DEVELOPMENT OF MATLAB SIMULINK MODEL OF FUZZY BASED POWER SYSTEM STABILIZER FOR POWER QUALITY

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Abstract: The power system is a dynamic system and it is constantly being subjected to disturbances. It is important that these disturbances do not drive the system to unstable conditions. This paper presents the performance of fuzzy logic based adaptive power system stabilizer (PSS) for stability enhancement of Single Machine Infinite Bus power system. The PSS is used to generate supplementary control signals for the excitation system in order to damp the low frequency power system oscillations. Here speed deviation and accelerated power are the two inputs to the fuzzy logic controller. The inference mechanism of the fuzzy logic controller is represented by 49 if then rules.The performance of the fuzzy logic power system stabilizer (FLPSS) and conventional power system stabilizer was compared. A proposed FLPSS provides a good damping compared to conventional pss over a wide operating range.
Keywords: Power System Stabilizer, Low Frequency Oscillations, Single Machine Infinite Bus System, Fuzzy Sets And Logic

I. INTRODUCTION

The conventional power plants of the 19th century were equipped with continuously acting voltage regulators to improve the transient stability of system. The high gain of these voltage regulators has a destabilizing effect on power system. The power oscillation of small magnitude and high frequency, which often persisted in power system, presents the limitation to the amount of power transmitted within the system. Improved performance has been achieved by adding damping to the system by employing power system stabilizer (PSS).
The conventional Power System Stabilizer (CPSS), a fixed parameters lead-lag compensator, is widely used by power system utilities. The gain settings of these stabilizers are determined based on the linearized model of the power system around a nominal operating point to provide optimal performance at this point. Generally, the power systems are highly non-linear and the operating conditions can very over a wide range. Therefore, CPSS performance is degraded whenever the operating point changes from one to another because of fixed parameters of the stabilizer. The application of a power system stabilizer for improving the stability of power systems has received much attention. Fuzzy control appears to be the most suitable one, due to its robustness and lower computation burden [1]. The fuzzy logic controllers could easily be constructed using a simple micro-computer. The supplementary stabilizing signal is determined using fuzzy membership.

This paper presents a Fuzzy Logic Power System Stabilizer (FLPSS) for the real time non-linear control of generator excitation. Control output signals of the AVR and the fuzzy PSS are given to an exciter unit and will provide sufficient damping torque for synchronous generator unit. Its robustness makes it suitable for interconnected non-linear synchronous generators. For steady state operation, the system with fuzzy logic PSS settles down much faster than system with conventional PSS. [4]
In this Paper, the performance of the Single machine Infinite Bus system with fuzzy power system stabilizer is presented. Here speed deviation and accelerated power are the two inputs to the fuzzy logic controller. Performance is studied for triangular membership functions of fuzzy sets and compared with conventional lead-lag compensator. The simulations are tested under different operating conditions in SIMULINK.

II. SYSTEM MODELLING

The system comprises of synchronous machine, excitation system and power system stabilizer model.
The system model is developed as follows:-

A. Synchronous Machine Model

The generator is represented by second order system with the help of standard K-constant representation. The configuration of synchronous machine connected to infinite bus through transmission network is represented as the Thevenin's equivalent shown in Fig.1.[2]

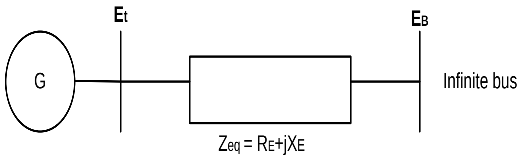

Fig.1: The equivalent of synchronous machine connected to infinite bus.

The equations of governing machine model [2] are:-

$$p\Delta\omega_r = \frac{1}{2H}\left(\Delta T_M - \Delta T_e - K_D\Delta\omega_r\right) \quad (1)$$

$$p\Delta\delta = \omega_0\Delta\omega_r \quad (2)$$

Where,

$$\Delta T_e = K_1\Delta\delta + K_2\Delta\psi_{fd} \quad (3)$$

$$\Delta\psi_{fd} = \frac{K_3}{1+pT_3}\left[\Delta E_{fd} - K_4\Delta\delta\right] \quad (4)$$

Where, Tm and Te are the prime mover input and electrical output torques respectively, H is the inertia constant,δ and ω are rotor angle and speed respectively.

B. Excitation System Model

The thyristor excitation system as shown in Fig. 2 is considered [2]. The nonlinearity associated with the ceilings EFMAX and EFMIN, is ignored for small-disturbance studies.

