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Comparative study on Angular Position and Angular Speed in 36 Rules of Fuzzy Logic Based PSS for SMIB Model of Power System

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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. For this purpose, additional signal derived from deviations, excitation deviation, and accelerating power are injected into voltage regulators. The device to provide these signals a referred as power system stabilizer. The use of power system stabilizer has become very common in operation of large electric power systems. The conventional PSS which uses lead-lag compensation, where gain setting 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 point of electric power systems. In an attempt to cover a wide range of operating conditions, Fuzzy logic control has been suggested among various soft computing techniques like Artificial Neural Network (ANN), Genetic Algorithm (GA),Particle Swarm Optimization(PSO).*

Key Words: **Generator Excitation System, Synchronous Machine Model, Power System Stabilizer Model. Fuzzy Logic Controller**

1. INTRODUCTION

Power system stability is the tendency of a power system to develop restoring forces equal to or greater than the disturbing forces to maintain the state of equilibrium. Since power systems rely on synchronous machines for generation of electrical power, a necessary condition for satisfactory system operation is that all synchronous machines remain in synchronism.

This aspect of stability is influenced by the dynamics of generator rotor angles and power-angle relationships. The power system is a dynamic system [1][2]. The electrical power systems today are no longer operated as isolated systems, but as interconnected systems which may include thousands of electric elements and be spread over vast geographical areas. In order to get stability of a power system many researchers have come with their new innovative techniques ;but here we can use Fuzzy Logic Controller concept with Single machine infinite bus model of a power system It is important that these disturbances do not drive the system to unstable conditions. For this purpose, additional signal derived from deviations, excitation deviation, and accelerating power are injected into voltage regulators. The device to provide these signals a referred as power system stabilizer. The use of power system stabilizer has become very common in operation of large electric power systems. The Fuzzy Logic based power system stabilizer (FLPSS) damps the low frequency oscillations in the shaft speed of a synchronous machine. Since the design is on the basis of a block diagram of the system derived for a specific operating point, the FLPSS has the best response for operating point.

2. SMIB MODEL

The performance of a synchronous machine connected to a large system through transmission lines which is vital for power system operation.

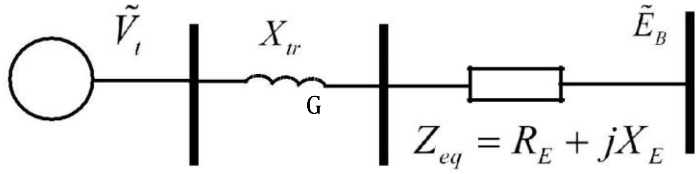


Fig -1: Equivalent Circuit of SMIB

The general system configuration of synchronous machine connected to infinite bus through transmission network can be represented as the Thevenin's equivalent circuit. At first the synchronous machine will be represented by the classical model. Then, the model details will be increased to account for the effects of the dynamics of the field circuit and the excitation system which is shown as Fig-1.

3. POWER SYSTEM STABILIZER MODEL

The basic function of a PSS is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signal. To provide damping, the stabilizer must produce a component of electrical torque in phase with the rotor speed deviation [3].

For the simplicity a conventional PSS is modeled by two stage (identical), lead/lag network which is represented by a gain K_{STAB} and two time constants T_1 and T_2.

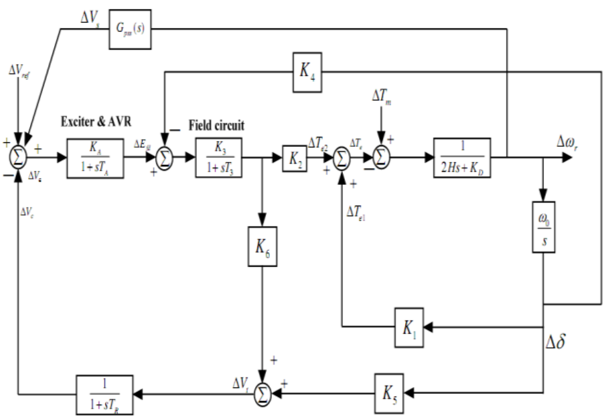


Fig -2: Block Diagram of PSS

The purpose of a PSS is to introduce a damping torque component, a logical signal to use as the input of PSS is $\Delta\dot{\omega}_r$. If the exciter transfer function and the generator transfer function between ΔE_{fd} and ΔT_e were pure gains, a direct feedback of $\Delta\dot{\omega}_r$ would result in a damping torque component[4][5]. However, both transfer functions between ΔE_{fd} and ΔT_e exhibit frequency dependent gain and phase characteristics.

