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Design and Analysis of Fuzzy Logic based Power System Stabilizer

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***Abstract*— This paper presents a new fuzzy logic controller as power system stabilizer being used for stability enhancement and improving the dynamic response of the power system under faulty conditions. Power system stabilizer is added to the generator excitation system to enhance the damping during low frequency oscillations. In order to improve the stability of the power system, acceleration and rotor speed deviation of the synchronous machine are taken as input of fuzzy logic controller. These variables produce an effect on controlling the damping of generator mechanical shaft. In this paper proposed control power system stabilizer is being compared with the conventional power system stabilizer and multi brand power system stabilizer. Proposed control techniques are simulated over the IEEE 39 bus system under different conditions (with noise, without noise). Simulations of the control technique are carried out on MATLAB/SIMULINK tool.**

Keywords — Power System Stabilizer (PSS), Fuzzy Logic power system stabilizer (FL-PSS), Multi-Brand Power System Stabilizer (MB-PSS), Fuzzy Logic Controller (FLC).

I. INTRODUCTION

Electrical power system is basically a dynamic system. In this type of system disturbances occur constantly which causes generator angle and voltage to change. When disturbances are removed, steady state operating condition is attained [14].

In today's modern time, all synchronous machines operate in synchronism and deliver power to load. When load of the generator changes, fast or slow down of synchronous generator rotor occur which in turn changes the frequency of 0.7 to 2Hz. However, PSS associated with generator is an essential control to bring the frequency back to normal value. It also improves the transmission capacity and stability of the power system [11].

PSS are the most important devices to damp out p low frequency oscillations caused by various disturbances like fault, load changes. Stability of electrical power system is improved by using suitable design and tuning of the PSS which improves the damping frequency oscillation. PSS is added to the generator excitation system in order to provide a supplementary signal to excitation system and to extend the stability limit by modulating generator excitation which provides the positive damping torque to power swing mode[14,9,11].

One of the most occurring stability problems arising from large electric power system is the low frequency oscillations of interconnected power systems. These oscillations can be removed by connecting PSS with the associated generator. In this paper, concept of 3 phase fault is introduced in the bus system having 10 distributed generators (DG) units. Ideally, different types of tuned PSS are used for frequency control methods of bus system to minimize the impact of stability enhancement of complete power system. Here, the time domain reaction with different cases namely without PSS and with different type of PSS are being investigated for synchronous machine and are also compared with the proposed controller by Fuzzy logic based PSS controller [9-14]. This comparison of control technique will demonstrate that the proposed technique have lower setting time and more robustness against parameter variations and external disturbances than the conventional controller which is shown in simulation result using IEEE 39 test bus system .It also presents the effect of 3 phase fault on the network using proposed controlling PSS methods.

In this paper, MATLAB/simulation software is used to test the proposed PSS methods using IEEE 39 bus system. This system is employed to verify and demonstrate the superiority of the proposed PSS verses the conventional PSS. Several simulation conditions have been illustrated, compared and evaluated in this paper.

The objective of this paper is the frequency control of IEEE 39 test system using fuzzy logic based PSS and compare with the proposed technique. This paper is designed in the following manner: The section (ii) provides an overview of conventional PSS, section (iii) states the theory of proposed method and section (iv) compares the different type of PSS used in this paper. Finally the conclusion is being given.

II. MODELLING OF 39 BUS SYSTEM

In this paper, MATLAB/SIMULINK software is being used to test the proposed PSS methods using IEEE 39 bus test system. It consist of 10 generators, 19 loads, and 39 buses[4].

