Augmentation of Power System Stability through Fuzzy Logic Power System Stabilizer & It's Analysis Using Various Membership Functions

[1]Dheeraj Kumar Rai, [2]Manish Kumar Verma and [3]Kananbala Devi Kharibam

Department of Electrical Engineering
IET-Alwar
Rajasthan Technical University-KOTA

[1]dheeraj927@yahoo.co.in, {[2]ee.manishverma and [3]abemkh}@gmail.com

Dr. Praduman Kumar Dwivedi

Department of Computer Science
IET-Alwar
Rajasthan Technical University-KOTA

drpkdwivedi@yahoo.co.in

Abstract- **Power System suffers from the small frequency problems which, finally results to make the system unstable and produces oscillations in smallfrequency range. These oscillations restrict the transmission power capacity of the system. Hence, power system stabilizers (PSSs) are used to provide additional control signals. In a large electric power system, the power stabilizer with lead-lag compensation is used for the excitation system. It provides additional control signals in order to damp these small frequency problems.In conventional power system stabilizers gain settings are designed for a particular loading condition. Under varying loading conditions of the power system, it is very difficult to design conventional power system stabilizers (CPSSs). To reduce the demerits of CPSSs we canimplement many methods such as fuzzy logic, genetic algorithm, neural network etc.Here fuzzy logic based techniques are preferred as a solution to overcome the problems of various loading conditions. Using this technique we have avoided complex mathematical model. In this paper, we have used fuzzy logic controller (FLPSSs) for various membership functions by using mamdani method. For this, we have made the model of power system with its excitation & AVR by observing the generator rotor angles with reference to various loading conditions. Here we have been used mamdani method of fuzzy logic technique because, it is intuitive, well suited to human input and has widespread acceptance. The results are better and encouraging for those power systems where regular variations of loading conditions persist. The performance of FLPSS with triangular membership function is superior to other membership functions.**

Keywords – Synchronous Generator, Fuzzy Logic Controller (FLC), CPSS, FLPSS, AVR

I. INTRODUCTION

There is always an essential requirement of making electrical energy generation and transmission. The voltage throughout the power system controlled within ± 5 % of their rated values by automatic voltage regulators (AVRs) acting on the generator field exciters, and by the sources of reactive power in the network. For proper operations, this large integrated system requires a stable operating condition. The power system is a dynamic system & constantly being subjected to small disturbances, which cause the generators relative angles to change.

II. POWER SYSTEM STABILIZER (PSS) MODEL

Adding damp to the generator rotor oscillations through controlling its excitation system by auxiliary stabilizing signal (s), is the basic function of power system stabilizer. Component of electrical torque must be produced by the stabilizerto provide damping in which component is in phase with the rotor speed deviation [11].It is well known that fast acting exciters with high gain AVR can contribute to oscillatory instability in power system.

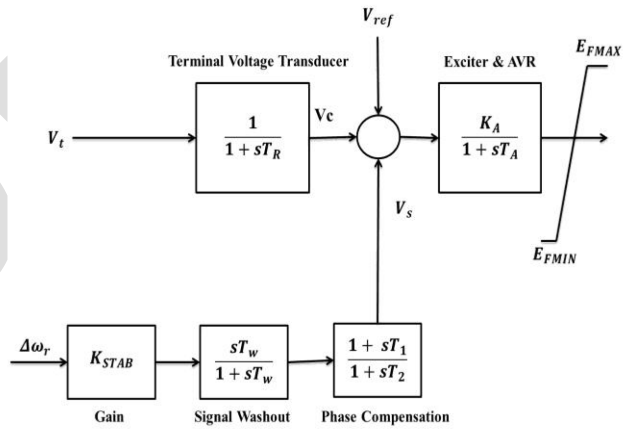


Fig 2.1 Block diagram of thyristor excitation system with AVR and PSS

This type of instability is characterized by low frequency (0.2 to 2.0 Hz) oscillations which can continue for no apparent reason. This type of stability can harm system security and restrict power transfer [4]. The major factors which contribute to the instability are:

a. Loading of the generator or tie line
b. Power transfer potential of the transmission line
c. Power factor of the generator
d. Gain of AVR

III. CONVENTIONAL POWER SYSTEM STABILIZERS

Here, in the frequency domain design procedure is made. Conventional power system stabilizers (CPSSs) are basically designed on the basis of a linear model for the power system. Then, assuming that disturbances are small such that the linear model remains valid, the CPSS is designed. Therefore, a CPSS is most useful for preserving dynamic stability of the power system [4], [11].

