COMPARATIVE STUDY OF CONVENTIONAL AND FUZZY BASED POWER SYSTEM STABILIZER

BHAVANS SHAH

Department of Electrical Engineering

Government Engineering College, Bhuj

techengg08@gmail.com

Abstract— Power system stabilizers (PSSs) are used to enhance the damping during low frequency oscillations. The paper presents a study of power system stabilizerusing fuzzy logic to enhance stability of single machine infinite bus system.In this paper basic problem of conventional power system stabilizer for stability enhancement is defined which is traditionally used. Fuzzy logic provides one alternative for stability enhancement and speeddeviation (Δw).The proposed method using fuzzy logicachieves better improvement than conventional power system stabilizer. Fuzzy logic rules were developed for triangular membership function of input and output variables. The system is simulated in SIMULINK environment and the performances of conventional and Fuzzy based power system stabilizers are compared.

Keywords: Power system stabilizer;Stability; Single machine system; Fuzzy logic; SIMULINK.

1. INTRODUCTION

Power system stability is a property of a power system that enables it to remain in in a state of operating equilibrium under normal operating conditions. Small signal and transient are two categories of stability. Small signal stability is the ability of the system to return to a normal operating state following a small disturbance. Transient stability is the ability of the system to return a normal operating state following a severe disturbance, such as a single or multi-phase short-circuit or a generator loss.

Low frequency oscillations are a major problem in large power system. A power system stabilizer provides supplementary control signal to the excitation system of electric generating unit for damping these low frequency oscillation. Power system stabilizers are successfully used in power systems for few years because of their flexibility low cost and easy implementation.

The power system stabilizer is used to generate supplementary control signal in order to dampen the low frequency oscillation. The conventional power system stabilizer is widely used in existing power system and has contributed to the enhancement of the dynamic stability of power systems [3].

The parameters of conventional power system stabilizer are based on linearized model of power system around of nominal operating point. Power systems are highly nonlinear systems so the design of conventional power system stabilizer based on linearized model of the power systems cannot guarantee its performance in practical operating environment [4].

To improve the performance of conventional power system stabilizer many techniques have been proposed for the design for example genetic algorithm, neural network, simulated annealing fuzzy logic and many other intelligent optimization techniques. From last few years fuzzy logic controller is used in power system applications as a powerful tool.

The paper presents the performance of single machine infinite bus system with fuzzy power system stabilizer of triangular membership function.Here I have taken speed deviation (Δw) and acceleration as input variables then performance of conventional and fuzzy based power system stabilizer with triangular membership function are studied and compared with conventional lead-lag compensator. The simulations are implemented in SIMULINK environment.

2. SYSTEM DESIGN

The system consists of synchronous machine, excitation system and power system stabilizer.

i) Synchronous Machine Model:
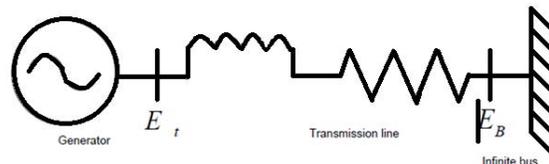
Fig.1: Synchronous Machine Connected To Infinite Bus

Fig.1 shows the synchronous machine connected to infinite bus through transmission line.The Governing equations for machine model are:

$$p\Delta\omega_r = 1/2H(\Delta T_M - \Delta T_e - K_d.\Delta\omega_r)$$

$p\Delta\delta = \omega_o\Delta\omega_r$

Where, $\Delta T_e = K_1\Delta\delta + K_2.\Delta\psi_M$

$\Delta\psi_{fd} = K_3/(1+pT_3).[\Delta E_{fd} - K_4\Delta\delta]$

Here T_M is prime mover input and T_e is electrical Output torque, H is inertia constant, ω and $\delta$are speed and rotor angle respectively.

ii) Excitation System:
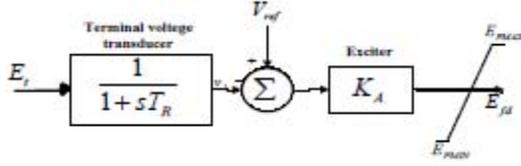
Fig.2: Block diagram of excitation system