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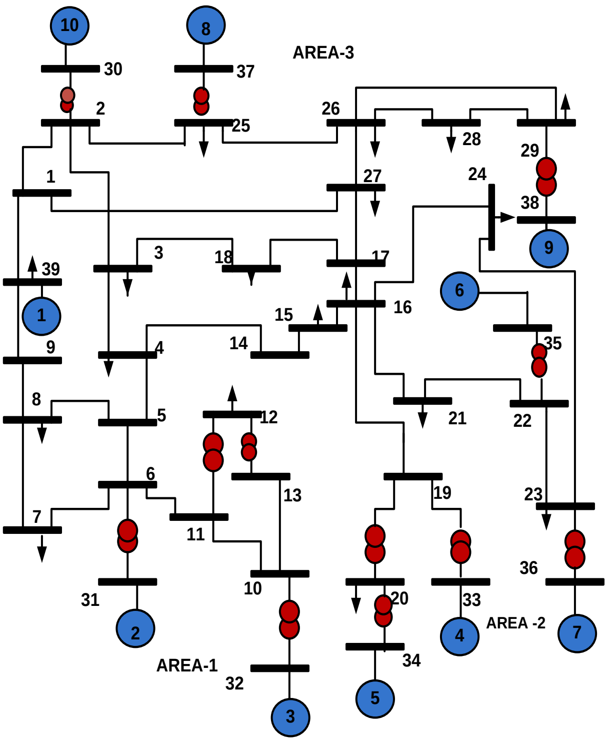

Fig 1. 39 bus 10 machine test system

10-machine New-England Power System is shown in figure 1. For simplification, this system was divided in three areas (AREA 1, AREA 2, and AREA 3). The AREA 1 consist of machine 3 and machine 2. Machine 1 is taken as reference bus and the value of speed and rotor angle deviation is zero. So, the interaction between *M*2 and *M*3 is defined as local-area mode in AREA 1. The interaction between machines (*M*2 and *M*3) in the Area 1 to machines in other areas (*M*10 and *M*8) is called as inter-area mode [15,16]. Performance of 39 bus system in case of 3-phase fault is applied close to the bus 17 and 16, result shown in section IV.
Figure 2 shows the generalized model of synchronous generator with different type of PSS associated model.

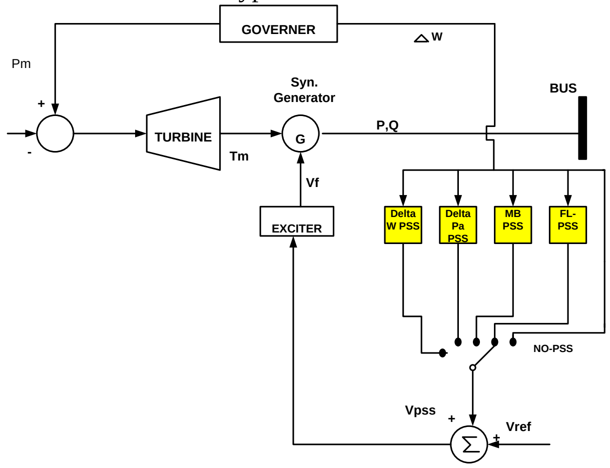

Fig 2. Synchronous generator model with PSS

III POWER SYSTEM STABILIZER

In the literature of PSS, there are many methods for frequency control of power system using PSS. In this paper, we study and simulate conventional PSS (Delta w PSS, delta Pa PSS), MB-PSS and Fuzzy logic based PSS.

A. Conventional Power System Stabilizer

The basic function of Power System Stabilizer is used to add damping to the rotor oscillations of the synchronous machine (DG) by controlling its excitation. The disturbances (fault, noise, etc.) occurring in power system induces electromechanical oscillations of the synchronous generators. These electromechanical oscillations also called as power swings, must be effectively damped to maintain the stability of the power system. The output signal of PSS is used as an additional input (vstab) to the Excitation System. The PSS input signal can be either the acceleration power, Pa = Pm - Peo (the difference between the mechanical power and the electrical power), or its (dw) speed deviation [9,11].
A complete block diagram of the PSS for non linear system is shown in figure 3. it consist of a washout high pass filter, a low pass filter, a gain, a phase compensator, and an output limiter.

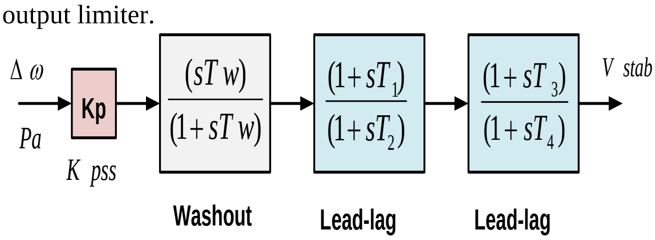

Fig 3. Power System Stabilizers

Gain (K) is the amount of damping produced by the PSS.
Washout high pass filter (W) subtract low frequency signal present in dw.
Phase compensator device made up of two lag-lead transfer function which is used to compensate the phase lag between the excitation voltage and the electrical torque of the synchronous machine.

