Dynamic Stability and Analysis of SMIB system with FLC Based PSS including Load Damping Parameter Sensitivity

P. Jagadeesh, Ch. D. Prasad, Dr. M. Sai Veerraju

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ABSTRACT - *This paper studies Dynamic Analysis and Stability of Single machine connected to infinite bus (SMIB) with power system stabilizer (PSS) in presence of Fuzzy logic controller (FLC) including load damping parameter sensitivity. Here PSS is modeled using fuzzy logic controller and the response is compared with the responses of the system in presence of conventional PI, PID controllers including load damping parameters sensitivity. In case of FLC based PSS the responses are compared different load damping parameters. Matlab-Simulink is used to test the results.*

KEYWORDS: POWER SYSTEM STABILIZERS, FUZZY LOGIC CONTROLLER, MEMBERSHIP FUNCTIONS AND LOAD DAMPING PARAMETERS.

INTRODUCTION

As interconnected power system depending upon size has hundreds to thousands modes of oscillation. In the analysis and control of system stability, two distinct type of system oscillations are usually recognized. One type is associated with unit at a generating station swinging with respect to the rest of the power system. Such oscillations are referred as "Local Plant Mode" oscillations. [1]The frequencies of these oscillation and are typically the range 0.8-2.0 Hz. the second type of oscillation is associated with the swinging of many machine in one pare of the system machine at other part. These are referred to as "inter Area Mode". Oscillation and have frequencies in the range 0.1-0.7-Hz. The basic function of the PSS is to add damping to both types of system oscillation. It provides a positive damping torque in phase with the speed signal to cancel the effect of the system negative damping torque.

The effect of power system stabilizers on the oscillatory modes of a generating plant, which consists of a number of equal, identical generators, is discussed. It is shown that the power system stabilizer design and the type of power system stabilizer input may alter the damping produced by the stabilizer on the exciter mode and the intra-plant electromechanical modes. A power system stabilizer which is designed to match the ideal phase lead over a wide frequency range is shown to add damping to plant, interarea and intra-plant electromechanical modes. The exciter mode damping is shown to be reduced by power system stabilizers having frequency input.

Small Signal Stability which is the ability of the system to maintain stability under small disturbance. Such disturbances occur continuously in the normal operation of a power system due to small variations in load and generation. The first is the oscillations linked with a single generator or a single plant that is called “local modes” or “plant modes”.

The need of power system stabilizations has been increasing day by day. The demand for electric power requirement has motivated the usage of power system in an effective and reliable way. The stability of the power system is the ability to extend restoring forces equal to or greater than the disturbing forces to sustain the state of equilibrium [2]. Power industries are restructured to provide effective utilization to more users at lower prices and better power efficiency. The complexity of the Power systems has been increasing as they become inter-connected. Load demand also increases linearly with the increase in users. Since stability phenomena limits the transfer capability of the system, there is a need to ensure stability and reliability of the power system due to economic reasons. With these conditions, experts and researchers were continually tasked to find simple, effective and economical strategy of attaining stabilization of the power system, which is considered of highest priority. Thus, because of the importance of the stability of the power systems, methods [6]. The optimal sequential design for single machine power systems is very essential. As a result, serious consideration is now being given on the concern of power system stabilization control. In recent times, the utilization of optimization techniques becomes possible to deal with control signals in power system stabilizing control techniques have been used for the multi-machine power system with the help of intelligent.

SYSTEM MODEL

For stability assessment of power system adequate mathematical models describing the system are needed. The models must be computationally efficient and be able to represent the essential dynamics of the power system. The mathematical model for small signal analysis of synchronous machine, excitation system and the lead-lag power system stabilizer are briefly reviewed [2].

Here single machine connected to the infinite bus system (SMIB) is taken for this study. The equivalent circuit of a SMIB system can be shown in following figure.

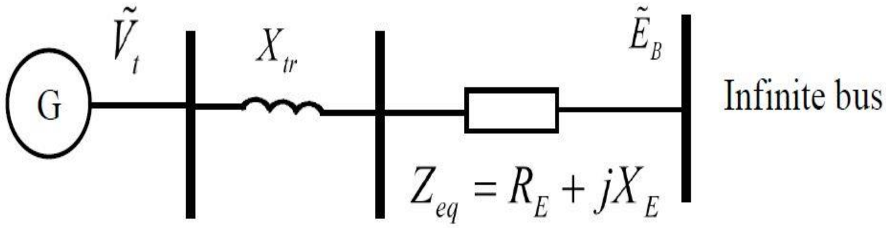


Figure 1: SMIB System Representation

Modeling is the method of developing mathematical equations for the system parameters. The basic modeling is the classical model for the generator. To this basic model the effect of synchronous machine field circuit dynamics and excitation system is added to frame the complete system block diagram when it is taken as single machine infinite bus system shown in following figure.