Excitation system is capable of responding rapidly to a disturbance so as to enhance transient stability and of modulating the generator field so as to enhance small scale stability. The duty of an exciter is to provide necessary field current in rotor winding of an alternator. Terminal voltage transducer senses generator terminal voltage rectifies and filters it to dc quantity. Exciter provides dc power to synchronous machine field winding, constituting the power angle of excitation system

iii) Power System Stabilizer (PSS):

Power system stabilizers (PSS) were developed to aid in damping these oscillations viamodulations of excitation system ofgenerator s. The action of a PSS is to extend the angular stability limits of a powersystem by providing supplemental damping to the oscillation of synchronous machinerotors through the generator excitations.

3. Fuzzy Logic Controller(FLC)
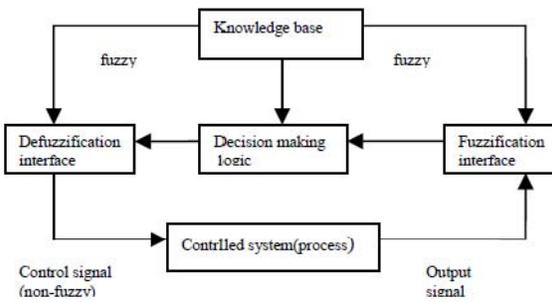
Fig. 3: Fuzzy Logic Controller Diagram

The figure (3) shows block diagram of fuzzy logic controller. It consists of four basic components: Knowledge Base, Fuzzification Interface,De-fuzzification Interface and Decision Making Logic. The fuzzy controller is a two input and single output component. It is mostly a MISO system [5].

Knowledge Base: It includes definitions of fuzzy membership function and the necessary rules which specified the control goals using linguistic variables. It also stores the knowledge about all input-output fuzzy relationships.

Fuzzification Interface: It converts the crisp quantities into fuzzy quantities. There are several ways to assign membership values to fuzzy variables in comparison with the probability density functions to random variables. The process of membership value assignment is done by intuition, logical reasoning, procedural methods or algorithm approach.

Defuzzification Interface: It has the capability to reduce a fuzzy set into a crisp single-valued, quantity. It may also be termed as "rounding it off". The selection of method is done on the basis of the computational complexity involved and applicability to the situations considered.

Decision Making Logic: This module converts the inferred decision from linguistic variables. It is the kernel of an FLC system and it has the capability to simulate human decisions by performing approximate reasoning to achieve desired control strategy.

4. Conventional Power System Stabilizer
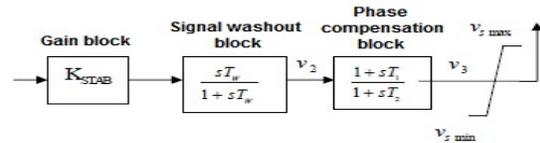
Fig. 4: Block Diagram of Conventional PSS

The basic structure of conventional PSS is shown in figure (4). It contains three components: phase compensation block, signal washout block and gain block. The phase lag between exciter input and generator electrical output provides by phase compensation block with appropriate phase lead characteristic.The signal washout block serves as high pass filter. The stabilizer gain K_{st} determines the amount of damping. The transfer functions of conventional PSS are:

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

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

Here $T_W$is washout filter time constant.

5. Fuzzy Logic based PSS

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 PSS. Therefore, the need for fuzzy logic PSS arises. 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. 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. The stabilizing signals are computed using the standard fuzzy membership functions depending upon these variables.

The variables chosen for this controller are speed deviation, acceleration and voltage. In this, the 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. Usually an odd number is used. A reasonable number is seven. However, increasing the number of fuzzy subsets results in a corresponding increase in the number of rules. 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 areassigned seven linguistic fuzzy subsets varying from negative big (NB) to positive big (PB). Each subset is associated with a triangular membership function to form a set of seven membership functions for each fuzzy variable.

