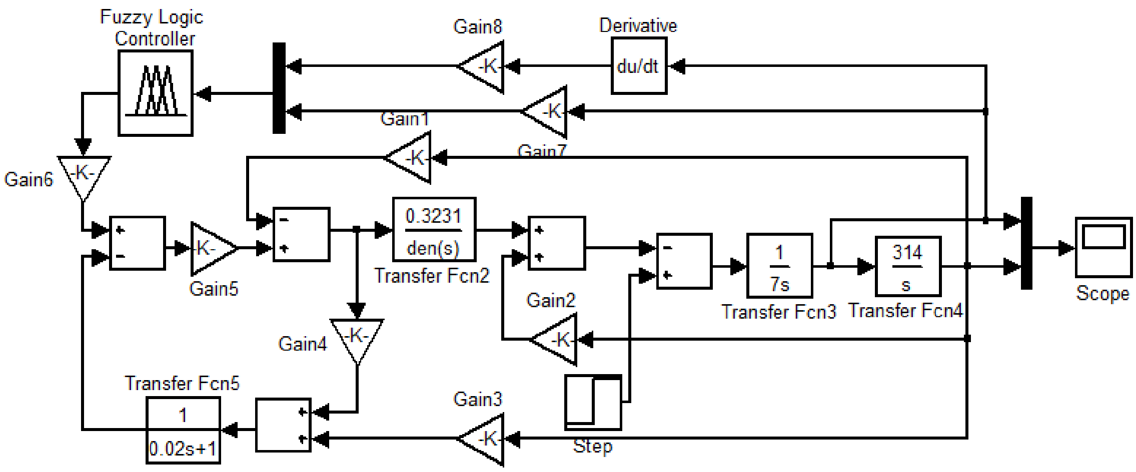

Figure 5. Simulink model with fuzzy logic based PSS

The step responses of both lead-lag PSS and fuzzy logic based PSS are compared for both positive and values of K5.

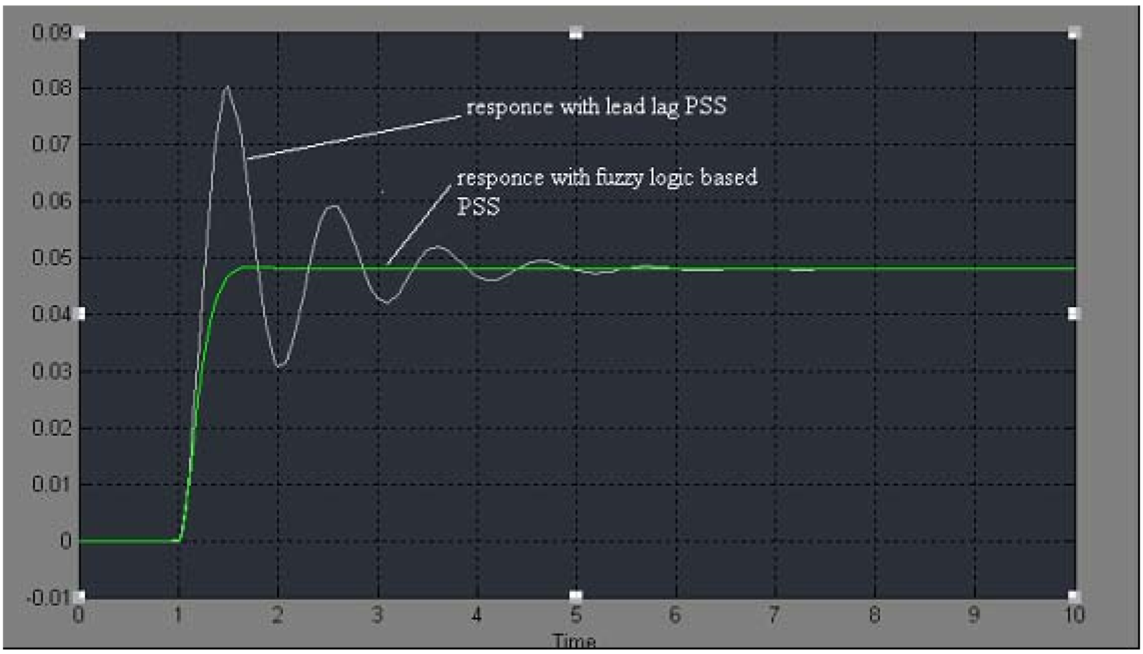

Figure 6. Comparison of angular position with conventional PSS (lead-lag) and fuzzy logic based PSS with K5 negative