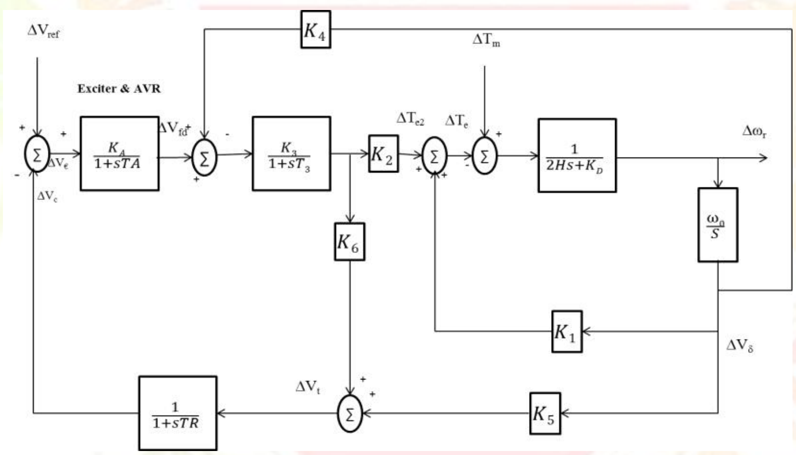


Figure 2: SMIB System

POWER SYSTEM STABILIZERS

The generic Power System Stabilizer (PSS) block is used in the model to add damping to the rotor oscillations of the synchronous machine by controlling its excitation current. Any disturbances that occur in power systems can result in inducing electromechanical oscillations of the electrical generators. Such oscillating swings must be effectively damped to maintain the system stability and reduce the risk of outage. The output signal of the PSS is used as an additional input (Vstab) to the excitation system block. The PSS input signal can be either the machine speed deviation (dω) or its acceleration power. The conventional power system stabilizer representation as shown in following figure.

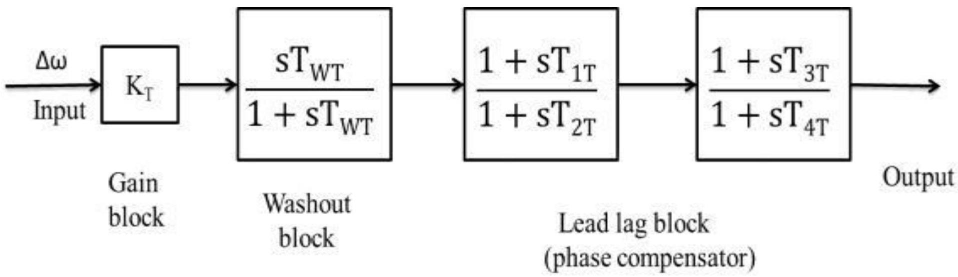


Figure 3: Block Diagram of Conventional Power System Stabilizer

It consists of a gain block, signal wash out block and a two stage lead-lag phase compensation blocks. It consists of a gain block with gain KT, a signal washout block and two stage phase compensation block as shown in figure. The phase compensation block provides the appropriate phase-lead characteristics to compensate for the phase lag between input and the output signals [11]. The signal washout block serves as a high-pass filter, with the time constant TW high enough to allow signals associated with oscillations in input signal to pass unchanged. The signal washout block serves as high pass filter, with time constant Tw high enough to allow signals associated with oscillations in ωr 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 KSTAB determines the amount of damping introduced by PSS. Ideally, the gain should be set at a value corresponding to maximum damping; however, it is limited by other consideration [8]. The block diagram of a single machine infinite bus (SMIB) system, which illustrates the position of a PSS, is shown in above Figure. The system consists of a generating unit connected to an infinite bus through a transformer and a pair of transmission lines. An excitation system and automatic voltage regulator (AVR) are used to control the terminal voltage of the generator. An associated governor monitors the shaft frequency and controls mechanical power.

By adding the Conventional power system stabilizer to this SMIB is shown in following figure.