A. Multi Brand Power System Stabilizer

The disturbances (fault, noise etc) occur on a power system produces various electromechanical oscillation modes on synchronous generators. These electromechanical oscillations lie in the range of 0.05 to 5.0 Hz frequency range. MB-PSS are used to tune different mode of frequency oscillation and improve the stability of power system.
The MB-PSS made up of the transducer, the lead-lag compensator, the transducer and the limiter.
Speed deviations of two transducers are used to feed three band structures

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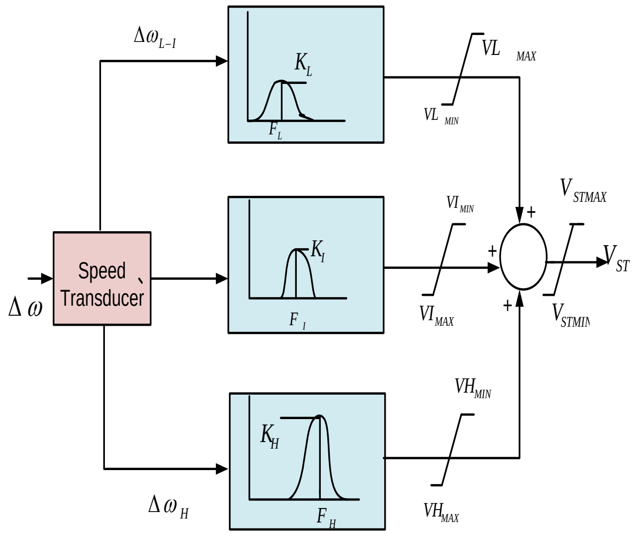

Fig 4. MB-PSS

1) Low band for slow oscillating phenomena (0.05 Hz)
2) Intermediate band for inter area mode (0.2-1.0 Hz)
3) High band for local modes like plant or machine (0.8-4.0 Hz).

Simplified diagram of the MB-PSS is given in figure 4. [1,2].

B. Fuzzy Logic Controller (FLC)

Now a day, fuzzy logic is emerging as a powerful tool. It is basically used to maintain the power system stability. It is in the form of many valued-valued logic which is based on degree of truth. Truth sets allows the objects to get grades of membership from zero to one (true or false). These sets are mainly represented in terms of linguistic variables which is ordinary language being used to represent a specific fuzzy set in a problem such as 'large', 'medium' and 'small'[9-14].

Fuzzy logic is a flexible approach and its concept is easy to understand.

The fuzzy logic power system stabilizer is comparatively more robust than the other power system stabilizer. It has lower settling time then the other methods. The proposed FL-PSS has two input namely acceleration power and rotor speed deviation of synchronous machine. Its give voltage as the output. Membership functions for input and output are shown in the figure 5,6,7. Rule table is also given in table 1[10].

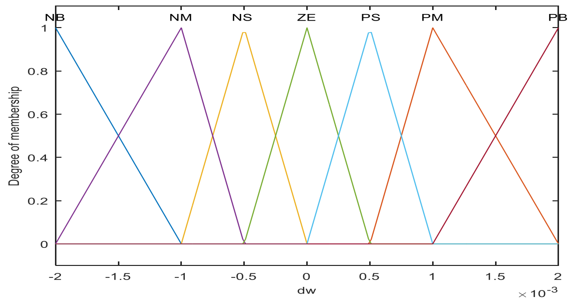

Fig 5. Membership function of rotor speed deviation (dw)

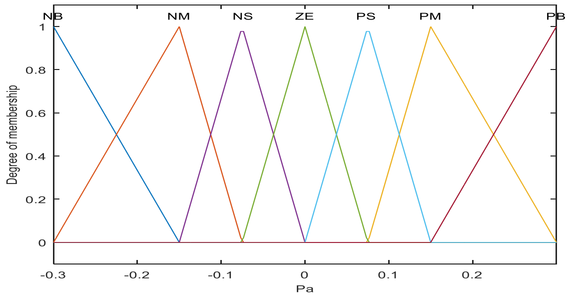

Fig 6. Membership function for Acceleration power (Pa)