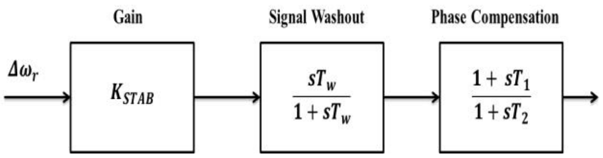


Fig 3.1 Block diagram of PSS

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 andT_2 . This network is connected with a washout circuit of a time constant T_ω as shown in Figure 3.1

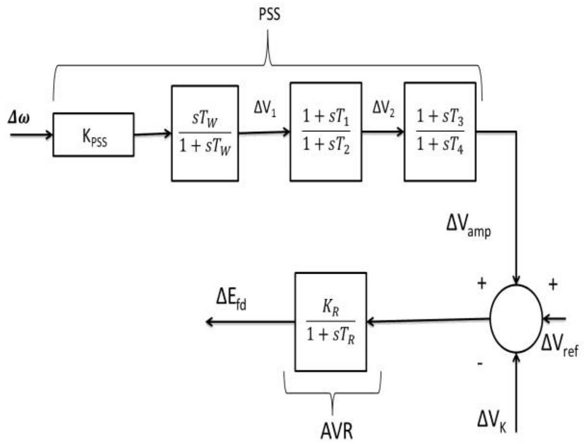


Fig 3.2 Basic Structure of Conventional PSS

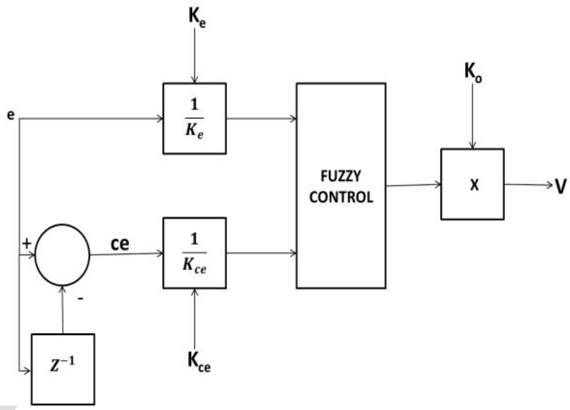
In Figure 3.2 the phase compensation block provides the appropriate phase lead characteristics to compensate for the phase lag between exciter input and generator electrical torque. The conventional power system stabilizer (CPSS) damps the low frequency oscillations in the shaft speed of a synchronous machine. Since, the design is on the basis of a block diagram of the system derived for a specific operating point, the CPSS has the best response for this operating point [4], [5]. The performance *of* the CPSS will decrease, if the operating point of the system changes.

IV. FUZZY SYSTEMS

Normalized values of error 'e' and change of error 'ce'are the inputs to the fuzzy logic controller. To limit the universe of discourse of the input between -1 to 1 normalization is done, such that the controller can be successfully operated within a wide range of input variation. Here 'K_e 'and 'K_{ce}' are the normalization factors for error input and change of error input respectively. For this fuzzy logic controller design, the normalization factors are taken as constants. The output of the fuzzy logic controller is then multiplied with a gain 'K_0' to give the appropriate control signal 'V'. The output gainfor this fuzzy logic controller is also taken as a constant [2], [9].

The fuzzy controller used in power system stabilizer is normally a two- input and a single-output component. It is usually a MISO system. 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 [15].The Fuzzy inference system or fuzzy system is a popular computing frame work based on the concept of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning.

Fig. 4.1 Basic Structure of Fuzzy Logic Controller



There are number of implication methods to fuzzy logic, but only two widely used methods mamdani type fuzzy model and Sugeno type fuzzy model. Here we have been used mamdani method of fuzzy logic technique. Because, it is intuitive, well suited to human input and has widespread acceptance while Sugeno method works well with linear techniques, with optimization and adaptive techniques & computationally efficient [16].

V. DESIGN OF FUZZY LOGIC BASED PSS

When an exact mathematical model of the plant is not available thenFLCs are very useful; however, experienced human operators are available for providing qualitative rules to control the system.
The importance of fuzzy logic derived from the fact that most modes of human reasoning and especially common sense reasoning are approximate in nature [9], [16]. In doing so, the fuzzy logic approach allows the designer to handle efficiently very complex closed-loop control problems. There are many artificial intelligence techniques that have been employed in modern power system, but fuzzy logic has emerged as the powerful tool for solving challenging problems. As compared to the conventional PSS, the Fuzzy Logic Controller (FLC) has some advantages such as:

- A simpler and faster methodology.
- It does not need any exact system mathematical model.
- It can handle nonlinearity of arbitrary complexity.
- It is based on the linguistic rules with an IF-THEN general structure, which is the the basis of human logic.