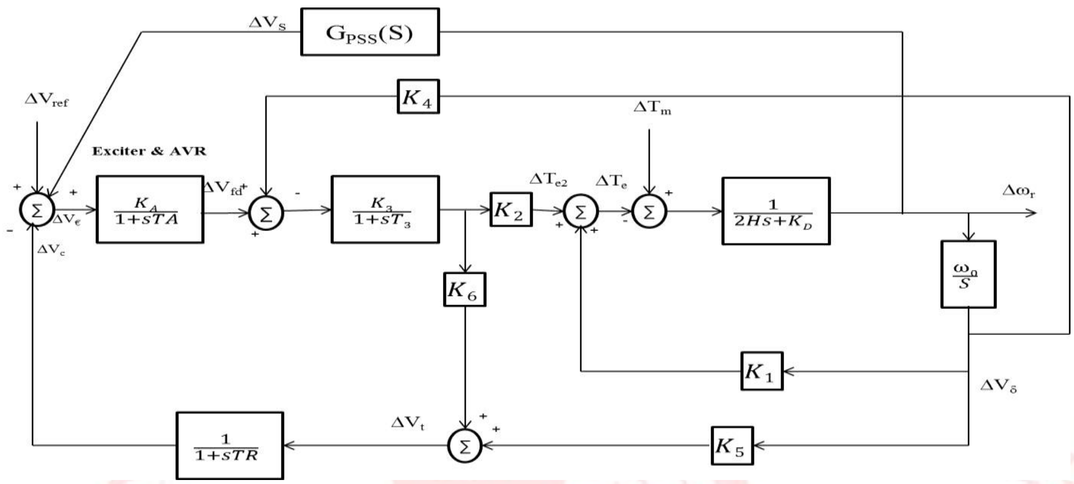


Figure 4: SMIB system with conventional power system stabilizer

Adding a PSS to the block diagram shown in Figure 2, the block diagram of the power system with PSS is obtained as shown in Figure. Since the Purpose of a PSS is to introduce a damping torque component, a logical signal to use as the input of PSS is Δωr. If the exciter transfer function and the generator transfer function between ΔEfd and ΔTe were pure gains, a direct feedback of Δωr would result in a damping torque component [15]. However, both transfer functions between ΔEfd and ΔTe exhibit frequency dependent gain and phase characteristics. Therefore, the CPSS transfer function should have an appropriate phase compensation circuit to compensate for the phase lag between the exciter input and the electrical torque[7]. In the ideal case, with the phase characteristics of Gpss(s) being an exact inverse of the exciter and generator phase characteristics, the CPSS would result in a pure damping torque at all oscillating frequencies.

DESIGN OF FUZZY LOGIC BASED PSS

SELECTION OF INPUT VARIABLES

The first step in designing a fuzzy logic power system stabilizer (FLPSS) is to decide which state variables representing system dynamic performance must be taken as the input signal to FLPSS. However, selection of proper linguistic variables formulating the fuzzy control rules is very important factor in the performance of fuzzy controllers. For the present investigations generator speed deviation Δω and Acceleration Δ.ω are chosen as input signals to FLPSS[4]. In practice, only shaft speed deviation Δω is readily available. The acceleration signal can be derived from speed signals measured at two sampling instant by the following expression.

$$\Delta\dot{\omega}(kT) = \frac{[\Delta\omega(kT) - \Delta\omega(k-1)T]}{T}$$

MEMBERSHIP FUNCTION

After choosing proper variables for input and output of fuzzy controllers, it is important to decide on the linguistic variables. The linguistic variables transform the numerical values of the input of the fuzzy controllers to fuzzy values. The number of these linguistic variables specifies the quality of control, which can be achieved using fuzzy controller [12]. As the number of linguistic variables increases, the quality of control increases at the cost of increased computer memory and computational time. Therefore, a compromise between the quality of control and computational time is needed to choose the number of variables.

All the investigations are carried out considering Triangular Membership functions [1]. A triangular membership function is specified by three parameters f {a; b; c} as follows:

$$f(x;a,b,c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases}$$

The parameters a and c locate the feet of the triangle and the parameter b locate the peak

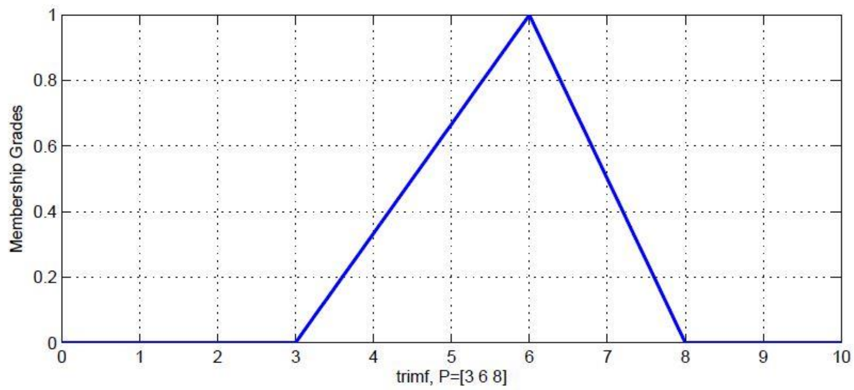


Figure 5: Triangular Membership Function

A triangular membership function is used here, they are shown in table:

Table 1: Membership function variables

Membership Function	
NB	Negative Big
NM	Negative Medium
NS	Negative Small
ZE	Zero
NS	Negative Small
ZE	Zero
PS	Positive Small
PM	Positive Medium
PB	Positive Big

The rules for the required fuzzy logic controller to get the desired performance can be shown in following table:

Table 2: Decision Table

Acceleration / Speed Deviation	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NS	ZE	ZE	PS
NM	NB	NB	NM	NS	ZE	PS	PM
NS	NB	NB	NM	ZE	PS	PM	PB
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NB	NM	NS	ZE	PM	PB	PB
PM	NM	NS	ZE	PS	PM	PB	PB
PB	NS	ZE	ZE	PS	PB	PB	PB

The De-fuzzification technique use here is centroid method, Centroid method is also known as center of gravity method, it obtains the center of area z* occupied by the fuzzy set A of universe of discourse Z. It is given by the expression,

$$z^* = \frac{\int_z \mu_A(z) z dz}{\int_z \mu_A(z) dz}$$ for continuous membership function,

And,

$$z^* = \frac{\sum_{i=1}^{n} z_i \mu(z_i)}{\sum_{i=1}^{n} \mu(z_i)}$$

For discrete membership function, Where µA(z) is the aggregated output MF. This is the most widely used adopted Defuzzification strategy, which is reminiscent of the calculation of expected values of probability distributions. The system with Fuzzy Logic based PSS is

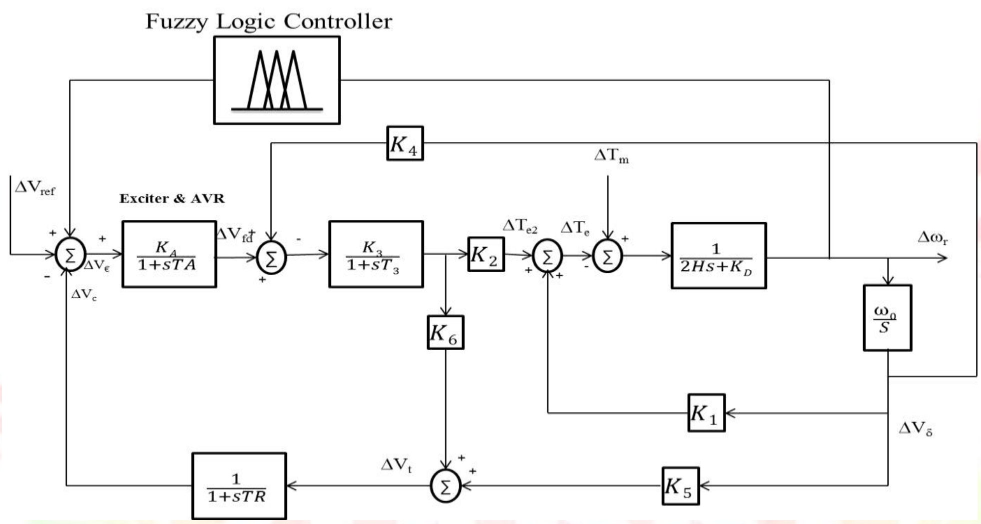


Figure 6: The System with Fuzzy Logic Based PSS

RESULTS

The response of the system which is SMIB system without using Power System Stabilizers is shown in figure.7 Response of the system using PID controller based PSS is shown in figure 8. The required response of the system using Fuzzy logic controller based PSS is shown in figure.9. By obsorving the following results tha oscillations are in the respose of the system with fuzzy logic controller based power system stabilizer is much less when compared it to the PID controller based power system stabilizer, but without using any controller or power system stabilizer the system stability will be occure in after many oscillations and takes much time. By applying fuzzy logic based power system stabilizer the dynamic stability of single machine infinite bus system will be get stability in short time