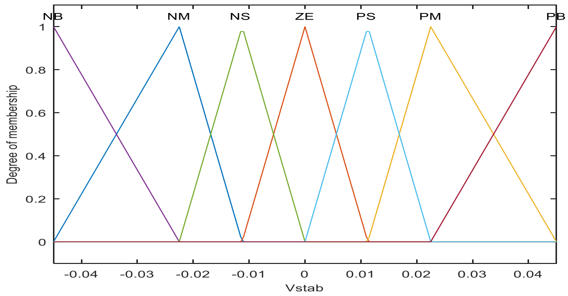

Fig 7. Membership function of output Voltage (Vstab)

TABLE-1: Rule based table for the Fuzzy Logic Controller

dw/pa	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NS	ZE	ZE	PM	PB	PB
PS	NM	NS	PS	PM	PM	PB	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	ZE	PM	PB	PB	PB	PB

IV SIMULATION RESULT

10-machine New-England Power System as shown in figure 1 is being considered for this work.

The model of the synchronous generator with different type of PSS (conventional PSS, MB-PSS, FL-PSS) is being tested under different conditions.

The system was subjected to a disturbance 3 phase fault condition (with and without noise). We have studied the variation of above. Rotor speed deviation and Rotor speed of generator 1 is as shown below. It also show the rotor speed of generator 10-8 (local-area mode) generator 10-3 (inter-area mode) as shown in figure 12 and 13.

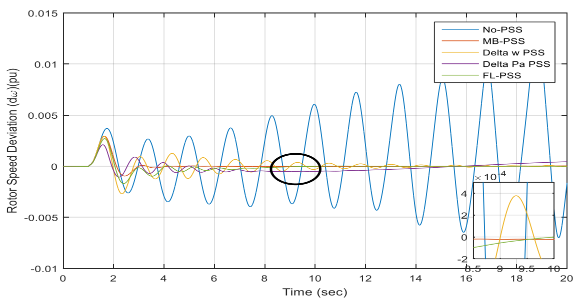

Fig 8 Rotor Speed Deviation (d\omega) of Generator 1(Without noise)

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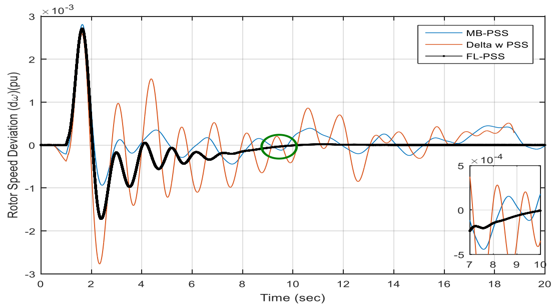


Fig 9 Rotor Speed Deviation (d\omega) of Generator 1(With noise)