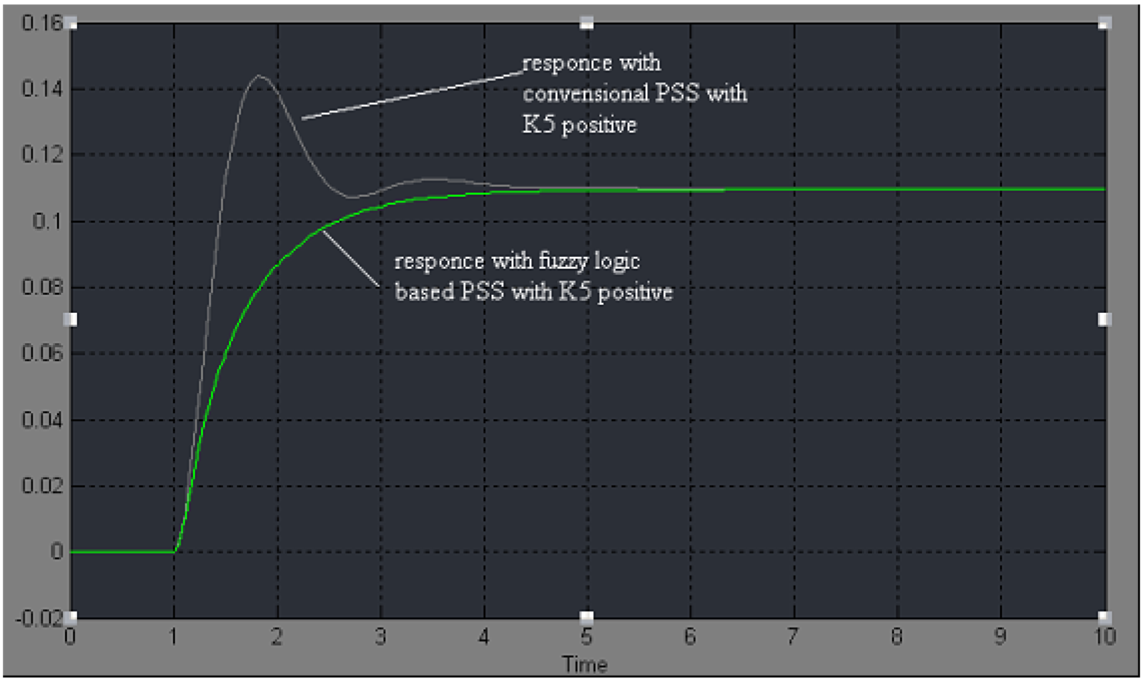

Figure 7. Comparison of angular position with conventional PSS (lead-lag) and fuzzy logic based PSS with K5 positive

