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IMPROVEMENT OF DYNAMIC STABILITY OF A POWER SYSTEM BASED ON 36 RULES OF FUZZY LOGIC BASED POWER SYSTEM STABILIZER

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ABSTRACT

Power systems are subjected to low frequency disturbances that might cause loss of synchronism and an eventual breakdown of entire system. 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. The device to provide these signals is 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, gives 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) etc.This fuzzy logic control is used as a possible solution to overcome this problem, thereby using linguistic information and avoiding a complex system mathematical model, while giving good performance under different operating conditions.

KEY WORDS: PSS-Power system stabilizer. GA-Genetic algorithm. FLPSS-Fuzzy logic based Power system stabilizer,Artificial Neural Network (ANN)

1. INTRODUCTION

Fuzzy logic is one of the most vital tools for solving complex nonlinear problems in electric power system subjected to valve point loading. Most of these applications are in the field of excitation control of power system devices. Basically for the power system stabilizers it finds immense importance. From ancient to recent power system stabilizers it is found that fuzzy logic based power system stabilizer (FLPSS) requires less computational time in comparison to conventional ones. Robustness[15] is more in comparison to conventional stabilizers. This paper basically focuses on fuzzy concepts at the beginning, merits and demerits of conventional stabilizer and importance of FLPSS

Over conventional stabilizer .In this dissertation better simulated performances are obtained as illustrated in Fig.3 and Fig.5.The dynamic characteristics of FLPSS are expressed in terms of so called K constants enumerated out of the Simulink model. The selection of triangular membership function for FLPSS proves beneficial solving nonlinear problem to a great extent. Variable excursions for membership functions give rise to smooth variation of angular position and settling time for FLPSS.

2. METHODOLOGY FOR FUZZY LOGIC BASED POWER SYSTEM STABILIZER

The power system stabilizer is used to improve the performance of synchronous generator. However, it results into poor performance under various loading conditions when implemented with conventional power system stabilizer (PSS)[1][2]. Therefore, the need for fuzzy logic PSS(FLPSS) arises. The fuzzy controller used in power system stabilizer is normally a two-input and a single-output component. It is usually a multi input single output (MISO)system[12][14]. The two inputs are change in angular speed and rate of change of angular speed whereas output of fuzzy logic controller is a voltage signal. A modification of feedback voltage to excitation system as a function of accelerating power on a unit is used to enhance the stability of the system.

2.1 Identification of input & output variables

Define input and control variables, i.e. determine which states of the process should be observed and which control actions are to be considered. For FLPSS design, generator speed deviation and acceleration can be observed and have been chosen as the input signal of the fuzzy PSS. The dynamic performance[6][7][8][9] of the system could be evaluated by examining the response curve of these two variables. The voltage is taken as the output from the fuzzy controller.

After choosing proper variables as input and output of fuzzy controller, it is required to decide on the linguistic variables. These variables transform the numerical values of the input of the fuzzy controller to fuzzy quantities. The number of linguistic variables describing the fuzzy subsets of a variable varies according to the application.

2.1.1Construction of control rules

According to the construction of rules all the 36 rules governing the mechanism between CPSS and FLPSS[3][5] results are explained.

2.1.2 Membership function

The variables chosen for this controller are speed deviation, acceleration and voltage. Inthis , speed deviation and acceleration are the input variables and voltage is the output variable. The number of linguistic variables describing the fuzzy subsets of a variable varies according to the application. Each linguistic variable has its fuzzy membership function. The membership function maps the crisp values into fuzzy variables. The triangular membership functions are used to define the degree of membership. It is important to note that the degree of membership plays an important role in designing a fuzzy controller.

Each of the input and output fuzzy variables is assigned six linguistic fuzzy subsets varying negative big (NB) to positive big (PB). Each subset is associated with a triangular membership function to form a set of six membership functions for each fuzzy variable. Table (1) shows the Membership functions for fuzzy variables. The membership function maps[13] the crisp values into fuzzy variables.(For output voltage).

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

Table (1) Membership functions for fuzzy variables

In this paper we employ 36 rules it means that the input and output fuzzy variables is assigned six linguistic fuzzy subsets varying negative big (NB) to positive big (PB) without Zero (ZE). Each subset is associated with a triangular membership function to form a set of six membership functions for each fuzzy variable.

Therefore,table (2) shows the Membership functions for fuzzy variables. The membership function maps the crisp values into fuzzy variables. (For inputspeed deviation and acceleration).

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

Table (2) Membership functions for fuzzy variable

The membership function for acceleration, speed deviation and voltage are shown as below.