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

Table 1. Membership functions for fuzzy variables

Fuzzy Rule Base:
A set of rules which define the relation between the input and output of fuzzy controller can be found 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 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).

Rule 3: If speed deviation is PS (positive small) AND acceleration is PS (positive small) then voltage (output of fuzzy PSS) is PS (positive small). And so on.

All the 49 rules governing the mechanism are explained in Table 3.2 where all the symbols are defined in the basic fuzzy logic terminology.

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. Fuzzy rules

The stabilizer output is obtained by applying a particular rule expressed in the form of membership functions. Finally the output membership function of the rule is calculated. This procedure is carried out for all of the rules and with every rule an output is obtained.Using min-max inference, the activation of the ith rule consequent is a scalar value (Vs) which equals the minimum of the two antecedent conjuncts' values. For example if speed deviation belongs to NB with a membership of 0.3 and acceleration belongs to NM with a membership of 0.7 then the rule consequence i.e. Voltage signal (Vs) will be 0.3.

Using fuzzy rules shown in table 2, Conventional PSS is replaced in Fuzzy controller block.
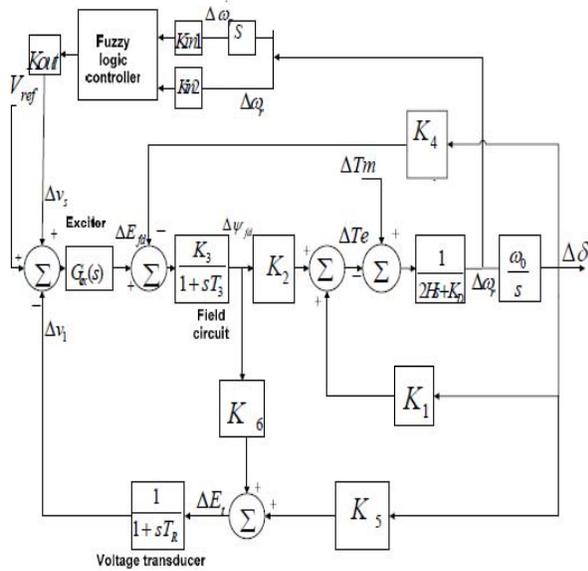
Fig. 4: Block diagram of fuzzy logic controller implemented on single machine infinite bus system

The figure 4 shows the diagram of the representation of fuzzy based controller for single machine infinite bus system. Here the angular velocity and its derivative are inputs and voltage is output.K_{in1}, K_{in2} and K_{out} are gains which normalize inputs and output according to the range in which the membership functions are defined. The gain parameters are tuned to give the desired response.
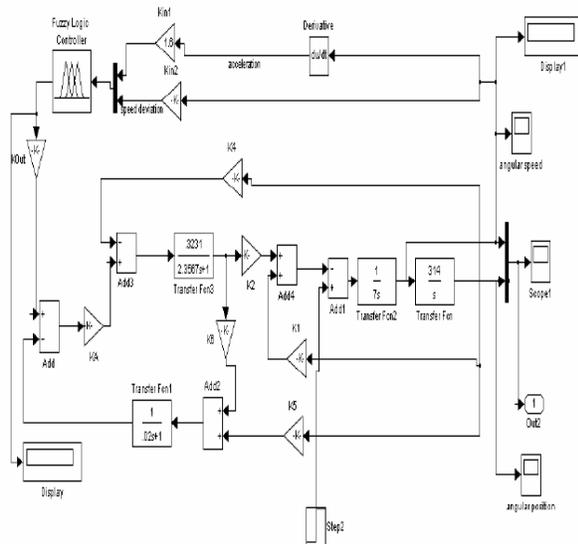
Fig. 5: Simulink model with Fuzzy Logic Based PSS
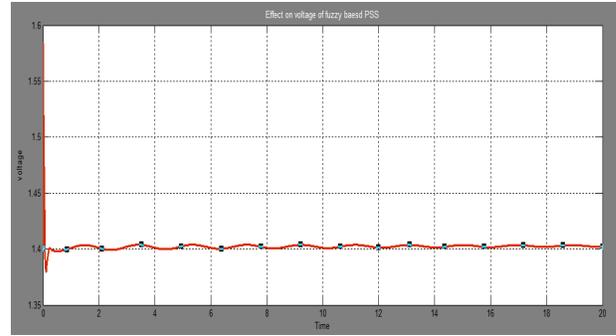
Fig. 6: Result of Conventional PSS
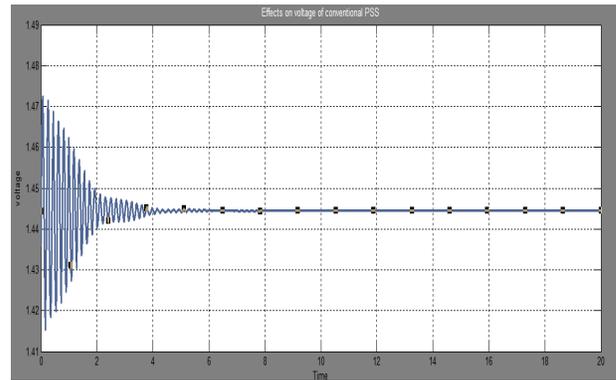
Fig. 7: Result of Fuzzy Logic Based PSS