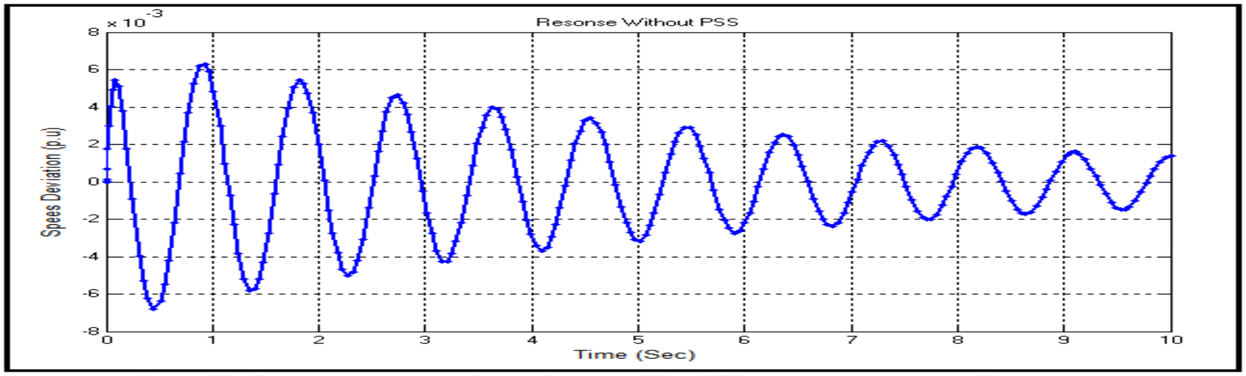


Figure 7: Response of the system without PSS

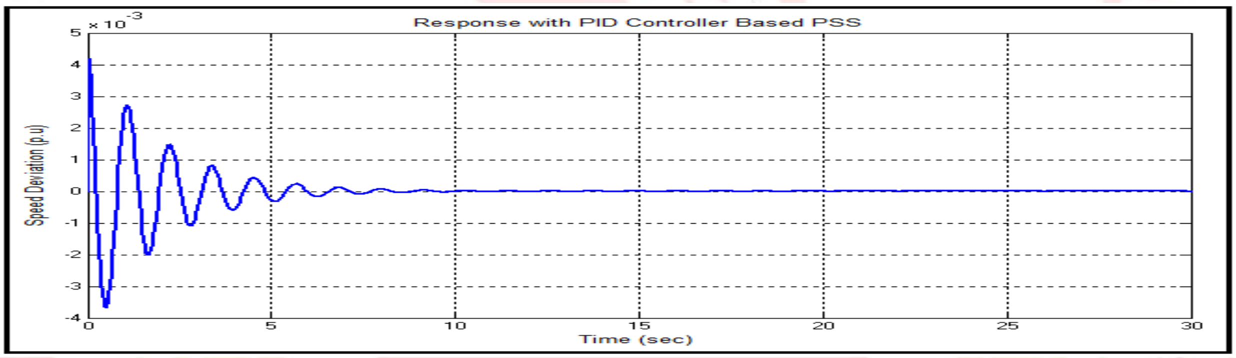


Figure 8: Response with PID controller based PSS

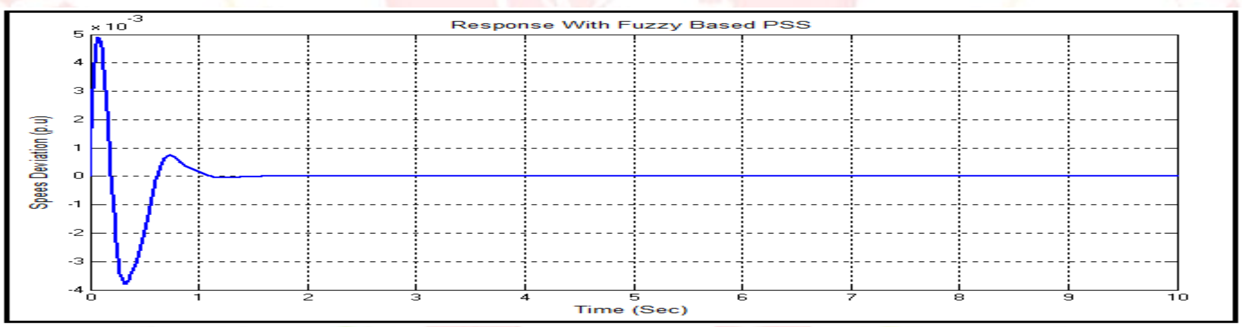


Figure 9: Response of the system with Fuzzy Logic based PSS

By varying damping torque coefficient (Kd) in the Single machine connected to an infinite bus system without any power system stabilizer and is tuned with a fuzzy logic controller based power system stabilizer the responses are taken at ΔTe ,Δωr and ΔVt.