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

Table (3): Rule base of fuzzy logic controller

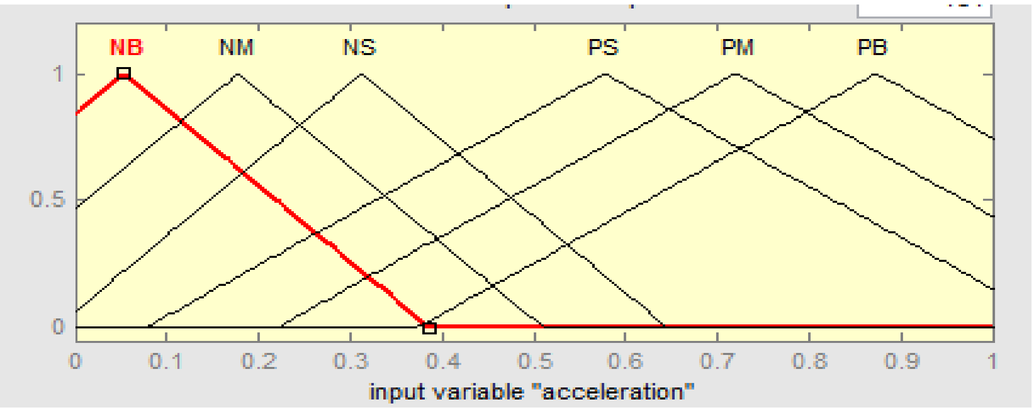

Figure 1(a) Membership function for acceleration

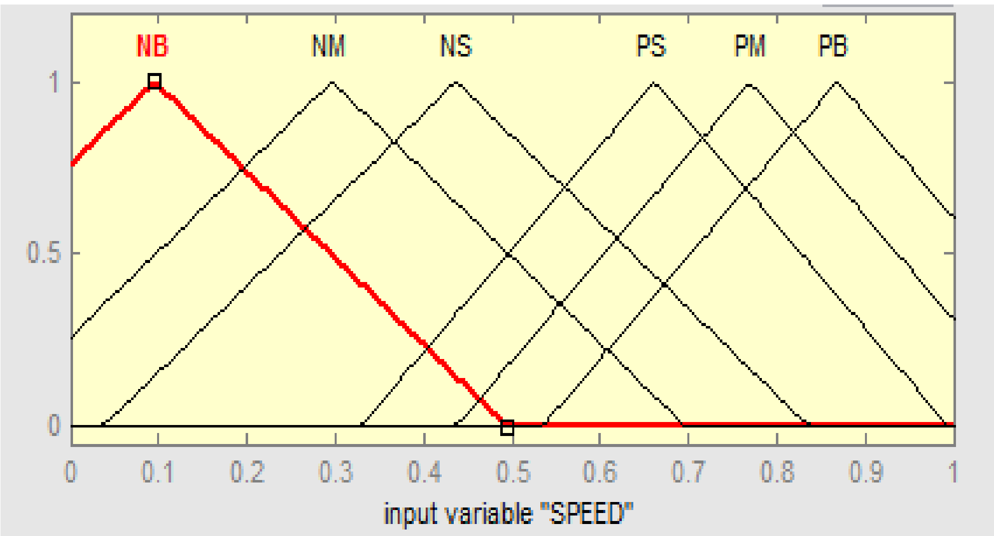

Figure 1(b) Membership function for speed deviation

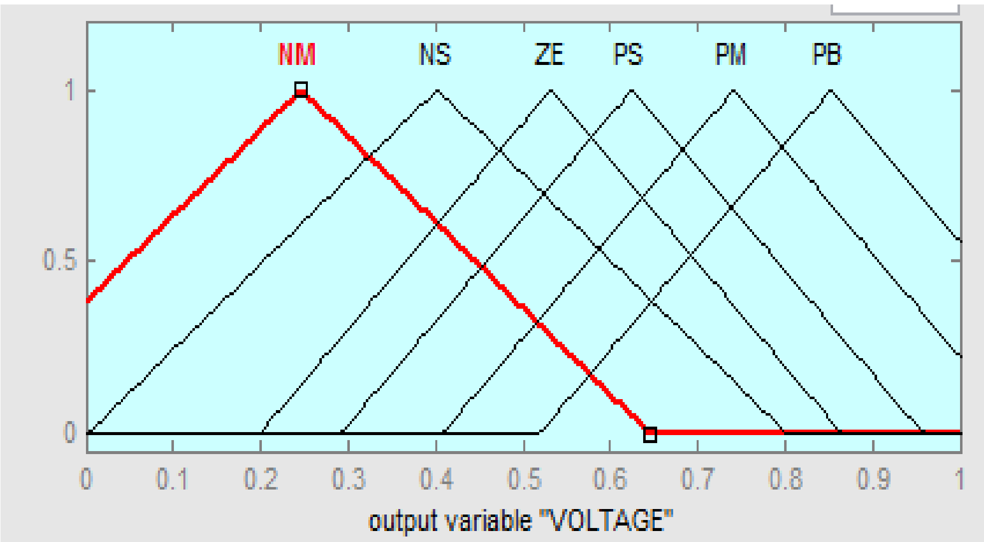

Figure 1(c) Membership function for voltage

Selection of the compositional rule of inference; The variables are normalized by multiplying with respective gain K_e, K_{ce}, K_0 so that their values lie between -1 and +1.Knowledge base involves defining the rules represented as IF - THEN rules statements governing the relationship between input and output variables in terms of membership functions. In this stage the input variables speed deviation and acceleration are processed by the inference engine that executes 36 rules represented in rule Table (3).