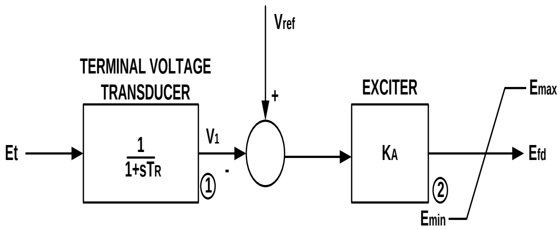

Fig. 2: Thyristor excitation system

The equations governing the exciter model are:-

$$p\Delta v_1 = \frac{1}{T_R}(\Delta E_t - \Delta v_1) \quad (5)$$

$$E_{fd} = K_A(V_{ref} - v_1) \quad (6)$$

$$\Delta E_t = K_5\Delta\delta + K_6\Delta\psi_{fd} \quad (7)$$

C. Power System Stabilizer Model

The PSS is used to provide damping to electromechanical oscillations. The PSS counters the oscillations by forcing the change in excitation level appropriately. Without PSS, the reduced damping in power system is due to phase lags resulted by the field time constants and the phase lags in the normal voltage regulation loop. The PSS uses phase compensation by adjusting the timing of correction signal opposing the rotor oscillations. A power system stabilizer can therefore increase the generator's damping coefficient. The PSS as shown in Fig. 3 has three components, the phase compensation block, the signal washout block and gain block. The phase compensation block provides the appropriate phase lead characteristics to compensate for the phase lag between exciter input and generator electrical torque. 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. The stabilizer gain KSTAB determines the amount of damping introduced by PSS [2].

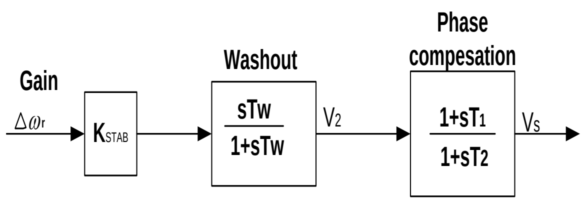

Fig. 3: Conventional lead-lag PSS

For the conventional PSS following transfer functions is considered:

$$\Delta v_2 = \frac{pT_W}{1+pT_W}(K_{STAB}\Delta\omega_r) \quad (8)$$

$$\Delta v_s = \frac{1+pT_1}{1+pT_2}(\Delta v_2) \quad (9)$$

T_w, is the washout filter time constant.

III. FUZZY CONTROLLED POWER SYSTEM STABILIZER

The concept of fuzzy logic given by Zadeh in 1965 has found applications in various areas including a controller for power system stabilizer. The aim of fuzzy control systems is normally to replace a skilled human operator with a fuzzy rule-based system. The fuzzy logic controller provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy. A fuzzy logic system, as shown in Fig. 4, comprises of four stages: a fuzzification interface, a knowledge base, an inference engine and a defuzzification interface. The fuzzification interface is mapping from the crisp domain into the fuzzy domain and converts input data into suitable linguistic values that can be viewed as label fuzzy sets [3] and [5].

Fuzzy sets can be characterized by membership functions. There are many types of membership functions e.g., the bell shaped, linear function, triangular function, trapezoidal function and exponential function

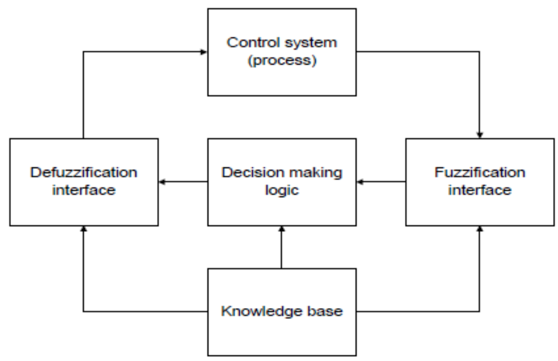

Fig.4. the General Structure of a Fuzzy Logic System

The knowledge base comprises knowledge of application domain and attendant control goals by means of set of linguistic control rules. The inference engine determines the operating condition from the measured values and selects the appropriate controlactions using the rule base created from the expertknowledge. The defuzzification inference performs scale mapping, which converts the range of values of output variables into corresponding universe of discourse and also converts the inferred decision from the linguistic variables back the numerical values. Choosing the proper linguistic variables formulating the fuzzy control rules are very important factors in the performance of the fuzzy control system. Here the speed deviation (Δω) and acceleration (ΔP) are chosen to be the input signals of fuzzy PSS. The linguistic variables transform the numerical values of the input of the fuzzy controller to fuzzy quantities. The number of these linguistic variables specifies the quality of the control which can be achieved using the fuzzy controller. For the power system under study, seven linguistic variables for each of the input and output variables are used to describe them as shown below in Table 1.