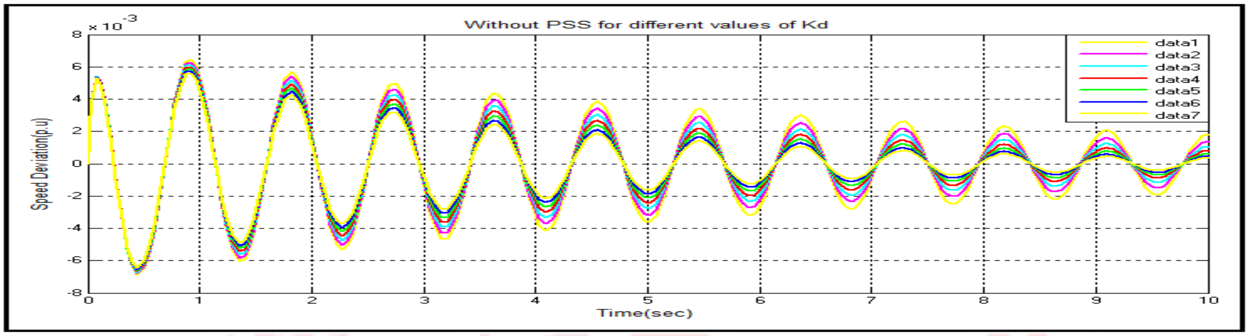


Figure 10: Response without PSS at $\Delta\omega r$

The response at ΔTe without using any Power system stabilizer

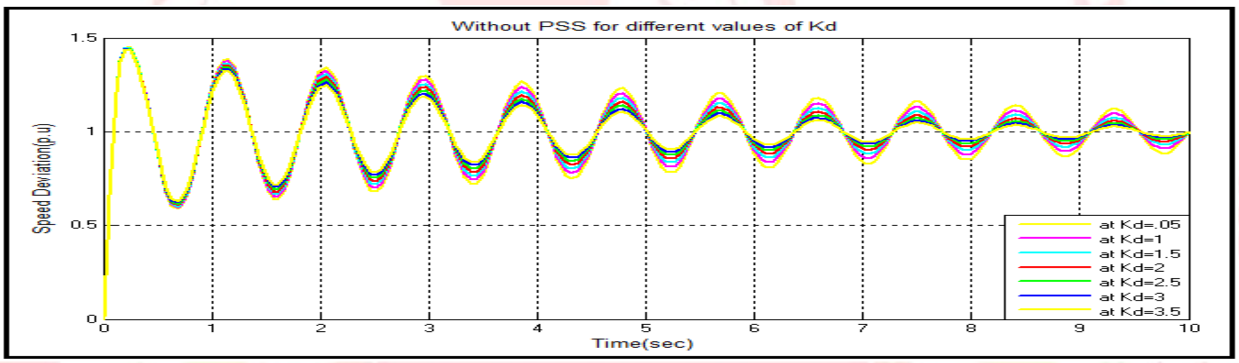


Figure 11: Response without PSS at ΔTe

The response at ΔVt without using any Power system stabilizer

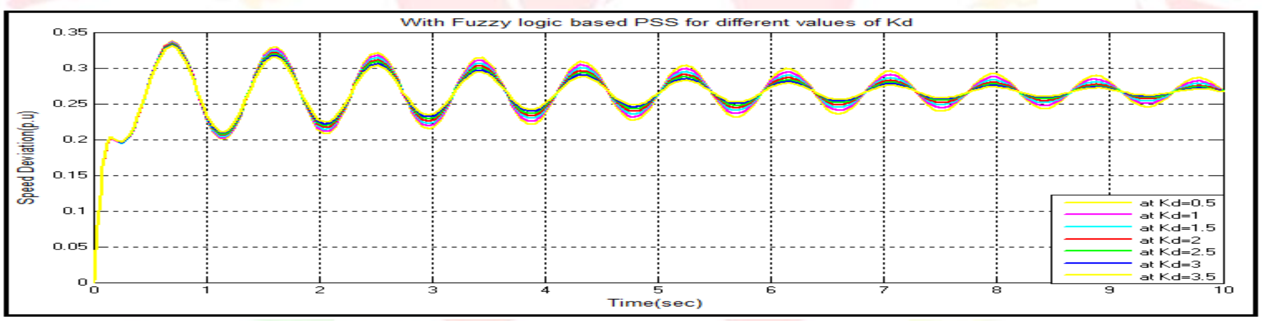


Figure 12: Response without PSS at ΔVt

The response taken from at ΔTe ,$\Delta\omega$r and ΔVt for the system with fuzzy logic based PSS by taking different damping coefficient are obtained as