- It is more robust than conventional nonlinear controllers.

Here we used four types of membership functions [16] for the analysis:

A. *Triangular Membership Function*

A triangular membership function is specified by three parameters {a, b, c} which are described as follows:

f(x; a,b,c) =

0,	$x \leq a$
$\frac{x-a}{b-a}$	$a \leq x \leq b$
$\frac{c-x}{c-b}$	$b \leq x \leq c$
0,	$c \leq x$

The parameters a and c locate the feet of triangle and the parameter b locate the peak.

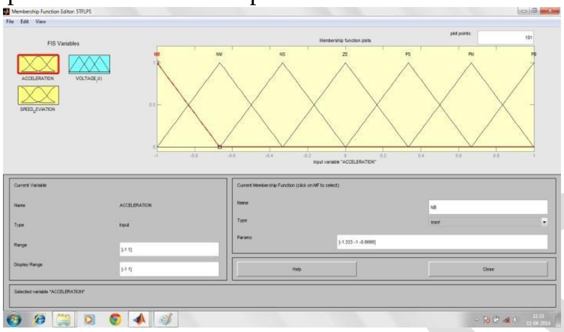


Fig. 5.1Triangular Membership Function

B. *Trapezoidal Membership Function*

A trapezoidal membership function is specified by four parameters:

$f(x; a, b, c, d) =$

0,	$x \leq a$
$\frac{x-a}{b-a}$	$a \leq x \leq b$
1 ,	$b \leq x \leq c$
$\frac{d-x}{d-c}$,	$c \leq x \geq d$
0,	$d \leq x$

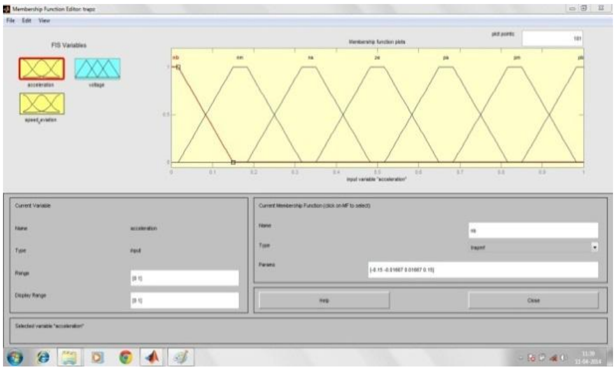


Fig. 5.2Trapezoidal Membership Function

The parameter a and d locates the feet of the trapezoid and the parameters b and c locates the shoulders.

C. *Gaussian Membership Function*

A Gaussian membership function is specified by two parameters {c,σ} as follows:

Gaussmf (x;c,σ) = $e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2}$

A Gaussian membership function is determined completely by c & σ; C represents the MFs centre& σ determines MFs width.

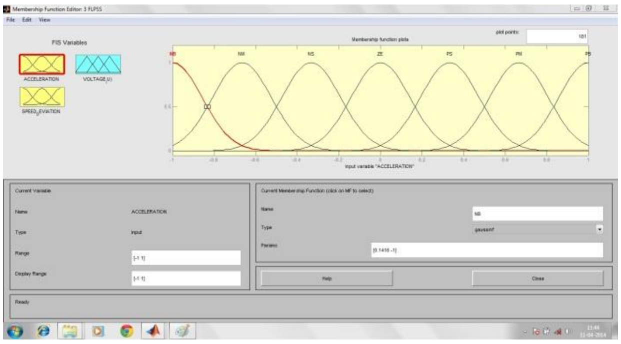


Fig. 5.3Gaussian Membership Function

D. *Sigmoidal Membership Function*

A sigmoidal membership function is defined by

F(x; a,c) = $\frac{1}{1+e^{[-a(x-c)]}}$

Where a controls the scope at the crossover point x=c. Depending on the sign of the parameter, the Sigmoidal membership function is inherently open to the right or left, thus appropriate for representing the concepts such as “very large” or “very negative”.