Fuzzy Rule Base (36 rules) is explained to show the result of Comparison between conventional power system stabilizer (CPSS) and FLPSS.A set of rules which define the relation between the input and output of fuzzy controller can be found out using the available knowledge in the area of designing PSS. These rules are defined using the linguistic variables. The two inputs, speed and acceleration, result in 36 rules for each machine.

Simulink Model of Fuzzy logic based Power System Stabilizer:

Fuzzy logic based PSS is faster in case of settling time of angular position and angular speed as compared to conventional PSS which is shown as below.

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2.1.3. Performance of Conventional PSS (lead-lag) (- K5):

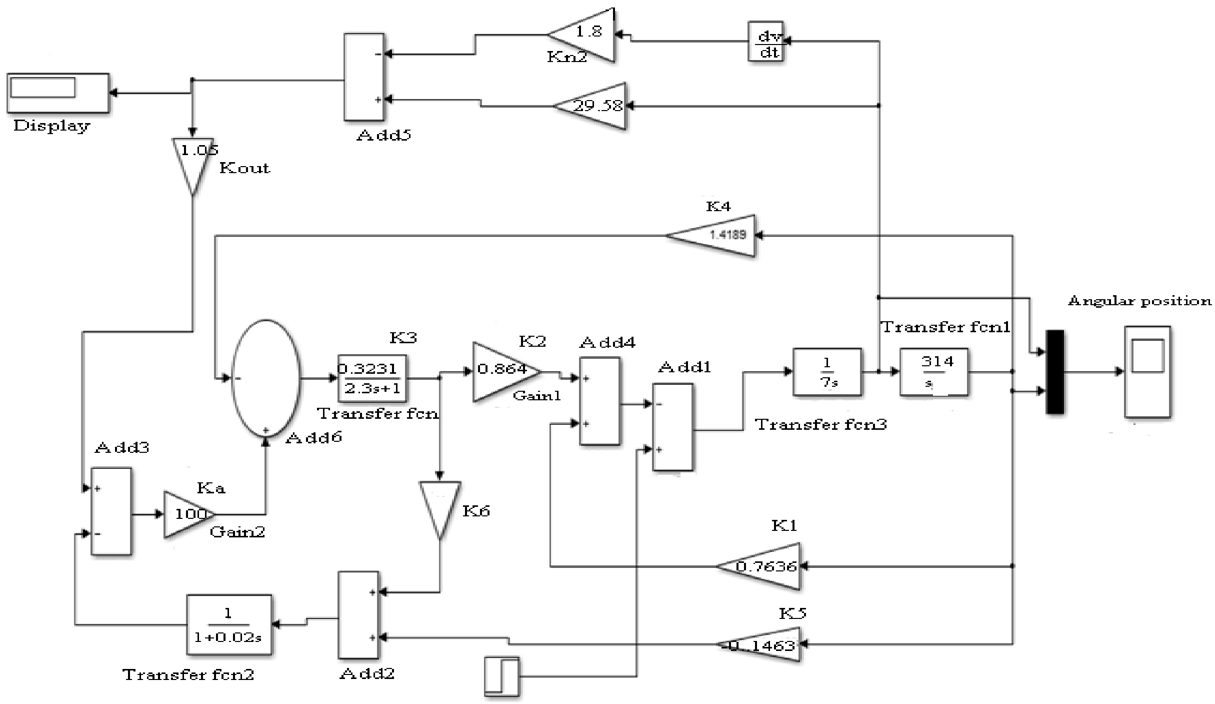

Fig.2 Performance of Conventional PSS (lead-lag) (- k5)

In the model presented above in Fig.2, the dynamic characteristics of the system are expressed in terms of the so-called K - constants. The values of K - constants calculated using above parameters are K1=0.7636, K2=0.8644, K3=0.3231, K4=1.4189, K5= - 0.1463, K6=0.4163 and Ka=100.