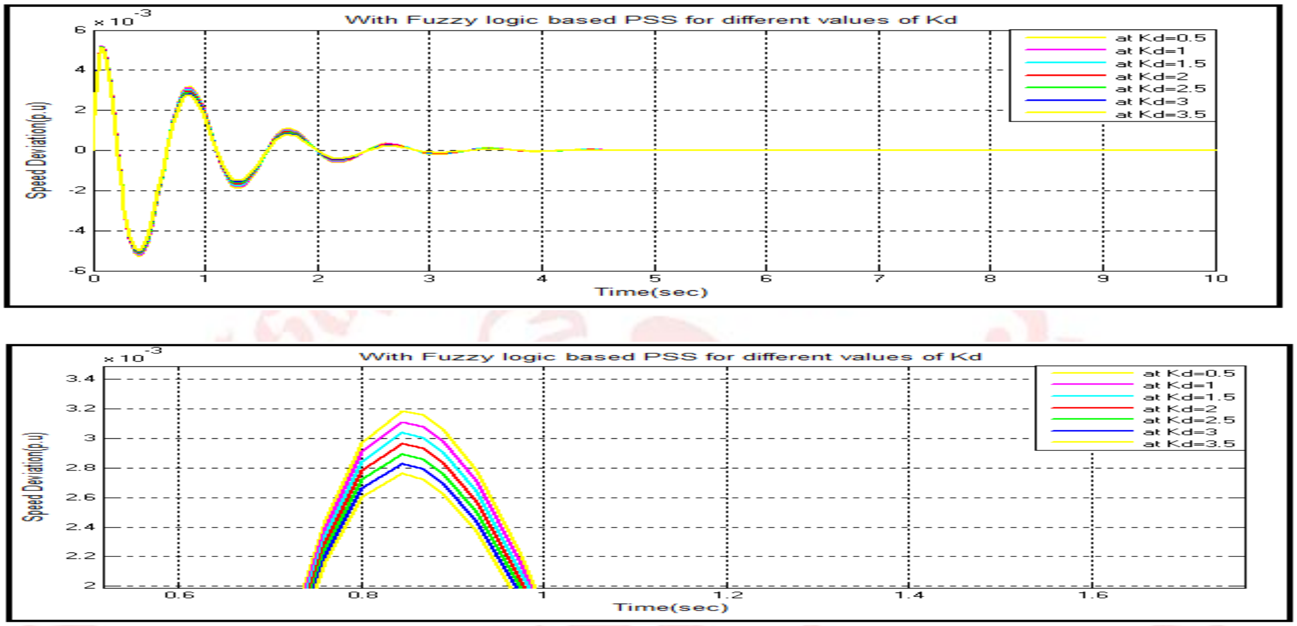
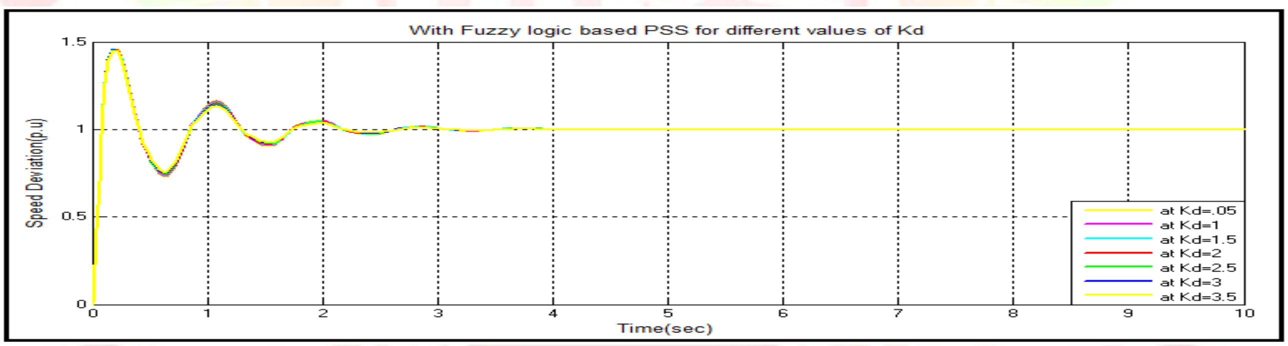


