



**THE GREAT EASTERN INSTITUTE OF MARITIME STUDIES  
(LONAVALA)**

**PAPER PRESENTATION**

**ON**

**SMALL SIGNAL STABILITY ANALYSIS WITH FUZZY PSS**

**FOR  
TRANSTECH -15**

**BY**

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## **ABSTRACT**

Power system stabilizers are effective in damping small signal oscillations in power system. In this paper a linearized Heffron-Philips model of a Single Machine Infinite Bus power system with a Fuzzy Logic Power System Stabilizer (FLPSS) is developed. Appropriate fuzzy rules are framed with speed deviation and acceleration as inputs to fuzzy controller. Simulation work is carried out in MATLAB/SIMULINK environment. The behavior of the SMIB system without PSS, with Conventional PSS and FLPSS are compared.

## **Keywords**

Small Signal Stability Analysis, Heffron-Phillips Model, SMIB, Conventional PSS, Fuzzy PSS

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## **1. INTRODUCTION**

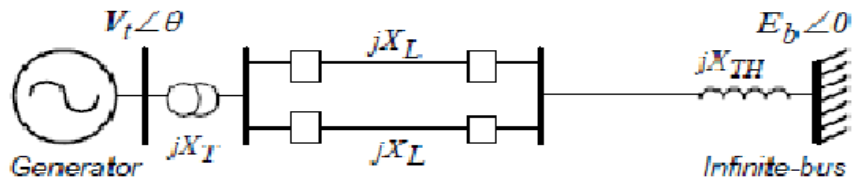
Modern power systems are characterized by extensive system interconnections and increasing dependence on control for optimum utilization of existing resources. The power systems are becoming more complex now a day with increase in power demand. Due to this complexity, any small disturbance in the system drives the system into unstable mode which consequently causes black outs. Hence stability is the major concern in power system. At any instant of time the power system should be stable for small disturbances.

In any power system, large synchronous machines are employed to generate the power. Thus stability of the entire system lies mainly on the stable operation of the synchronous machine. To ensure stable operation, modeling of synchronous machine is important. Proper modeling of synchronous machine plays a crucial role. Small signal oscillations can be damped using power system stabilizers. Fuzzy PSS can be used to damp the oscillations [1]. Speed deviation and rotor acceleration are considered as inputs to the FLPSS. Fuzzy rules are framed in the If-then format. Power system stability can be enhanced using FLPSS [2]. The number of fuzzy rules depends on linguistic variables. Reduced rules can be used to design FLPSS [3]. PSS can be used to improve the system performance and reduce the oscillations [5].

## **2. METHODOLOGY**

- Generator Modelling

Consider a system (represented by a single line diagram) shown in Fig 1. Here the single generator represents a single machine equivalent of the power plant (consisting of several generators). The generator G is connected to a double circuit line through a transformer T. The line is connected to an infinite bus through equivalent impedance. The infinite bus, by definition represents a bus with fixed voltage source. The magnitude frequency and phase of the voltage are unaltered by changes in the load.



**Fig .1:Single Machine Infinite Bus Power System**

The different synchronous machine equations are:

(1)

(2)

(3)

(4)

The synchronous machine constants can be calculated using the following equations and Phillipis Heffron model can be constructed.

(5)

(6)

(7)

(8)

(9)

(10)

Using above equation the initial condition of synchronous machine can be evaluated. The constants  $K_1, K_2, K_3$  upto  $K_6$  can be computed and in turn Phillipis Heffrons model can be created.

- **POWER SYSTEM STABILIZER**

Power system stabilizer is commonly used to damp low frequency oscillations. PSS produces additional torque to the rotor angle in phase with speed deviation.

Conventional power system stabilizer consists of washout circuit, dynamic compensator, torsional filter and limiter.

- **Washout Circuit**

The washout circuit is used to eliminate steady state bias in the output of PSS which will modify the generator terminal voltage.