Waveform of Conventional PSS (lead-lag) (- K5):

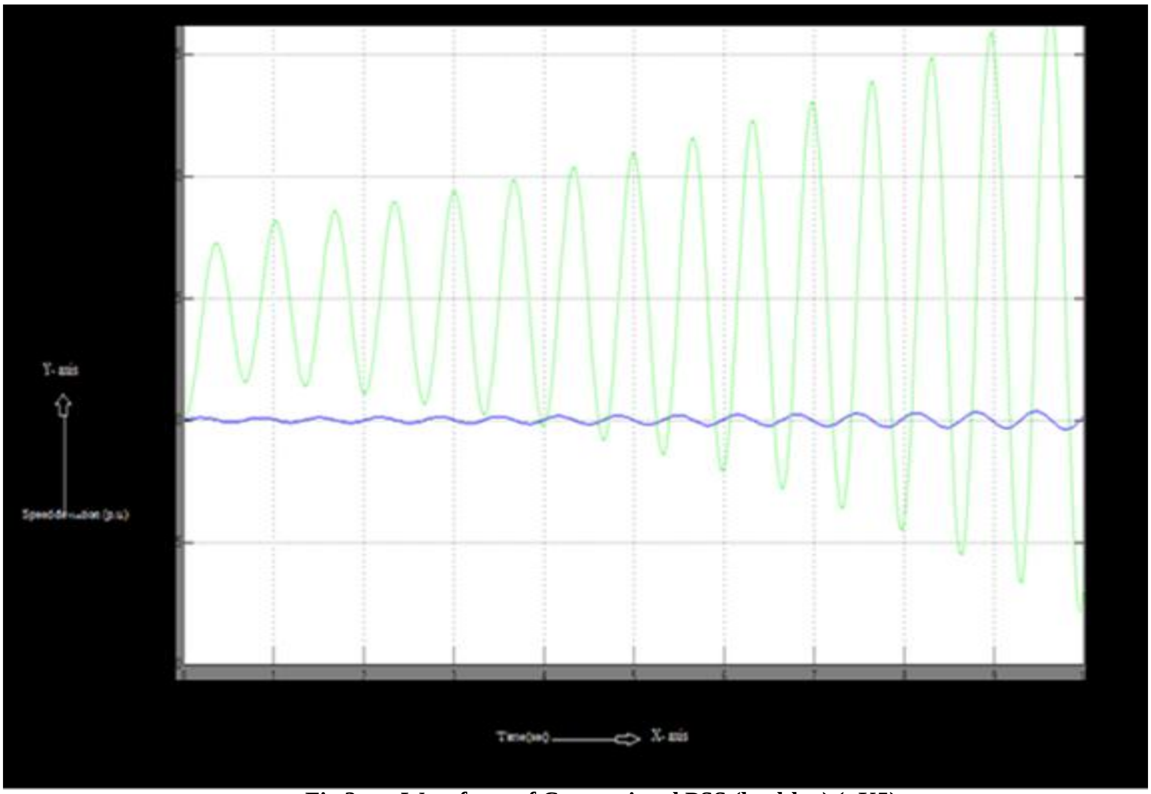

Fig.3 Waveform of Conventional PSS (lead-lag) (- K5)

Fig.3 shows the variation of settling time in angular position and angular speed of Conventional PSS (CPSS)

<u>Performance of Conventional PSS (lead-lag) (+ k5)</u>:

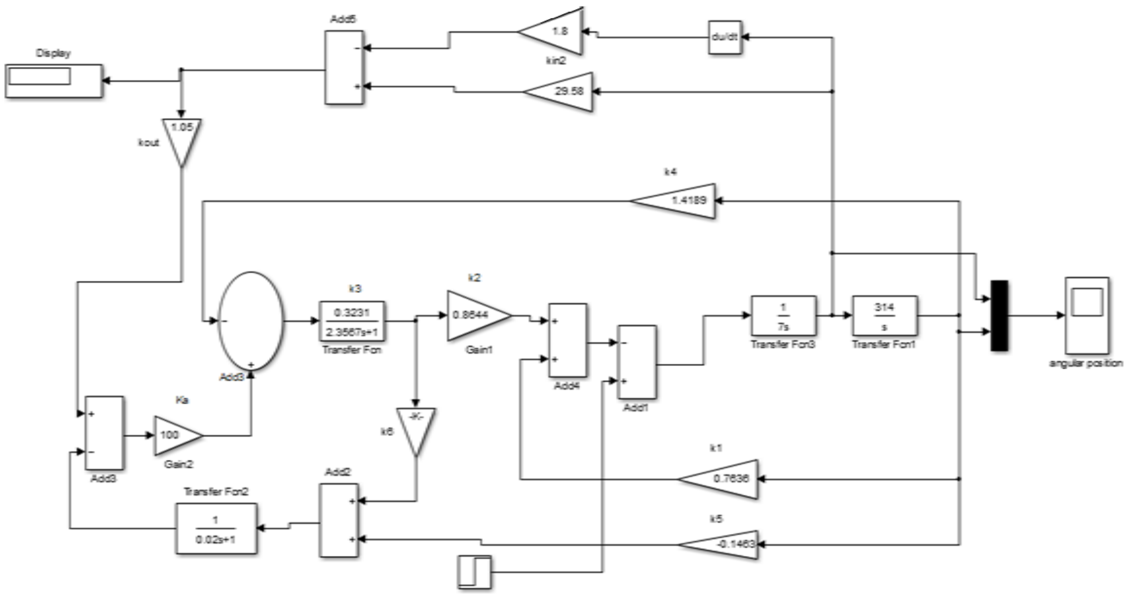

Fig.4.1 Performance of Conventional PSS (lead-lag) (+ K5)

In the model shown in Fig.4.1, the dynamic characteristics of the system are expressed in terms of the so-called K - constants. The values of K - constants calculated using above parameters are K1=0.7636, K2=0.8644, K3=0.3231, K4=1.4189, K5= 0.1463, K6=0.4163 and Ka=100.

4.2 <u>Waveform of Conventional PSS (lead-lag) (+ K5)</u>

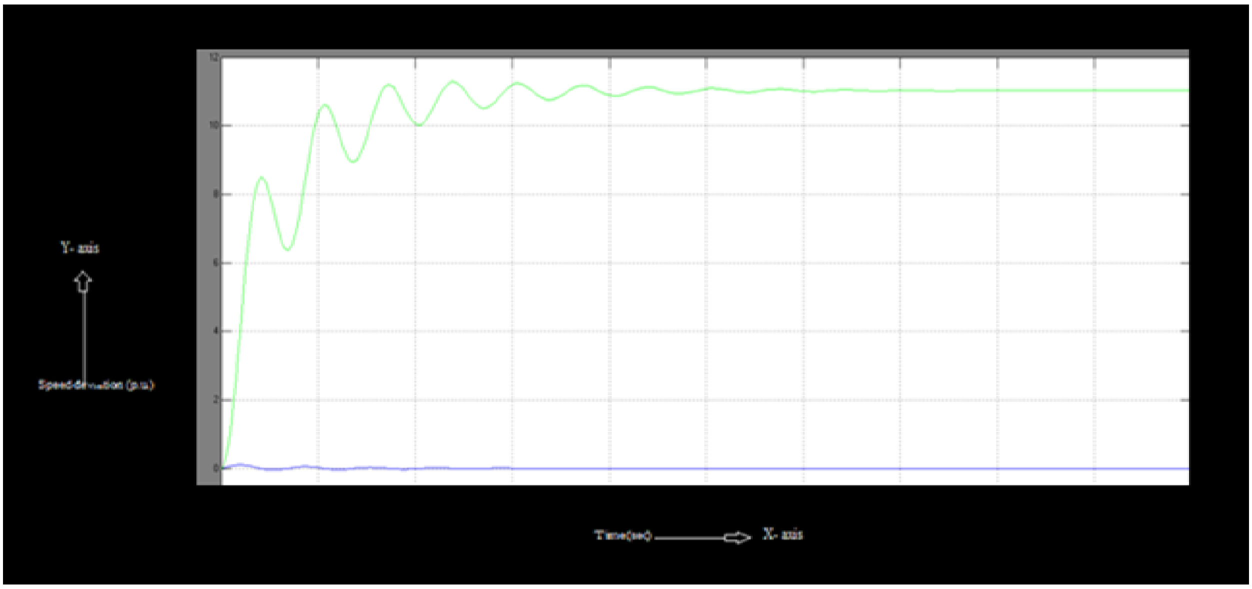

Fig.4.2 Waveform of Conventional PSS (lead-lag) (+ K5)

Fig.4.2 shows that the variation of settling time in angular position of CPSS takes 7.7 seconds to reach to final steady state value and angular speed of CPSS takes 3.0 seconds to reach its final steady state value.

