A Multi-Machine Power System Stabilizer Using Fuzzy Logic Controller

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Abstract:

In this paper a fuzzy logic controller as power system stabilizer for stability enhancement of a multi-machine power system is presented. Power system stabilizers (PSSs) are added to excitation system or control loop of the generating unit to enhance the damping during low frequency oscillations. In order to accomplish the stability enhancement, speed deviation (□□) and acceleration (□□) of the rotor of synchronous generator were taken as the input to the fuzzy logic controller. These variables produce significant effects on damping of the generator shaft mechanical oscillations. The simulations were tested under different operating condition and the responses of stabilizing signal were computed. The performance when compared with the conventional PID controller the results of fuzzy controller are quite encouraging and satisfactory.

Keywords: adaptive controller, fuzzy logic, PID stabilizer, synchronous generators.

I. Introduction

Fuzzy logic control has emerged as a powerful tool and it start to be used in various power system applications. The application of fuzzy logic control technique appears to be most suitable one whenever a well-defined control objective cannot specified, the system to be controlled is a complex, or its exact mathematical model is not available [1-3]. Most power system stabilizers are used in electric power systems to employ the classical linear control theory approach based on a linear model of a fixed configuration of the power system. Such a fixed-parameter PSS, called a conventional Power System Stabilizer (CPSS). [4, 5] Low -frequency oscillations are a common problem in large power systems. A power system stabilizer (PSS) can provide a supplementary control signal to the excitation system and/or the speed governor system of the electric generating unit to damp these oscillations [6]. Most (PSS) is used in electrical power system employing the classical linear control theory approach based on a linear model of affixed configuration of power system. Such affixed parameter PSS, is also called conventional PSS. It is widely used in power system and has made a great contribution in enhancing power system dynamics. The parameters of CPSS are determined based on a lineazed model of power system around a nominal operating point. Because power system are highly nonlinear systems, with configurations and parameters that change with time, the (CPSS) design based on the linearized model of the power system cannot guarantee its performance in a practical operating environment [7-9].

This paper presents power system stabilizer with an adaptive PID fuzzy controller for different operating conditions of the power system. Various simulations have been performed for multi-machine power system.

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II. Model of A process-Synchronous Generator

The system consists of synchronous generator, turbine, governor, and tie-line mode. The power flow over the transmission line will appear as a positive load to one area and equal but negative load to the other, or vice versa, depending on the direction of power flow. A block diagram represents this interconnection can be shown as in figure 1 the tie-power flow was defined as going from area1 to area2 [10,11].

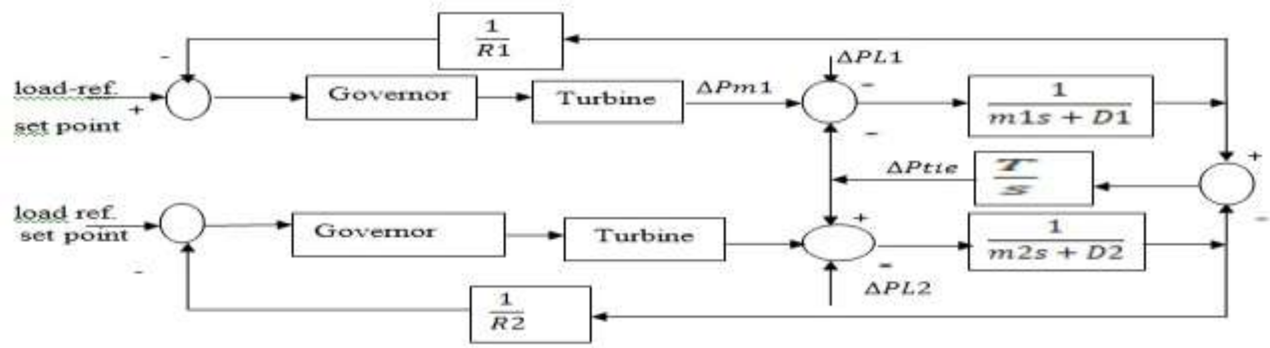

Figure 1 system model configuration

In figure 1 ΔPm is deviation of mechanical power, ΔP is non frequency sensitivity, m=2H where H is inertia constant, D is load of machine, ΔPtie is tie power deviation, 1/R is net gain.
The model of the system is built in the Matlab/Simulink software suite as shown in figure 2. Electric power is generated by converting mechanical energy into electrical. The rotor mass which contains turbine and generator unit, stored kinetic energy accounts for sudden increase in the load. Neglecting the rotation losses, a generator unit is said to be operating in the steady-sate at a constant speed when the difference between electrical torque and mechanical torque is zero [8].

III. Power System Stabilizer

Power system stabilizer is control device that used to enhance damping of power system oscillations in order to extend power transfer limits of the system and maintain reliable operation of the grid.
It can be proved that a voltage regulator in the forward path of the exciter generator systems will introduce a damping torque and under heavy loading conditions this damping torque becomes negative. This is a situation where dynamic instability may cause concern. Further, it has been also pointed out that in the forward path of excitation control loop, the three time constants introduce a large phase at low frequencies just above the natural frequency of the excitation systems. To overcome this effect and improve damping compensating network called "power system stabilizer (PSS)" can be introduced. The basic structure of the conventional power system stabilizer is shown in figure 3 [8].