- **Dynamic Compensator**

The dynamic compensator used in industry is made up of lead-lag stages and has the following transfer function

$$T(s) = K \frac{(1+sT_1)(1+sT_3)}{(1+sT_2)(1+sT_4)}$$

- Torsional Filter

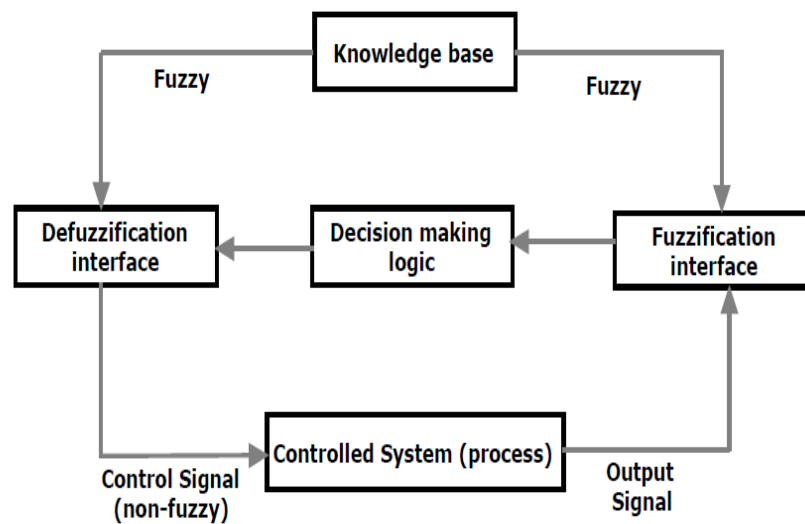
The torsional filter in the PSS is a band reject or a low pass filter to attenuate the first torsional mode frequency. It is used to avoid the adverse interaction of PSS with the torsional oscillations. This can lead to shaft damage, particularly at light generator loads when the inherent mechanical damping is small.

- Limiter

The output of the PSS must be limited to prevent the PSS acting to counter the action of AVR. At load rejections it is desired to trip the PSS, since AVR acts to reduce the terminal voltage to nominal value.

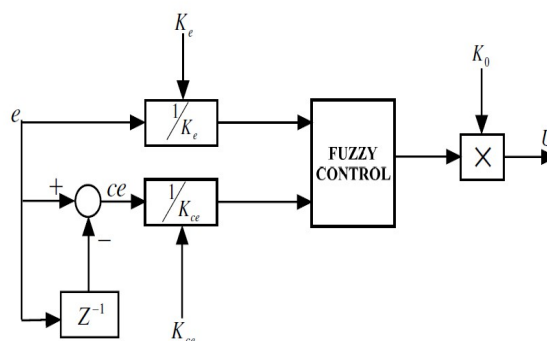
- FUZZY LOGIC STABILIZER

Fuzzy logic controller is used to build FLPSS. The basic structure of fuzzy knowledge representation is shown in the figure.2

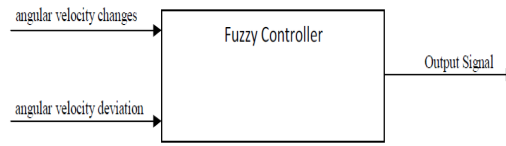


**Fig.2:Fuzzy Knowledge Base Representation 1**

The fuzzy logic controller used in power system stabilizer is normally a two- input and a single- output component. It is usually a MISO system. Fig. 3 shows a typical Fuzzy logic controller. 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.



**Fig.3:Fuzzy Logic Controller**

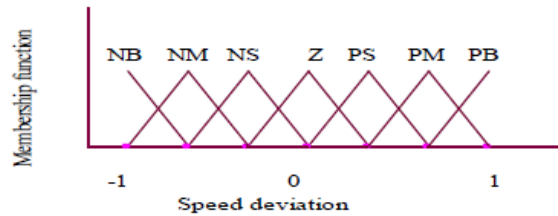


**Fig.4:Fuzzy Power System Stabilizer**

Fig. 4 shows the block diagram of FLPSS. The design starts with assigning the mapped variables inputs/output of the fuzzy logic controller (FLC). The first input variable to the FLC is the generator speed deviation and the second input is the rotor acceleration. The output variable from the FLC is the voltage signal.

Choosing linguistic variables: These variables transform the numerical values of the input of the fuzzy controller to fuzzy quantities.

The membership function maps the crisp values into fuzzy variables. The triangular membership functions are used to define the degree of membership. Fig.5 shows membership function for speed deviation.