3. PERFORMANCE OF FUZZY LOGIC BASED PSS (- K5)

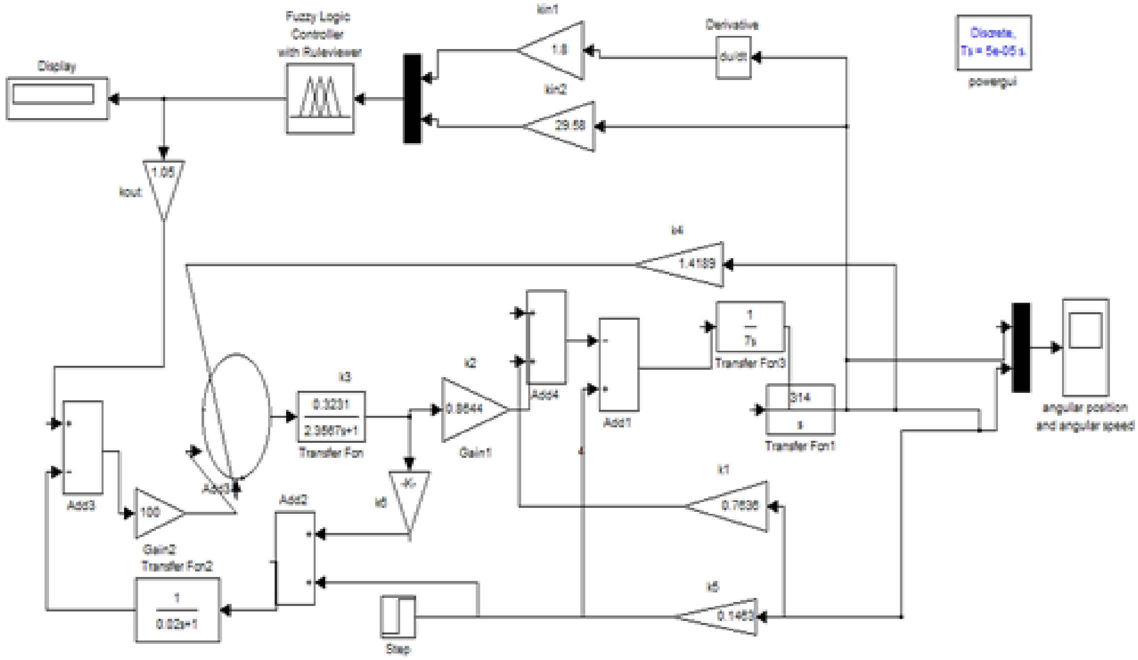

Fig.5 Performance of FLPSS with (- K5)

Fig.5 describes the dynamic characteristics of the system expressed in terms of the so-called K - constants. The values ofK - constants calculated using above parameters are K1=0.7636, K2=0.8644, K3=0.3231, K4=1.4189, K5= - 0.1463, K6=0.4163 and Ka=100.