NB	NEGATIVE BIG
NM	NEGATIVE MEDIUM
NS	NEGATIVE SMALL
ZE	ZERO
PS	POSITIVE SMALL
PM	POSITIVE MEDIUM
PB	POSITIVE BIG

Table.1: Input and output linguistic variables

The two inputs: speed deviation and acceleration, result in 49 rules for each machine.

The typical rules are having the following structure:

Rule 1**:** If speed deviation is NM (negative medium) AND acceleration is PS (positive small) then voltage (output of fuzzy PSS) is NS (negative small).

Rule 2**:** If speed deviation is NB (negative big) AND acceleration is NB (negative big) then voltage (output of fuzzy PSS) is NB (negative big).

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

Table 2: Rules for Fuzzy PSS

After replacing the conventional PSS block by fuzzy controller block, the representation of fuzzy logic controller implemented on single machine infinite bus system.

IV. SIMULATION RESULTS

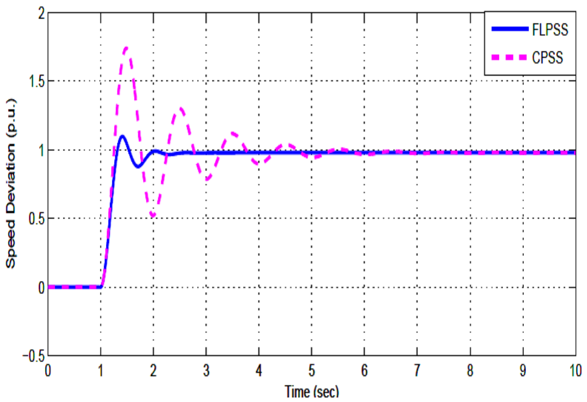

Fig.5.Comparison of angular speed between CPSS and FLPSS

In order to assess the PSS performance and robustness under wide range of operating conditions with various fault disturbances and fault clearing sequences, the test system depicted below is considered for analysis. The overall features of the proposed controllers are described based on a SMIB Model of power system.

As shown in results with fuzzy logic based PSS (FLPSS), the variation in angular speed reduces to zero in about 2 to 3 seconds but with conventional

PSS (CPSS), it takes about 6 seconds to reach to the final steady state value and also the oscillations are less pronounced in FLPSS.

V. CONCLUSION

In this paper the fuzzy logic based adaptive power system stabilizer is introduced. Simulation result shows that for different operating conditions, the fuzzy logic power system stabilizer (FLPSS) has increased the damping of the system causing it to settle back to steady state in much less time than the conventional power system stabilizer (CPSS) and it also decreases the peak value. The FLPSS, though rather basic in its control proves that it is indeed a good controller due to its simplicity. This paper show that the fuzzy logic pss given better performance then conventional power system stabilizer.

REFERENCES

[1] S. A. Taher and A. Shemshadi, “Design of Robust Fuzzy Logic Power System Stabilizer”, World Academy of Science, Engineering and Technology -27, 2007, pp. 8-14

[2] P. Kundur. “Power System Control and Stability”, New York: McGraw- Hill, Inc., 1994

[3] L. A. Zadeh, "Fuzzy Sets, Information and Control”, Vol. 8, 1965, pp. 338-353.

[4] KamaleshChandra Routand Dr.P.C.Panda, “An Adaptive Fuzzy Logic Based Power System Stabilizer for Enhancement of Power System Stability”, 2010 International Conference on Industrial Electronics, Control and Robotics.

[5] D. H. Patel and A. M. Upadhyay, “Modelling and Simulation of Power System Stabilizer using Fuzzy Logic”, International Journal for Scientific Research & Development Vol. 3, Issue 08, 2015

APPENDIX

Synchronous machine parameters:

x_d= 2.64 pu, x'_d= 0.28 pu,

x_q= 1.32 pu, x'_q= 0.29 pu,

R_E= 0.004 pu, X_E= 0.73 pu

f= 60 Hz, H= 4.5 sec

Excitation system constants:

K_A= 100, T_A= 0.05, T_R= 0.015

E_{FMAX}= 5.0, E_{FMIN}= -5.0

PSS constants:

K_{STAB}= 20, T_w= 1.4 sec

T_1= 0.154 sec, T_2= 0.033 sec

V_{SMAX}= 0.2, V_{SMIN}= -0.2