**Fig.5: MembershipFunction of Speed Deviation**

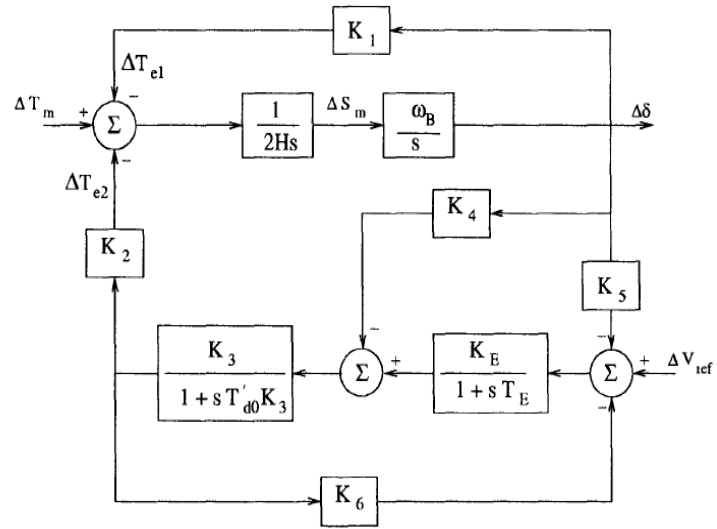
The rule base used in FLPS is shown in table 1. The typical rules employed are; if Speed deviation is NM and rotor acceleration is PS the output from the FLPSS is NS. Using Simulink the FLPSS is created. Input, output variables are selected, rules are framed in rule base. Simulink block of FLPSS is included in the SMIB simulation.

Speed Deviation	Rotor acceleration						
	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NM	NS
NM	NB	NM	NM	NM	NS	NS	Z
NS	NB	NM	NM	NM	NS	NS	Z
Z	NM	NS	NS	Z	PS	PS	PM
PS	NS	Z	Z	PS	PS	PM	PM
PM	Z	PS	PS	PM	PM	PM	PB
PB	PS	PM	PM	PB	PB	PB	PB

### 3. RESULTS AND DISCUSSION

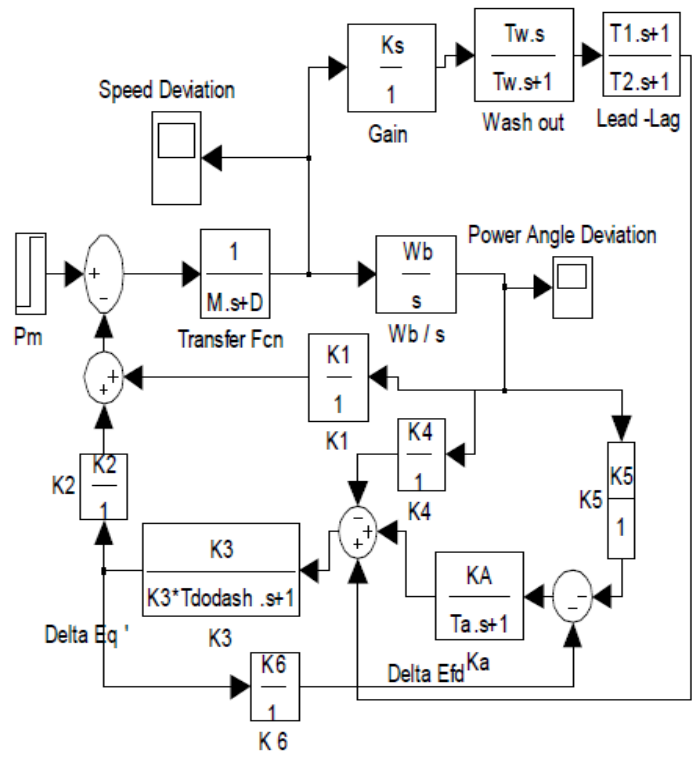
Heffron-Phillips Model is used to analyse the SMIB system. Fig. 6 shows a basic Heffron-Phillips model used for SMIB system. Fig. 7 shows the Heffron-Phillips model for SMIB system with CPSS. Fig. 8 shows Heffron-Phillips model of SMIB system with FLPSS.

The effectiveness of FLPSS is demonstrated by analysing an SMIB system subjected to a small signal disturbance. The disturbance is created at 1 sec in terms of rise in  $P_m$  by 10 percent. The results obtained are shown in figures 9 and 10.