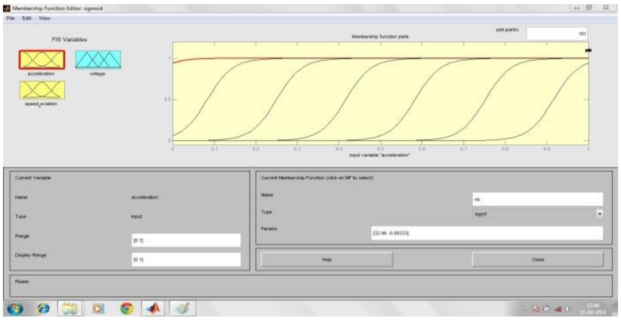


Fig. 5.4Sigmoidal Membership Function

Assigning the mapped variables in input/output of the fuzzy logic controller (FLC) the design starts. The first input variable to the FLC is the generator speed deviation and the second is acceleration. Voltage is the output variable to the FLC.After choosing proper variables as input and output of fuzzy controller, it is required to decide on the linguistic variables [16], [17]. These variables transform the numerical values of the input of the fuzzy controller to fuzzy quantities. The number of linguistic variables describing the fuzzy subset of a variable varies according to the application. Here seven linguistic variable for each of the input and output variables are used to describe them. Table 5.1 shows the Membership functions for fuzzy variables. The membership function maps the crisp values into fuzzy variables.

Table 5.1
DECISION TABLE FOR FUZZY VARIABLES

Acceleration → Speed Deviation ↓	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB	**NB**	**NB**	**NB**	**NS**	**ZE**	**ZE**	**PS**
NM	**NB**	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**
NS	**NB**	**NB**	**NM**	**ZE**	**PS**	**PM**	**PB**
ZE	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
PS	**NB**	**NM**	**NS**	**ZE**	**PM**	**PB**	**PB**
PM	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**	**PB**
PB	**NS**	**ZE**	**ZE**	**PS**	**PB**	**PB**	**PB**

Table 5.2 MEMBERSHIP FUNCTIONS FOR FUZZY VARIABLES

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

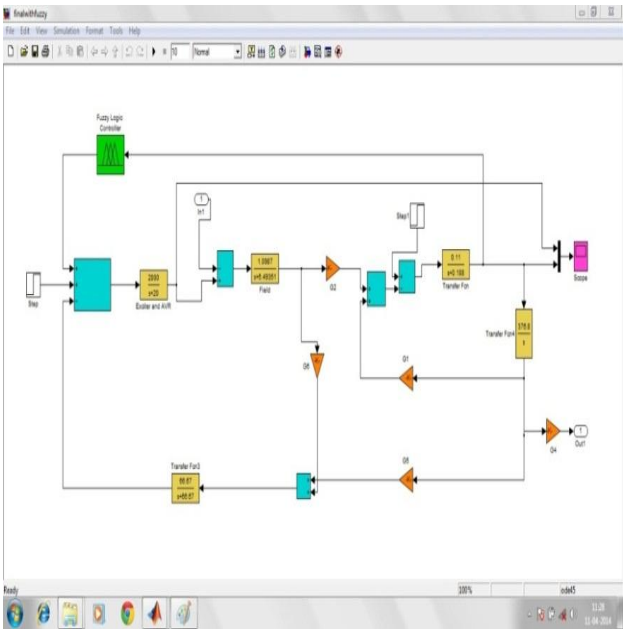


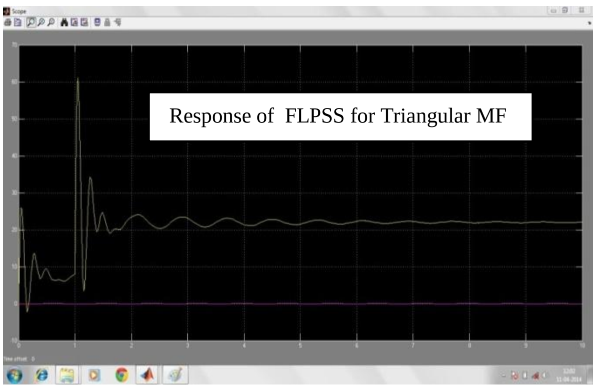
Fig. 6.1 Test systems for proposed fuzzy Logic Based PSS

Simulink diagram of the Single Machine Infinite Bus SystemSMIB system with PSS (Fig 6.1) are simulated and analyzed. The corresponding simulation results are shown in fig. 6.2.

In topic 2, Fig. 2.1 shows the block diagram representation with AVR and PSS. In this presentation, the dynamic characteristic of the system are expressed in terms of the so-called K-constants [13], [16]. The values of K-constants calculated using above parameters are: K_1=1.7299, K_2=1.7325, K_3=0.1692, K_4=2.8543, K_5= -0.0613, K_6=0.3954

E. *Performance with Different Membership Functions and comparison with CPSS without Fuzzy Controller*

The oscillations are more pronounced in case of inputs and outputs having sigmoidal membership function and the system becomes stable after a long time more than 9.5 seconds. Also the unstable behavior is resulted if the