Figure 13: Response with Fuzzy based PSS at Δωr

The response of fuzzy logic based power system stabilizer at ΔTe as shown below



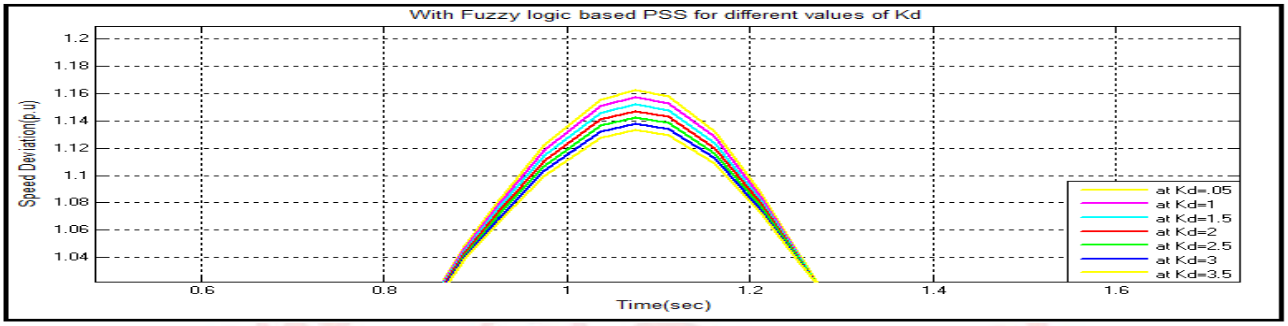


Figure 14: Response with Fuzzy based PSS at ΔTe

The response of the system with fuzzy logic based power system stabilizer at ΔVt as shown below,

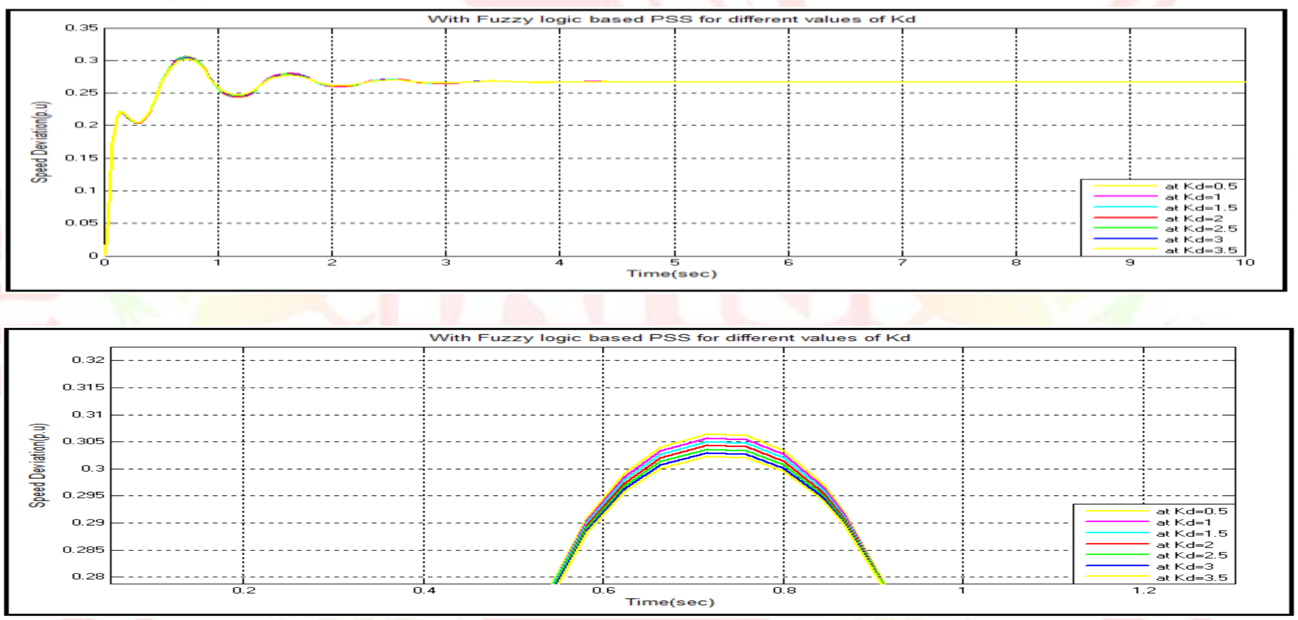


Figure 15: Response with Fuzzy based PSS at ΔVt

CONCLUSION

This paper presented a method for the design of fuzzy logic power system stabilizers (FLPSS) in a single machine connected to an infinite bus system (SMIB). The power system stabilizer used in this is fuzzy logic based controller and is tested in a SMIB system and the dynamic stability of the system responses is obtained including the load damping parameter sensitivity.

APPENDIX

SYSTEM DATA:

The Parameters of the synchronous machine, excitation system and conventional PSS are as follows.

a) Synchronous machine constants:
xd= 2.64 pu, x'd= 0.28 pu
xq= 1.32 pu, xq= 0.29 pu
RE= 0.004 pu, XE= 0.73 pu
f= 60 Hz, H= 4.5 sec

b) Excitation system constants:
KA= 100, TA= 0.05, TR= 0.015
EFMAX= 5.0, EFMIN= -5.0

c) PSS constants: KSTAB= 20, Tw= 1.4 sec
T1= 0.154 sec, T2= 0.033 sec
VSMAX= 0.2, VSMIN= -0.2

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