4. WAVEFORM OF FUZZY LOGIC BASED PSS (- K5)

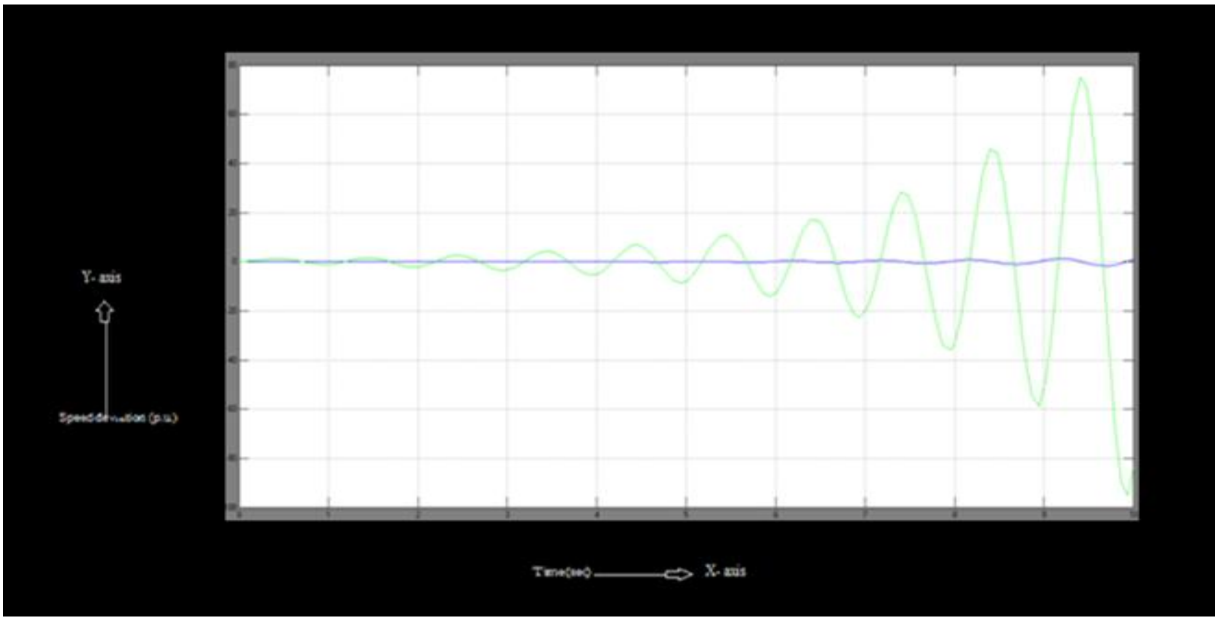

Fig.6 Waveform of FLPSS with (- K5)

Fig.6 shows the variation of settling time in angular position of FLPSS which takes 0.1 sec to reach to final steady state value and angular speed of FLPSS that takes 0.2 sec to reach its final steady state value.

4.1 Performance of Fuzzy logic based PSS (+ K5)

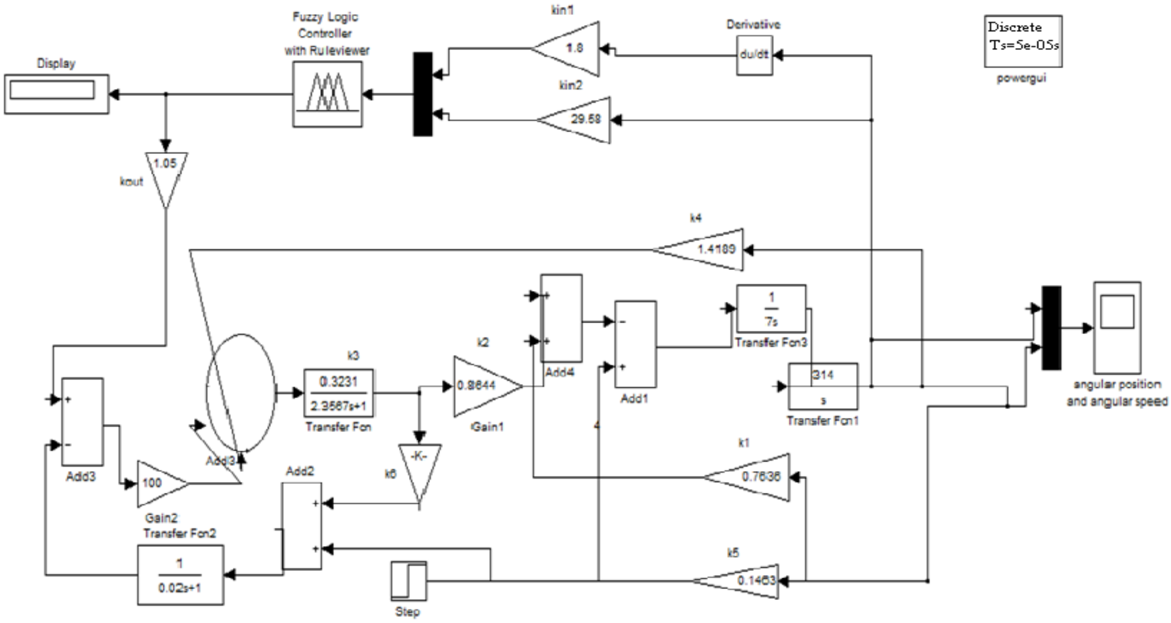

Fig.7 Performance of FLPSS with (+ K5)

In this presentation, the dynamic characteristics of the system are expressed in terms of the so-called K - constants. The values of K - constants calculated using above parameters are K1=0.7636, K2=0.8644, K3=0.3231, k4=1.4189, K5= 0.1463, K6=0.4163 and Ka=100.Fig.7 illustrates the Simulink model for FLPSS.