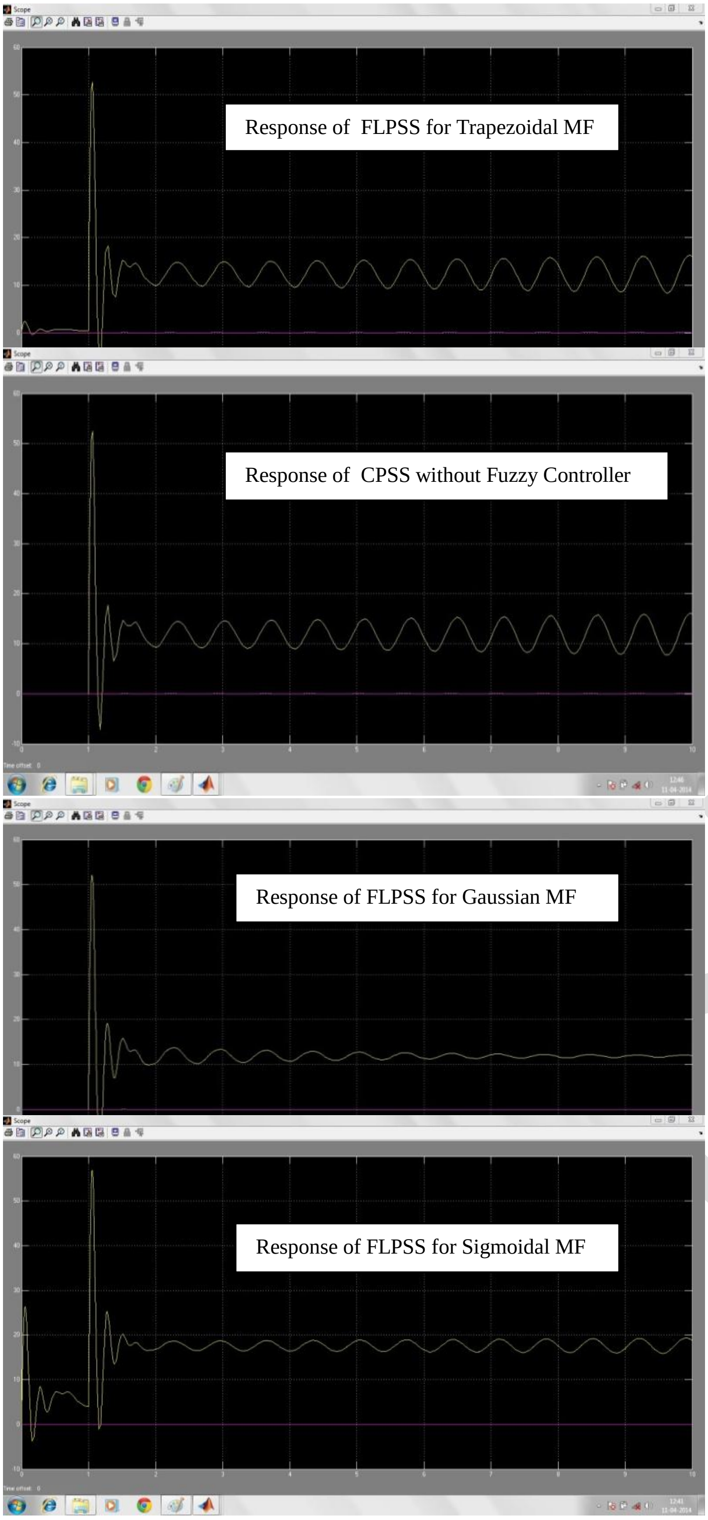


Fig. 6.2 Responses of angular speed with various membership functions compare to CPSS without Fuzzy Controller

VI. CONCLUSIONS

In this paper initially the effectiveness of power system stabilizer in damping power system stabilizer is reviewed. Fuzzy logic based power system stabilizer is introduced by taking speed deviation and acceleration of synchronous generator as the input signal to the fuzzy controller and voltage as the output signal. FLPSS shows the better control performance than power system stabilizer in terms of setting time and damping effect. Therefore, it can be concluded that the performance of FLPSS is better than conventional PSS. However, the choices of membership functions have an important bearing on the damping of oscillations. Here fuzzy logic based techniques are preferred as a solution to overcome the problems of various loading conditions. Using this technique we have avoided complex mathematical model. In this paper, we have used fuzzy logic controller (FLPSSs) for various membership functions by using mamdani method. For this, we have made the model of power system with its excitation & AVR by observing the generator rotor angles with reference to various loading conditions. From the simulation studies, it shows that the oscillations are more pronounced in case of trapezoidal membership functions and sigmoidal membership functions. The response with Gaussian membership function is comparable to triangular membership functions. However, the performance of FLPSS with triangular membership function is superior to other membership functions.

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