The overall transfer function with PSS from above block diagram from figure 2 is :

$$G(s) = \frac{G1(s)G2(s)}{1+G1(s)G2(s)H1(S)H2(S)}$$

And

$$G1\,(j\omega) = \frac{G(j\omega)}{1-G(j\omega)Gp(j\omega)}$$

It is important that these disturbances do not drive the system to unstable conditions. For this purpose, additional signal derived from deviations, excitation deviation, and accelerating power are injected into voltage regulators. The device to provide these signals a referred as power system stabilizer. The use of power system stabilizer has become very common in operation of large electric power systems. The power system stabilizer (PSS) damps the low frequency oscillations in the shaft speed of a synchronous machine. Since the design is on the basis of a block diagram of the system derived for a specific operating point, the PSS has the best response for operating point.

4. FUZZY LOGIC BASED PSS MODEL

The fuzzy logic controller (FLC) design consists of the following steps.

(i) Identification of input and output variables

(ii)Construction of control rules.

(iii)Establishing the approach for describing system state in terms of fuzzy sets, i.e. establishing fuzzification method and fuzzy membership functions.

(iv)Selection of the compositional rule of inference.

(v)Defuzzification method, i.e., transformation of the fuzzy control statement into specific control actions.

The above steps are explained with reference to fuzzy logic based power system stabilizer in the following section. Thus the below Table 1 shows that 36 fuzzy rule base of fuzzy logic controller.

Table (1): Rule base of fuzzy logic controller

Speed Deviation \ acceleration	NB	NM	NS	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS
NM	NB	NM	NM	NS	NS	ZE
NS	NM	NM	NS	ZE	ZE	PS
PS	NS	ZE	ZE	PS	PM	PM
PM	ZE	PS	PS	PM	PM	PB
PB	PS	PM	PM	PB	PB	PB

5. SIMULINK MODEL OF FUZZY LOGIC PSS

Matlab is a high-performance programming language used for technical application. It supports different toolboxes for engineering computation & interfaces. Simulink is a block diagram environment for multi domain simulation and Model-Based Design[6].

The dynamic characteristics of the system are expressed in terms of the so-called K - constants. The negative values of K – constants (-K5) calculated by using below parameters are K1=0.7636, K2=0.8644, K3=0.3231, K4=1.4189, K5= -0.1463, K6=0.4163 and Ka=100 for figure 3.1.

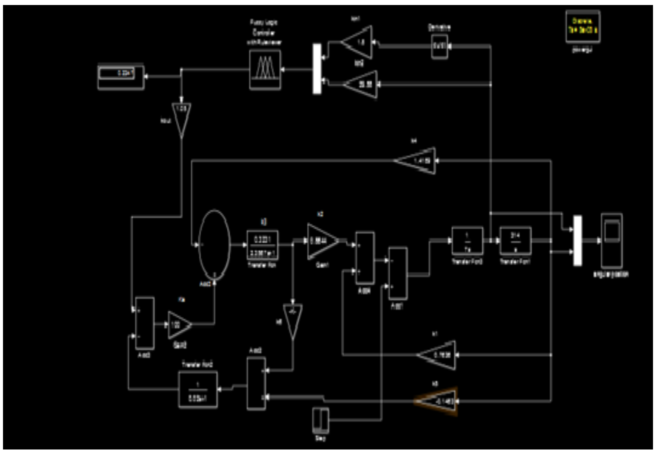
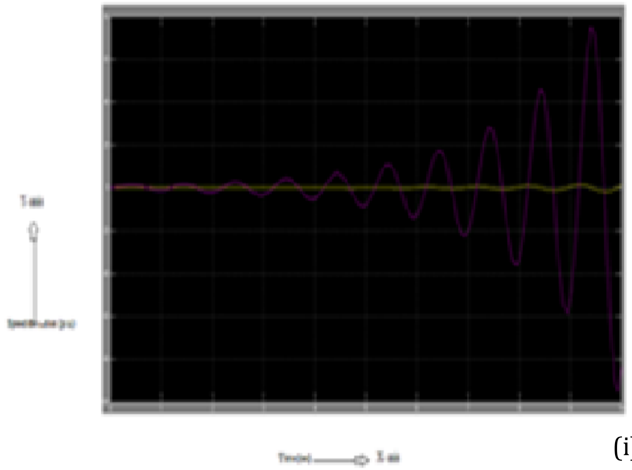


Fig -3.1: Performance of FLPSS with (- K5)



(i)

Fig -3.2: Waveform of FLPSS with (- K5)

The dynamic characteristics of the system are expressed in terms of the so-called K - constants. The positive values of K – constants (+K5) calculated by using below parameters are K1=0.7636, K2=0.8644, K3=0.3231, K4=1.4189, K5= 0.1463, K6=0.4163 and Ka=100 for figure 3.3.