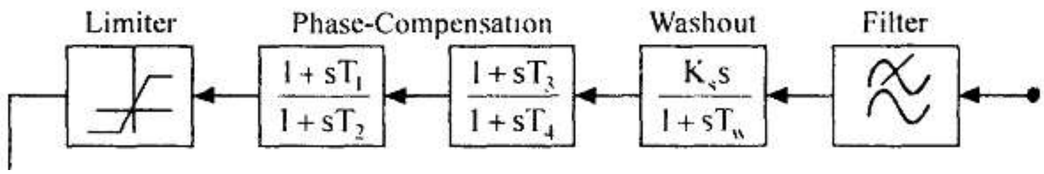

Figure 3: Conventional Power System Stabilizer.

The control equation is given by:

$$\text{Output (PSS)}= \frac{SK_sT_W(1+ST_1)(1+ST_3)}{(1+ST_W)(1+ST_2)(1+ST_4)} . \text{Input} \qquad (1)$$

Where;
K_s : Power System Stabilizer gain.
T_w : washout time constant.
T_1, T_2, T_3, T_4 :Time constant selected to provide a phase lead for the input signal in the range of frequencies of interest.

IV. **Fuzzy Logic Controller**

In last decade, fuzzy logic controllers (FLCs) has being used as PSSs, have been developed and tested [12, 13]. As shown in figure 4, there are specific components characteristic of fuzzy controller to support a design procedure-processing block. In the block diagram in Figure 4 the controller is between a preprocessing block and a post-processing [14].

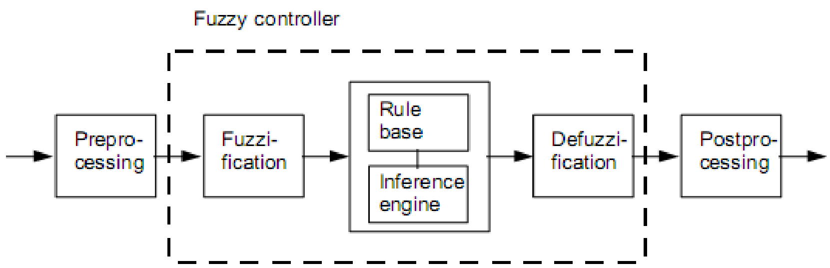

Figure 4: Fuzzy controller structure

The speed deviation (□□) and acceleration (□□) of the rotor of synchronous generator were taken as the input to the fuzzy logic controller. The main part of FLC is the rule base and the inference machine, the rule base is normally expressed in asset of fuzzy linguistic rule, with each rule triggered with varying belief for support. The complete set of control rules is shown in table 1.

Table 1: Fuzzy Rules.

Ce / e	**NB**	**NS**	**Z**	**PS**	**PB**
NB	NB	NB	NS	NS	Z
NS	NB	NS	NS	Z	PS
Z	NS	NS	Z	PS	PS
PS	NS	Z	PS	PS	PB
PB	Z	PS	PS	PB	PB

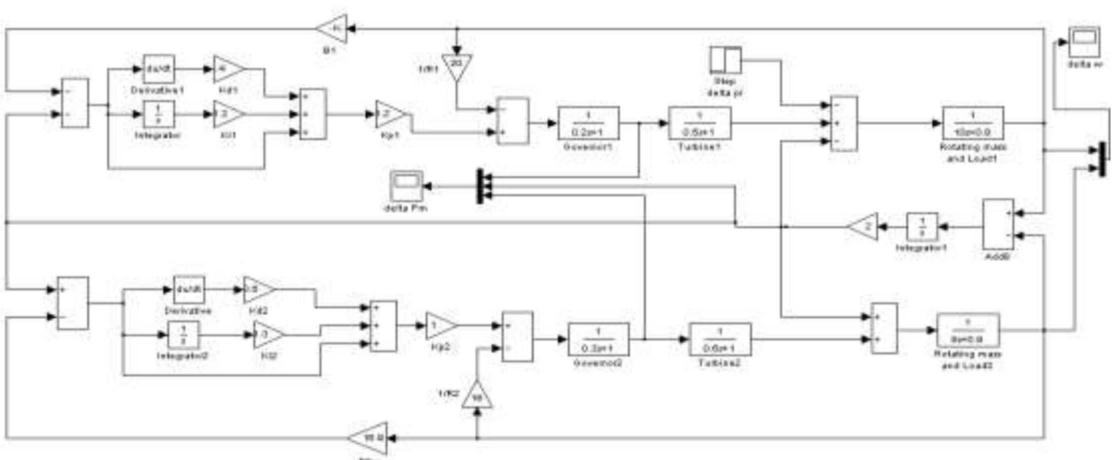

Figure 5: Simulink model of multi-machine power system using PID Controller.

