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A COMPREHENSIVE REVIEW ON POWER SYSTEM STABILITY ENHANCEMENT WITH DIFFERENT CONTROL TECHNOLOGIES

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Abstract: In this paper a linearized Heffron-Philips model of a Single Machine Infinite Bus (SMIB) power system stabilizer is analyzed with and without controller using MATLAB simulation. Power System Stabilizer (PSS) is compared for different functions. The effectiveness of PSS is providing damping and improving the dynamic response is well established. For PSS, speed deviation and acceleration deviation are taken as inputs. Comparison of the effectiveness (steady state error, ess, overshoot (Mp) and settling time (ts) of PSS for different functions with conventional PSS and without PSS is done. The performance of the SMIB system has improved significantly compared to SMIB system without PSS/with PSS. The results of the simulation show that for low frequency oscillations, PSS is more effective in damping compared to conventional controllers. A Fuzzy Logic Power System Stabilizer for different membership functions is proposed.
Keywords: Heffron-Philips model, Power system stabilizer, Steady state error, Stability, Controller, Maximum overshoot, settling time.

I. INTRODUCTION

In the present scenario of modern era the stability of electric power system is one of the most important concerns in any electric power system network. This can be traced from the fact that in steady state the average electrical speed of the generators must be in synchronism. The stability of power system can be defined as that property. Power system stability [1] can be classified into: Transient stability and Small signal stability. Transient stability of a system was conventionally suppressed using AVR (Automatic voltage regulator), has the electric system has been seen with oscillations of frequencies ranging from .1 to 2 Hz. These regulators have high gain leading to destabilizing effect on power system and also these are designed for specific operating condition hence limiting to specific level of performance [2].Heffron and Phillips model of SMIB represent a single synchronous generator connected to the grid through a transmission line. This model is being analyzed for stability study using Controller and Without Controller PSS. Further, the PSS is analyzed by fuzzy logic control. Fuzzy Logic [3-5] has the features of simple concept, easy implementation, and computational efficiency. This provides an easy method to draw the definite conclusion from hazy, uncertain or inexact information. So in this paper the comparison is done between the PSS with and without controller and an attempt is made to analyze fuzzy logic based power system stabilizer model. The paper is organized as follows; Section 2 describes the modelling of power system. The designs of the conventional power system stabilizer with results. Section 3 Comparison of Power system stabilizer with and without controller is made and Fuzzy logic is analyzed for improving the system stability in section 4. The conclusion is mentioned in section 5. Appendix A includes various parameters of the system and controllers.

II. MODELLING OF POWER SYSTEM

SMIB (Single Machine Infinite Bus) system consists of a synchronous machine connected to an infinite bus through a transmission line.

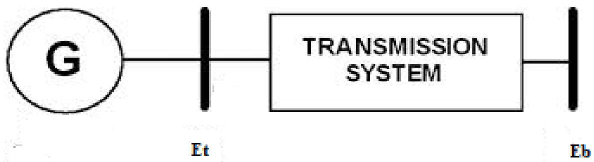


Fig. 1 Single machine infinite bus system (SMIB)

The fourth-order nonlinear system is described by the following set of equations.

$$\dot{\partial}=\omega y$$

$$\dot{\omega}=\frac{1}{M}\left(T_m+T_e+\mathrm{D}.\omega\right)$$

$$\dot{e}_q^{'}=\frac{1}{T_{do}^{'}}\left(E_{fd}-e_q^{'}-(X_d-X_d^{'})i_d\right)$$

$$\dot{E}_{fd}=\frac{1}{T_a}\left[K_A\left(V_{ref}-V_t\right)\right]-\frac{1}{T_a}E_{fd}$$

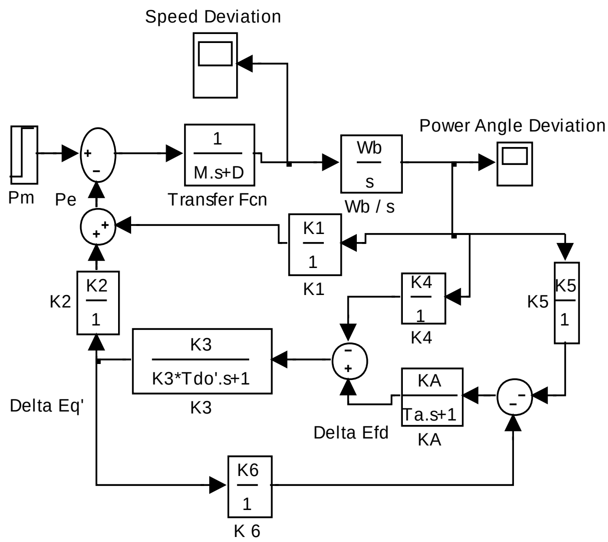
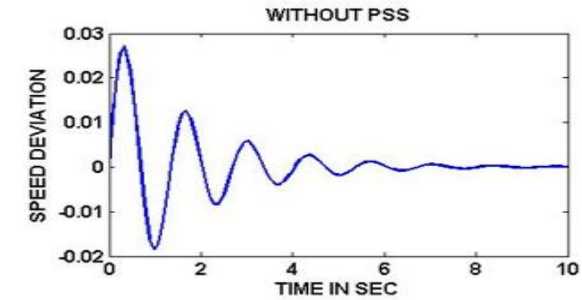
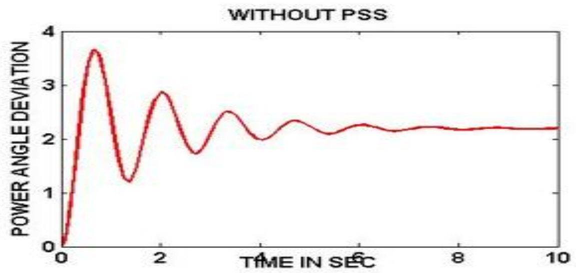