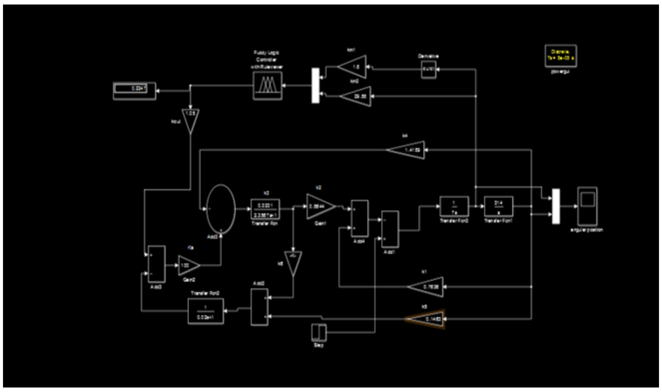


Fig -3.3: Performance of FLPSS with (+ K5)

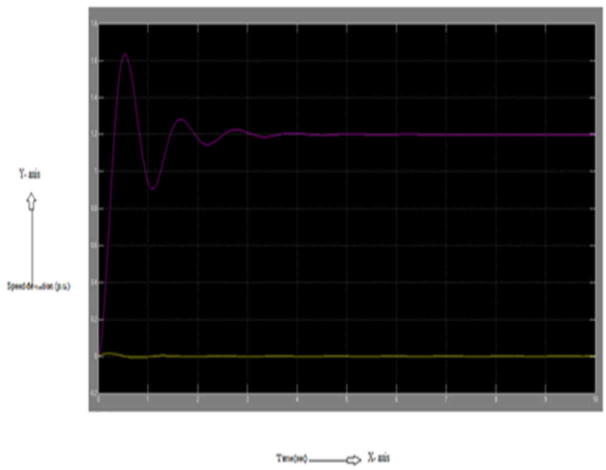


Fig -3.2: Waveform of FLPSS with (+K5)

6. COMPARATIVE STYDY OF FLPSS WITH ANN, GA, PSO BASED PSS

Comparison of results of FLPSS for angular position- For ANN, GA & PSO techniques the negative value of k5 the variation of settling time of angular speed of PSS are oscillatory. But for negative value of K5 the variation of settling time of angular speed of FLPSS takes 0.1 sec to reach its final steady state Value.

Similarly for positive value of K5 the variation of settling time of angular speed of FLPSS takes 3.6 sec to reach its final steady state value.

Comparison of results of FLPSS for angular speed- For ANN, GA & PSO techniques the negative value of k5 the variation of settling time of angular speed of PSS are oscillatory. But for negative value of K5 the variation of settling time of angular speed of FLPSS takes 1.2 sec to reach its final steady state Value.

Similarly for positive value of K5 the variation of settling time of angular speed of FLPSS takes 0.6 sec to reach its final steady state value.

From above it can be concluded that oscillations in angular position and angular speed reduces much faster with fuzzy logic power system stabilizer than other power system stabilizer for both the cases i.e. when k5 positive and negative. Therefore, it can infer that the fuzzy controller does not require any complex mathematical support and the response is much improved than conventional power system stabilizer.

7. CONCLUSION

As power system is a highly complex system and the system equations are nonlinear as the parameters vary due to noise and load fluctuation, the Fuzzy based Sliding Mode Control based Power System Stabilizer enhances the stability of the system and improves the dynamic response of the system operating in faulty conditions in a better way and it has also effectively enhanced the damping of electromechanical oscillations. According to non-linear simulation results of a multi-machine power system, it is found that the Fuzzy based Sliding Mode Controller work well and is robust to change in parameters of the system and to disturbance acting on the system and also indicate that the proposed Fuzzy logic controller based (FLPSS) can be extended to multi machine interconnected system having non linear loads & as compare to ANN ,GA & PSO FLPSS with frequency as input parameter can be investigated.

BIOGRAPHIES

Himanshu Shekhar Maharana completed his B. Tech degree in EEE from JITM, Paralakemundi under BPUT Rourkela, Odisha in 2010 and Completed M. Tech degree in Power System Engineering from GITA, Bhubaneswar under BPUT, Rourkela,, Odisha in the year 2014. Prior to it he worked in industry and then worked as an Asst. Professor in the Dept. of Electrical Engineering at Einstein Academy Of Technology & Management, Bhubaneswar for 4 years. Now he is working as an Asst. Professor in the Dept. of EEE at Gandhi Institute Of Excellent Technocrats (GIET), Ghangapatna, and Bhubaneswar. At present he is continuing full time Ph.D. under the guidance of professor Dr. Saroj Kumar Dash in BPUT, Rourkela, Odisha.

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