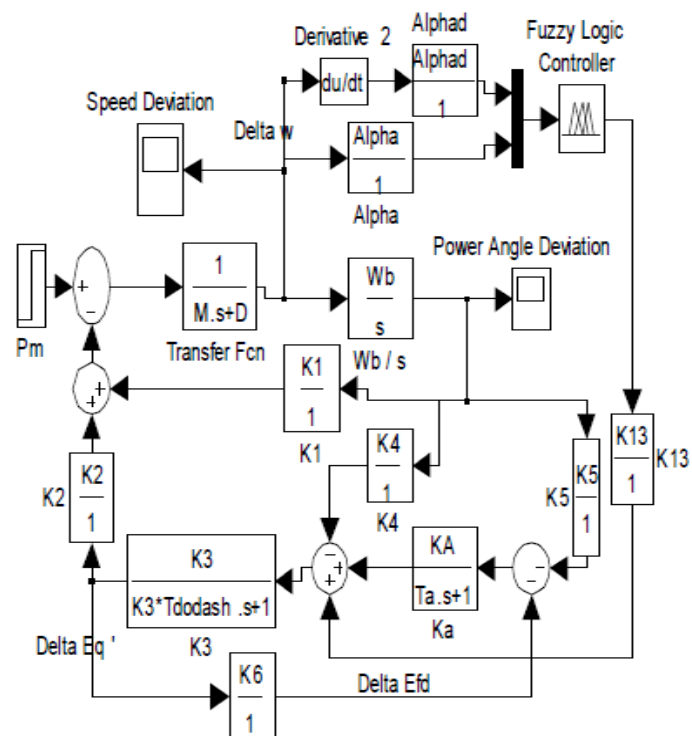


**Fig.6: SMIB System Using Heffron-Phillips Model**

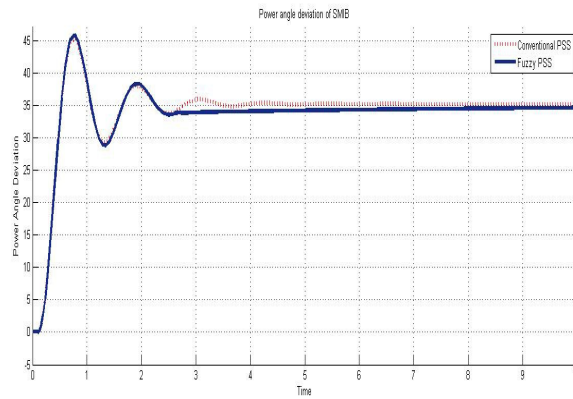
Table 1: Rule base of FLPSS



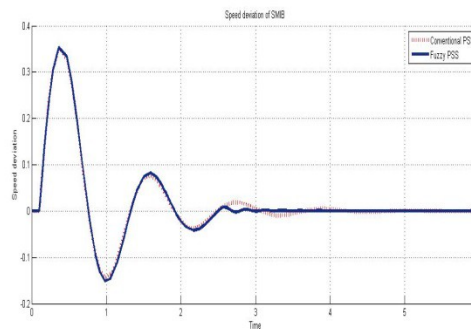
**Fig.7:SMIB System Using Heffron-Phillips Model With Conventional PSS**



**Fig 8.SMIB system using Heffron-Phillips With Fuzzy PSS**



**Fig.9:Power Angle Deviation for a change in  $P_m$**



**Fig.10: Speed Deviation for a change in  $P_m$**

The settling time for power angle deviation and speed deviation is better with FLPSS compared to CPSS. Results clearly indicate the advantage of employing FLPSS to damp the oscillations. The performance of FLPSS is better than CPSS.

#### 4. CONCLUSION AND FUTURE SCOPE

A small signal stability study was carried out on SMIB system. Synchronous machine was modeled using Heffron-Phillips model. SMIB system was subjected to small disturbance in terms of rise in  $P_m$  to evaluate the effectiveness of PSS. The SMIB system was analyzed with conventional PSS and Fuzzy PSS. It is observed that settling time for power angle deviation and speed deviation is improved when Fuzzy PSS is employed rather than conventional PSS. SMIB system employed with Fuzzy PSS have better settling time and oscillations are damped much effectively. The scope for future work is listed below:

1. PSS can be added to state variable model and stability of system can be analyzed.
2. Instead of using conventional PSS, ANN(Artificial Neural Network) based or an adaptive fuzzy based PSS with GA(Genetic Algorithm) optimization can be considered for analysis.
3. Many Optimization techniques can be employed for tuning PSS.

#### 5. REFERENCES

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Hope you find our paper content quite satisfactory, thanks a ton to provide us this opportunity to utilize our talent on this topic, “**SMALL SIGNAL STABILITY ANALYSIS WITH FUZZY PSS**”, for TRANSTECH 2015.

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