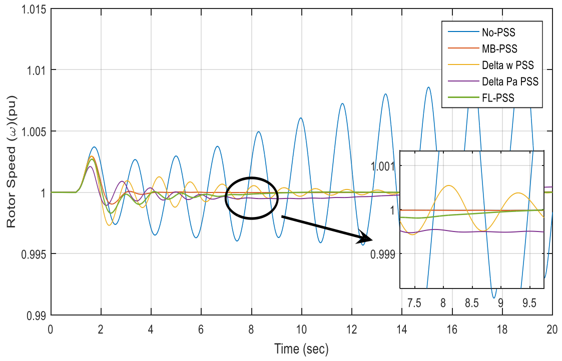


Fig 10 Speed of Rotor in Generator 1

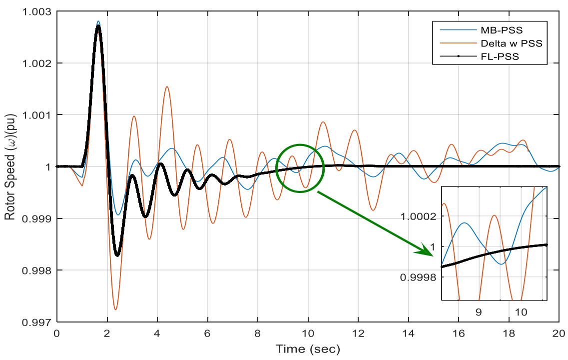
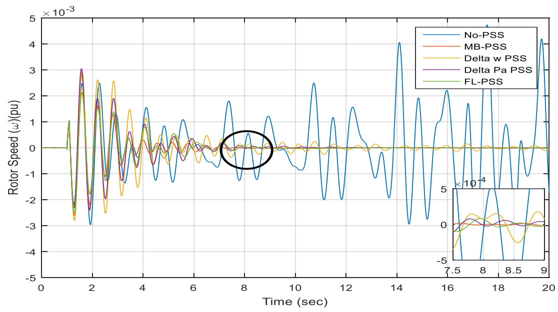
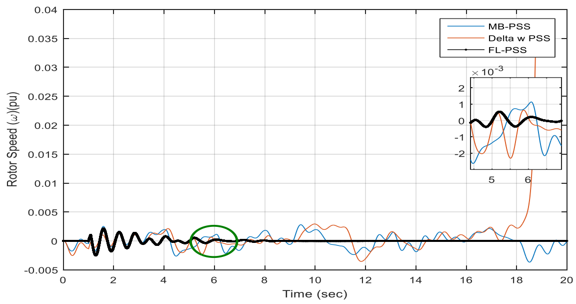


Fig 11 Speed of Rotor in Generator 1(with noise)



(a)

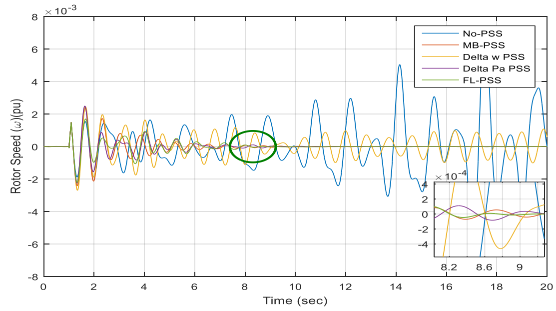


(b)

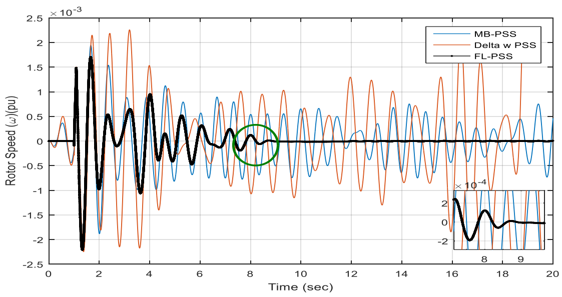
Fig 12. Rotor Speed (a) ω_{8-10} (without noise) and (b) ω_{8-10} (with noise) on local mode

TABLE-II: Comparison of rotor speed of different technique (local-area mode)

Control Technique	Settling time(s)	
	Without noise	With noise
FL-PSS	8.8	10.1
MB-PSS	9.2	Greater than 20
Delta w PSS	10.8	Greater than 20



(a)



(b)

Fig 13. Rotor Speed (a) ω_{10-3} (without noise) and (b) ω_{10-3} (with noise) on inter-area mode

TABLE-III: Comparison of rotor speed of different technique (inter-area mode)

Control Technique	Settling time(s)	
	Without noise	With noise
FL-PSS	8.6	9.1
MB-PSS	9.8	Greater than 20
Delta w PSS	10.5	Greater than20

V. CONCLUSIONS

In this paper, a design scheme of power system stabilizers for synchronous machine (10 generators) with 39 buses using different type of PSS model is given. It also shows the inter-area and local area mode of interaction. Comparison of control techniques (CLPSS and MB-PSS) has demonstrated that the proposed technique (FL-PSS) have lower setting time, more robustness against parameter variations and external disturbances, increase the power transfer limit of the system than the conventional. Improving the efficiency, controlling the frequency, system stability and reliability of system. For the further increment of stability we can use Neuro or Fuzzy-neuro control technique.

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