From fig.6 and fig.7 it can be perceived that with the application of fuzzy logic, the rise time and the settling time of the system decreases. The system reaches its steady state value much earlier with fuzzy logic power system stabilizer compared to conventional power system stabilizer. Here I have used triangular membership function in fuzzy logic controller.

6. Conclusion

The Matlab/Simulink simulation shows that the fuzzy controller has an excellent response with very small oscillation while conventional power system stabilizer (CPSS) response shows a ripple and reaching steady state operating point after some oscillations. The performance of fuzzy PSS is better one since it is effective for all type of conditions.

REFERENCES

[1] Wenxin Liu, Ganesh K. Venayagamoorthy, Donald C. Wunsch.Adaptiveneural network based power system stabilizer design. IEEE 2003, page 2970-2975

[2] Y. Zhang G. P. Chen, 0. P. Malik G. S. Hope, "An Artificial Neural Network BasedAdaptive Power System Stabilizer", IEEETransactions on Energy Conversion, Vol. 8, No. 1, March 1993.

[3] Neeraj gupta, Sanjay k. Jain, "Comparative analysis of fuzzy power system stabilizer using different membership functions", International journal of computer and electrical engineering, Vol.2, No. 2, April,2010,1793-8163.

[4] Jenica Ileana corcau,Eleonor stoenecu, "Fuzzy logic controller as a power system stabilizer" ,International journal of circuits, systems and signal processing, Issue 3, Volume 1, 2007.

[5] C J Wu and Y Y Hsu, "Design of Self-tuning PID Power System Stabilizer for Multimachine Power System", IEEE Transactions on Power Systems, vol. 3, pp. 1059-1064, Aug. 1998.

[6] K A El-Metwally and O P Malik, "Fuzzy Logic Based Power System Stabilizer", IEEE Proc- Gener.Transm. Distri., vol. 142, pp.277-281, May 1995.

[7] H Taliyat, J Sadeh and R Ghazi "Design of Augmented Fuzzy Logic Power System Stabilizer to Enhance Power System Stability" IEEE Transactions on Energy Conversion, vol 11, pp, 97-103, March 1996.

[8] T Hiyama, "Development of Fuzzy Logic Power System Stabilizer and Further Studies", IEEE International Conference on Systems, Man and Cybernetics '99, vol. 6, pp.545-550.

[9] S Majid, H A Rahman and O B Jais, "Study of Fuzzy Logic Power System Stabilizer", IEEE Student Conference on Research and Development 2002, pp. 335- 339.

[10] Jaun, L H Herron and A Kalam, "Comparison of Fuzzy Logic Based and Rule Based Power System Stabilizer", IEEE Conference on Control Application, pp.692- 697, sept.1992.