4.2 Waveform of Fuzzy logic based PSS (+ K5)

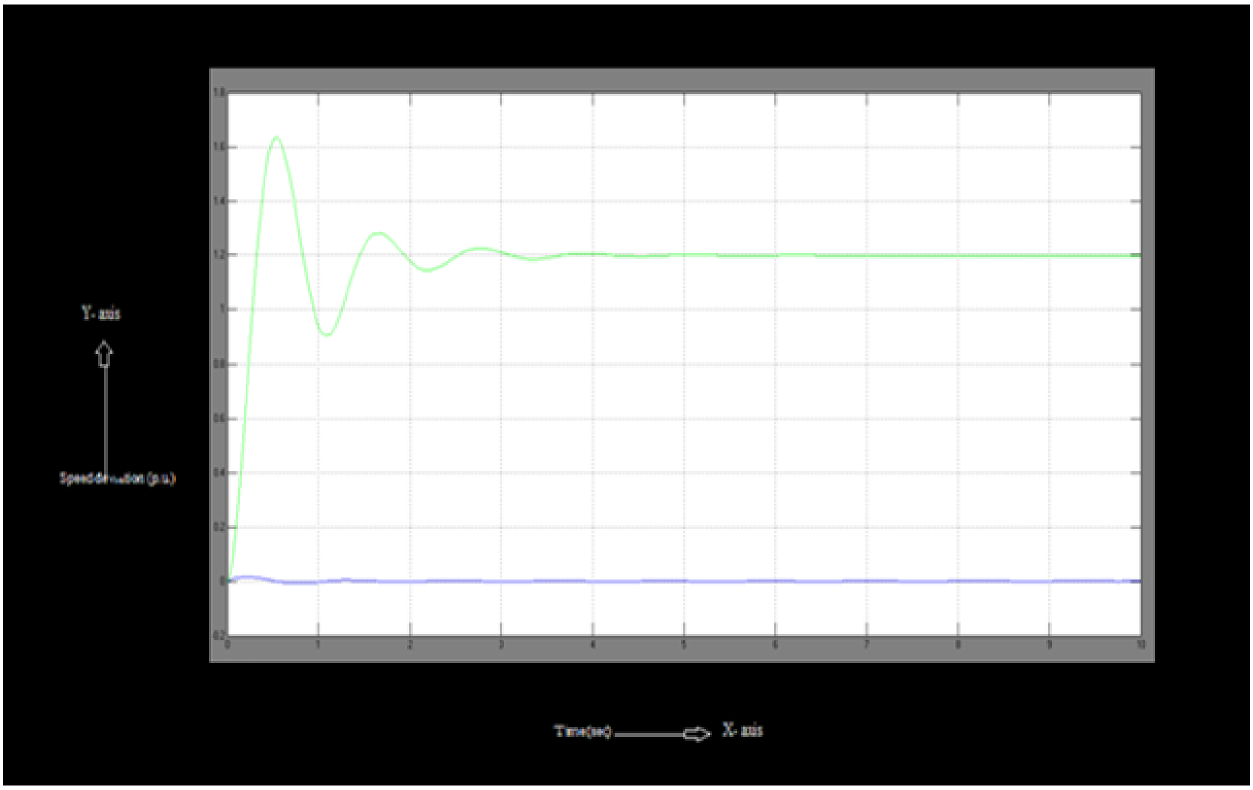

Fig.8 Waveform of FLPSS with (+K5)

Fig.8 shows that the variation or settling time in angular position of FLPSS takes 3.6 seconds to reach to final steady state [5]value and angular speed of FLPSS takes 0.6 sec to reach its final steady state value.

5. COMPARASION OF RESULTS BETWEEN CONVENTIONAL POWER SYSTEM STABILIZER AND FUZZY LOGIC BASED POWER SYSTEM STABILIZER

Comparison of results between CPSS and FLPSS for angular position

Angular Position of CPSS	Angular Position of FLPSS
i. For negative value of k5 the variation of settling time in angular position of Conventional PSS (CPSS) is oscillatory.	i. For negative value of k5 the variation of settling time in angular position of FLPSS takes 0.1 secto reach final steady state value.
ii. For positive value of k5 the variation of settling time in angular position of CPSS takes 7.7 sec to reach final steady state value.	ii. For positive value of k5 the variation of settling time in angular position of FLPSS takes 3.6 sec to reach the final steady state value.

5.1 Comparison of results between CPSS and FLPSS for angular speed

Angular speed of CPSS	Angular speed of FLPSS
i. For negative value of k5 the variation of settling time of angular speed of CPSS is oscillatory.	i. 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.
ii. For positive value of k5 the variation of settling time of angular speed of CPSS takes 3.0 sec to reach its final steady state value.	ii.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.

6. CONCLUSION

This paper workson the effectiveness of power system stabilizer .Then the fuzzy logic based power system stabilizer is introduced by taking speed deviation and acceleration of synchronous generator as the input signals to the fuzzy controller and voltage as the output signal.FLPSS[11] shows the better control performance than power system stabilizer in terms of settling time and damping effect. Therefore, it can be concluded that the performance of FLPSS is better than CPSS. However, the performance of FLPSS with triangular membership function is superior compared to the other membership functions.

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