Fig. 2 SIMULINK Model of Heffron and Phillips without Controller

Fig.2. shows the block diagram of Single Machine infinite bus (SMIB) power system model. This diagram was developed by Heffron and Phillips so to represent a single synchronous generator connected to the grid through a transmission line. Heffron and Phillips model [6] is a linear model. It is quite accurate for studying LFOs and stability of power systems. It has also been successfully used for designing classical power system controllers, which are still active in most power utilities.



(a)



(b)

Fig. 3 shows Output of SMIB system without PSS (a)Speed Deviation (Δω) (b) Power angle Deviation (Δδ) of Generator.

III. CONTROLLER

Controller is a device fabricated in a chip form, analogue electronics, or computer that supervise and actually alters the working conditions of a considered dynamical system. This paper deals with two types of power system controllers discuss below;

A. Conventional Power System Stabilizer (CPSS)

The Power System Stabilizer is used to provide a sufficient damping to electromechanical oscillations in SMIB energy system. So CPSS [7-11] is used to achieve desired transient behaviour and low steady state error. The Lead-Lag combination of compensator is used as Lead-Lag controller PSS. The input to controller is speed deviation ($\Delta\omega$).The PSS as represented in Fig. 3 has three components. These are phase compensation block, signal washout block and gain block.

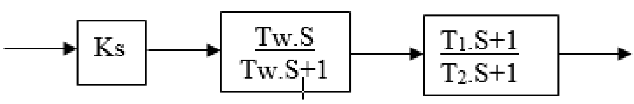


Fig. 4. Structure of conventional lead-lag controller

The controller gain Ks is an important factor as the damping provided by the PSS increase in proportion to an increase in the gain up to a certain critical gain value, after which the damping begins to decrease. The phase compensator block is used to make the system "settle down" quickly. The outcome value of the controller has to be gradually drawn towards zero in steady state condition. Therefore a washout transfer function [Tw. S/ (Tw.S+1)], which has a steady state gain zero is used. The value of washout time constant Tw, may be in the range of 1-20 sec.

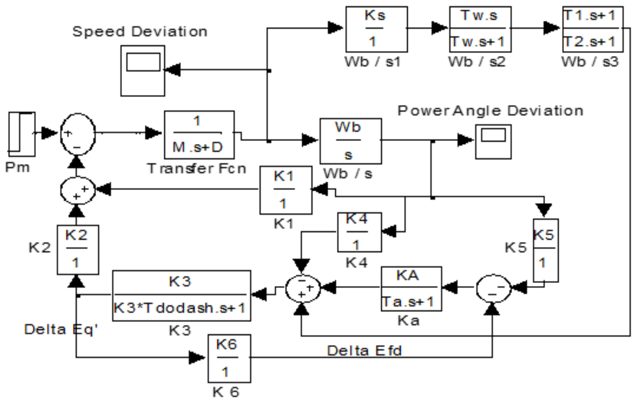
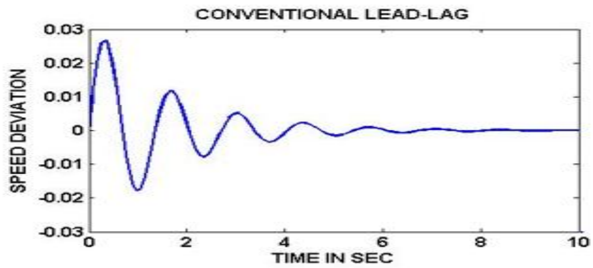


Fig. 5 SIMULINK Model of Power System with Controller.



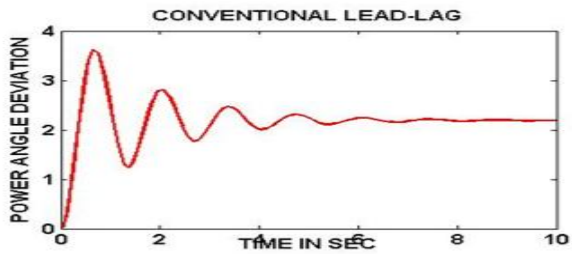


Fig. 6 shows Output of SMIB system with PSS (a)Speed Deviation (Δω) (b) Power angle Deviation (Δδ) of Generator.