The Simulink model shown in figure (5) shows multi-machine power system controlled with PSS. Frequency deviation response of multi- machine using conventional PSS is shown in figure (6). Figure (7) shows the synchronous machines controlled with fuzzy PD+I controller simulated in Matlab/Simulink software. Frequency deviation response of multi- machine using fuzzy controller is shown in figure (8).

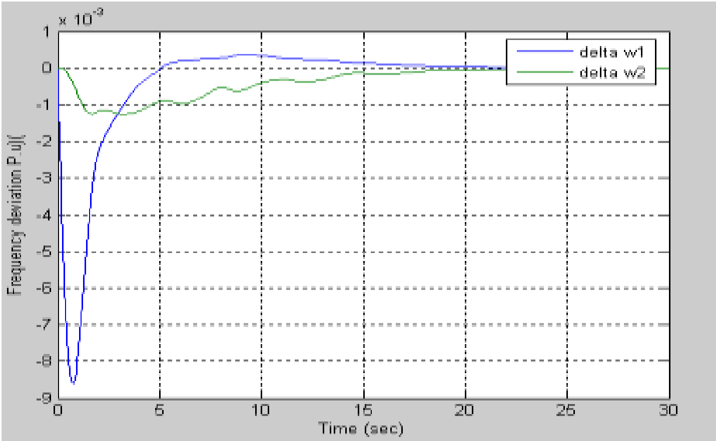

Figure 6: Frequency deviation response of multi machine using PID Controller.

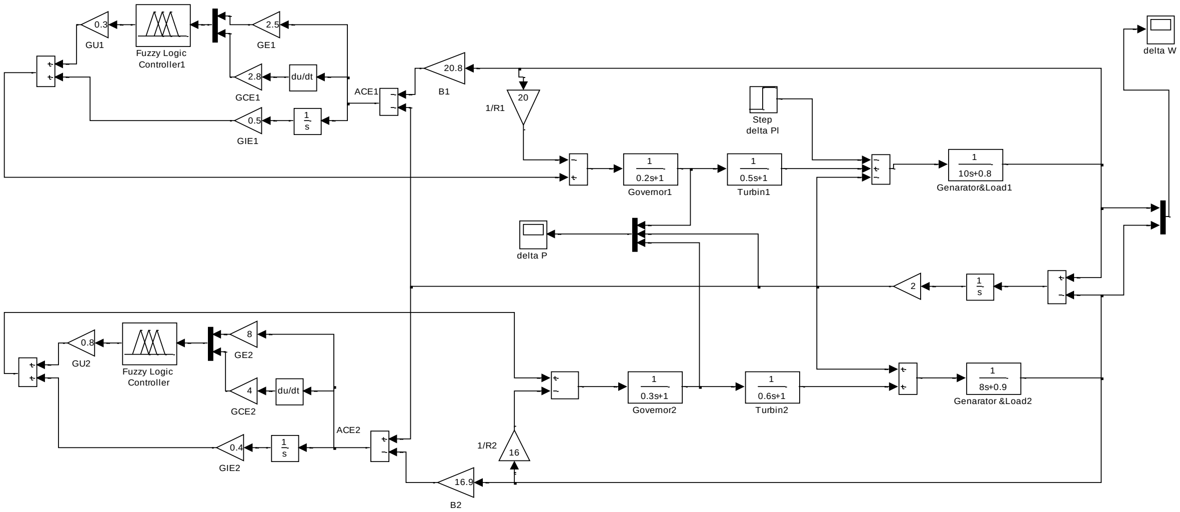

Figure 7: Simulink model of multi- machine power system using FPD+I controller.

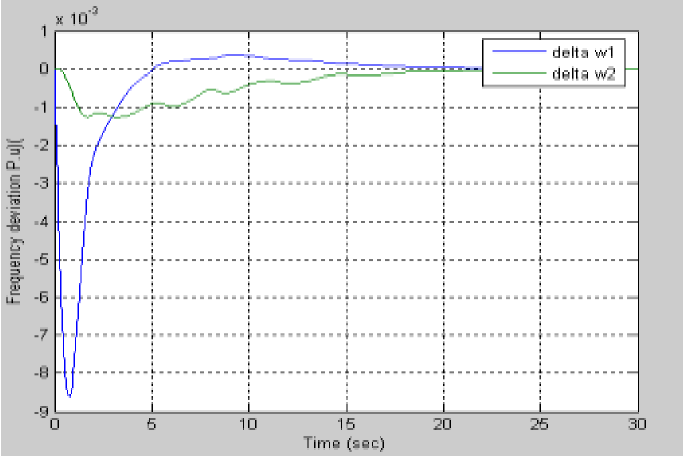

Figure 8: Frequency deviation response of multi- machine using fuzzy controller.

Concolustions

This paper he fuzzy controller has an excellent response with small oscillation, while the PID controller response shows ripples and some oscillation before reaching the steady-state operating point. It was shown that an excellent performance of the fuzzy controller in contrast to the conventional one is the control loop of the generating unit of power system achieved.

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