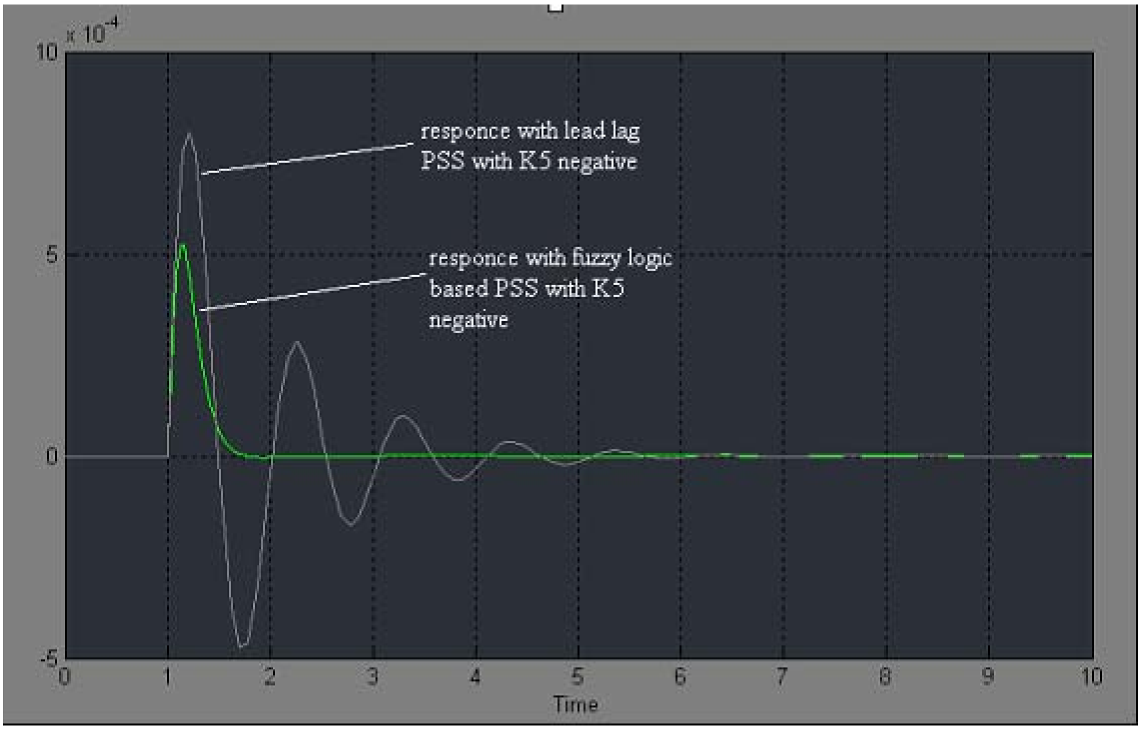

Figure 8. Comparison of angular speed with conventional PSS (lead-lag) and fuzzy logic based PSS with K5 negative

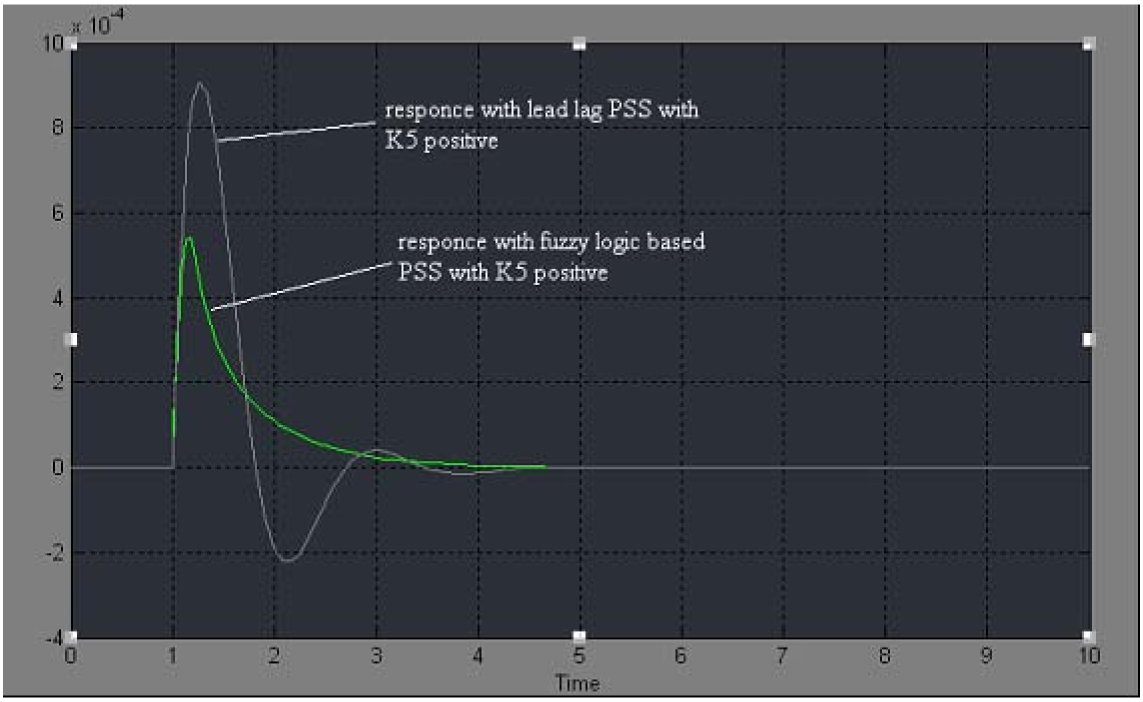

Figure 9. Comparison of angular speed with conventional PSS (lead-lag) and fuzzy logic based PSS with K5 positive

From relative plots it can be retrieved that oscillations in angular speed reduces much faster with fuzzy logic power system stabilizer than with conventional power system stabilizer for both the cases i.e. when K5 positive and negative

5. Conclusion

The purposed controller provides a more robust control versus an optimal controller and lead-lag stabilizer. The conventional lead-lag PSS is not giving desired performance under wide range of operating conditions. In this paper initially the effectiveness of power system stabilizer in damping power system stabilizer is reviewed then fuzzy logic power system stabilizer is introduced after taking speed deviation and acceleration of synchronous generator as the input signals to the fuzzy controllers and voltage as the output signal. FPSS shows the better control performance than power system stabilizer in terms of settling time and damping effect. The proposed FPSS produces better damping effect than PSS. It is thus possible to realize the controller efficiently. The overdamped response is resulted with positive K5, which is normally not encountered in practical situations. Therefore, it can be concluded that the performance of the proposed Fuzzy based Power System Stabilizer is much better and the oscillations are damped out much quicker.

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