IV. COMPARISON OF PSS WITH AND WITHOUT CONTROLLER

- The PSS with controller results in achieving a desired transient behaviour and low steady state error.
- The controller gain Ks of PSS with controller is an important factor as the damping provided by PSS increases in proportion to increase in gain up to a certain critical gain value after which the damping begins to decrease.

- Lead-Lag compensator based PSS provides an optimum performance for a nominal operating condition and system parameter.

V. FUZZY CONTROLLER

It is a form of knowledge representation suitable for notation that cannot be defined precisely but which depend upon their contexts. Unlike classical logic which require a deep understanding of the system exact equations and précised numeric value fuzzy logic incorporates an alternate way of thinking. Fuzzy logic PSS uses a rule base to describe relationship between the input variables and output variables. Fuzzy logic controller has proven to be a successful control approach to many complex non-linear systems or even system difficult to analyze by classical treatment.
These inputs are angular speed deviation and angular acceleration while output of fuzzy logic controller is a voltage signal.

FUZZY LOGIC CONTROLLED POWER SYSTEM STABILIZER (FPSS):

The fuzzy power system stabilizer is two-input component those have single output. These inputs are angular speed deviation and angular acceleration while output of fuzzy logic controller is a voltage signal.

FUZZY LOGIC CONTROL SYSTEM:

The term fuzzy logic has been given by LotfiZadeh in 1965. He was known as Father of Fuzzy Logic. This logic is used in many applications in the industry because of its some of the advantages: simple and faster methodology, reduce a design development cycle, easy implementation, reduce hardware cost, improve the control performance and simplify design complexity. So it is used as controller in a power system as a fuzzy power system stabilizer. The designing process is carried out with the help of MATLAB 2009a. A fuzzy controller comprises of three stages: fuzzification, fuzzy rule and defuzzification.

A. Fuzzification

Fuzzification is the process of making a crisp quantity to fuzzy. This paper simply recognizes that many of the quantities which are considered to be crisp and deterministic are actually not deterministic at all. They carry considerable uncertainty. If the uncertainty forms arise because of elusiveness, ambiguity then fuzzy may be change and can be represented by a membership function. In this system there are two input speed and acceleration which is converting into fuzzy value. Each of the input and output fuzzy variables is assigned seven linguistic labels. Seven membership functions is generating better result proved by some testing so these are defined as NH (Negative High), NM (Negative Medium), NS (Negative-Small), ZR (Zero), PS (Positive-Small), PM (Positive-Medium), PH (Positive High) membership functions are used to convert the fuzzy values between 0 and 1 for inputs and output value both.

B. Fuzzy rule base system

Fuzzy rules are defined to reduce the error in the system after analyzing the function of controller. For each fuzzy value there are seven membership functions, so 49 combinations of speed and acceleration are possible. There is an output for each of the membership functions and the linguistic variables can be determined by using IF–THEN fuzzy rules.

Table 1.Rule base of fuzzy logic controller

Speed Deviation	Acceleration						
	NH	**NM**	**NS**	**ZR**	**PS**	**PM**	**PH**
NH	NH	NH	NH	NH	NM	NM	NS
NM	NH	NM	NM	NM	NS	NS	ZR
NS	NM	NM	NS	NS	ZR	ZR	PS
ZE	NM	NS	NS	ZR	PS	PS	PM
PS	NS	ZR	ZR	PS	PS	PM	PM
PM	ZR	PS	PS	PM	PM	PM	PH
PH	PS	PM	PM	PH	PH	PH	PH

In a defuzzification part fuzzy values which are obtained from inference system converts into the specific values. For the inference Mamdani's minimum fuzzy implication and Max–Min compositional rule are used. For the defuzzification centroid method is used.

C. Defuzzification

It is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets. Defuzzification is interpreting the membership degrees of the fuzzy sets into a specific decision or real value.

VI. CONCLUSION

In this paper PSS is designed with and without controller and the system is simulated on a SMIB system using the platform of MATLAB simulation. The simulation result confirms that the PSS with controller can provide better performance in comparison with PSS without controller. Further the Fuzzy Logic will be analyzed for improving the system stability.

Appendix

PARAMETER VALUES
GENERATOR: M =7.10 s., D=0.0, X_d=1.81,X_q=1.75,X'_d=0.31,
T'_{do}= 7.295200, ω_b=314.00
Exciter :(IEEE Type ST1): K_A=200, T_A=0.021 s, T_1=0.1540,T_2 =0.033, K_S=9.50, T_W=1.40
K_1=0.76361, K_2=0.8644, K_3=0.32310, K_4=1.41890, K_5 = 0.14630, K_6=0.41671

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