MITIGATION OF LOCAL PLANT OSCILLATION IN SINGLE MACHINE INFINITE BUS SYSTEM USING POWER SYSTEM STABILIZER (PSS)

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Abstract: The local plant oscillation (LFO) or low frequency oscillations is related to the small signal stability of a power system. The main objective of this paper to achieve damping to low frequency electromechanical oscillation of synchronous generator rotor for stability of system and improve small signal stability. Modern power systems are widely interconnected, highly non-linear and constantly experience changes in generation, transmission and different load conditions. Due to that power system almost all major transmission network in the world are operated nearly close to their stability limit. One of the major factor in power system operation is related to small signal instability caused by insufficient synchronizing and damping torque in the system. It leads generators to pull out from synchronism and sometimes it is also reason for blackout. Small signal stability of synchronous machine under small disturbances is assessed and enhanced for Single Machine connected to an Infinite Bus (Heffron – Philips model). For the given operating conditions, comparative analysis is done with incorporation of power system stabilizer (PSS), PID – PSS for small signal stability enhancement of SMIB system. The system is simulated by using MATLAB / SIMULINK. Comparison is done for specific parameters i.e. Rotor speed deviation and Rotor angle deviation by using two different controller.

***Index Terms* - PSS, LFO, SMIB**

I. INTRODUCTION

Power system stability is defined as the property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance. Small signal stability is the ability of the power system to maintain synchronism when subjected to small disturbances. Small signal stability which is divided into two parts, Non-oscillatory Instability & Oscillatory Instability. Low Frequency Oscillation Occurs can be of two forms.(1). Steady increase in generator rotor angle due to lack of synchronizing torque.(2). Rotor oscillations of increasing amplitude due to lack of sufficient damping toque. Electric power systems are highly nonlinear systems and constantly experience changes in generation, transmission and load conditions. With the enormous increase in the demand for the electricity almost all major transmission networks in the world are operated close to their stability limits. Two distinct types of system oscillations First units at a generating station swinging with respect to the rest of the power system, such oscillations are referred to as "local plant mode" oscillations. The frequencies of these oscillations are typically in the range 0.8 to 2.0 Hz. Second oscillations is associated with the swinging of many machines in one part of the system against machines in other parts. These are referred to as "inter-area mode" oscillations. And have frequencies in the range 0.1 to 0.7 Hz. Automatic voltage regulator (AVR) gives the adjustment by controlling the first swing & keeps the electrical speed of the generator within the acceptable limit however the AVR is unable to control the oscillations in speed also known as low frequency oscillations (LFO).The power system stabilizer (PSS) introduced at generators to damp out these low frequency oscillation which is the main function of it. The synchronous generator consists of two essential elements, the armature winding placed on stator and the field winding placed on rotor &. When the rotor which houses the dc current excited field winding is rotated by prime mover and induces the alternating voltages in the three phase armature winding. The current starts flowing in the armature winding when load is connected across the synchronous machine output terminals. The frequency of the current and induced voltage is dependent on the speed of the rotor or it can be said that the frequency is synchronized to mechanical speed of the rotor. The stator current creates a revolving stator field which rotates at synchronous speed in air gap. It interacts with the revolving field of rotor & exerts a torque which opposes the rotation of rotor. This torque is known as “Electromagnetic Torque”. This torque reduces the speed of machine & retards the position of rotor relative to revolving stator field. The steady state is the equilibrium between these two opposing torques. Any fault or load changes the electromagnetic torque and upsets this equilibrium. This results into deceleration or acceleration of the rotor. The change in electromagnetic torque following can be resolved into two components as follows:

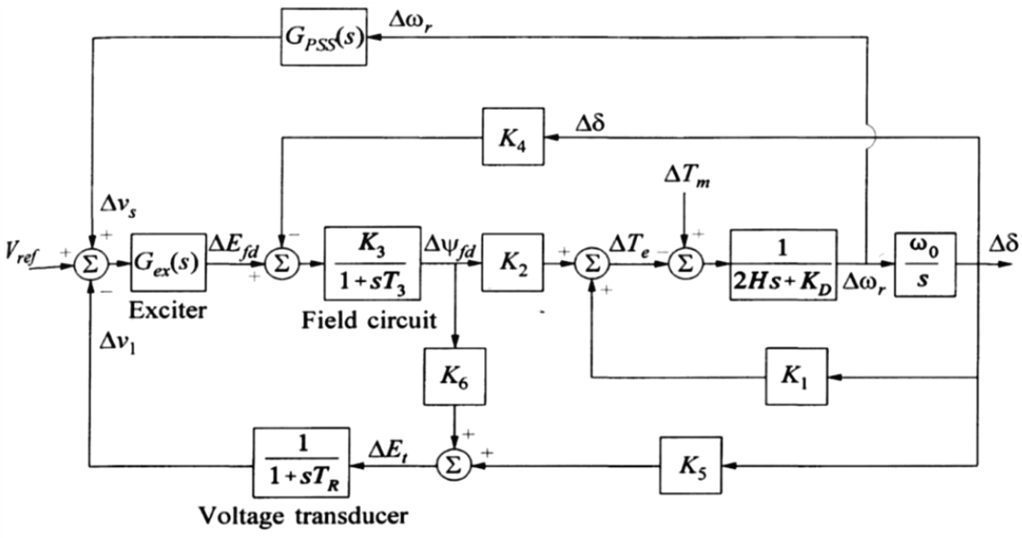

Fig:-1 SMIB (Heffron-Philips Model) with PSS and AVR

Modeling is the method of developing mathematical equations for the system parameters. The basic modeling is the classical model for the generator. To this basic Heffron-Philips model the effect of synchronous machine field circuit dynamics and excitation system is added to frame the complete system block diagram when it is taken as single machine infinite bus system as shown in Fig.1

II.POWER SYSTEM STABILIZER

Power system stabilizers (PSS) were developed to damping these oscillations via modulations of excitation system of generators. The action of a PSS is to extend the rotor angular stability limits of a power system by providing supplemental damping to the oscillation of synchronous machine rotors through the generator excitation

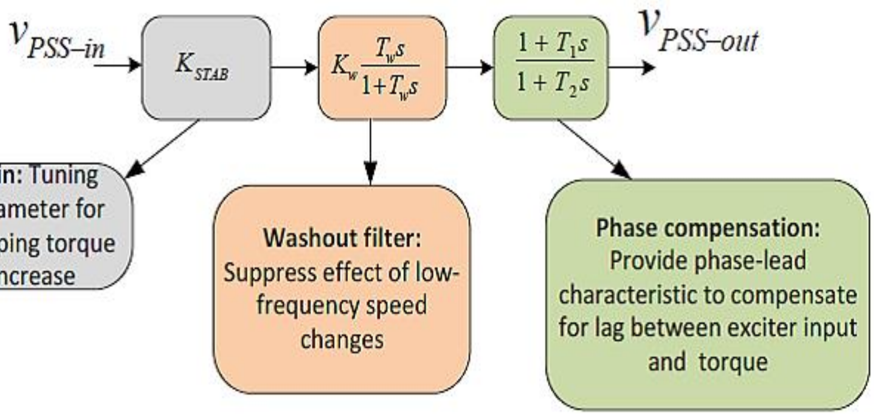

Fig:-2 Block Diagram of PSS

A. Structure of PSS

The block diagram of the PSS is shown below in Fig. 2. It consists of a signal washout block, phase compensation block and a gain block.

1) Gain block

The stabilizer gain Kstab determines the amount of damping introduced by the PSS. Ideally the gain should be set at a value corresponding to maximum damping; however it is often limited by other considerations.

2) Washout Circuit

The signal washout block serves as a high-pass filter, with the time constant Tw high enough to allow signals associated with oscillations to pass unchanged. Without it steady changes in speed would modify the terminal voltage. It allows the PSS to respond only to changes in speed. From the viewpoint of the washout function, the value of Tw is not critical and may be in the range of 1 to 20 seconds. The main consideration is that it be long enough to pass stabilizing signals at the frequencies of interest unchanged, but not so long that it leads to undesirable generator voltage excursions during system islanding conditions.

3) Phase Compensation Block

The phase compensation block provides the appropriate phase – lead characteristic to compensate for the phase lag between the exciter input and the generator electrical (air-gap) torque. The figure shows a single first order block. In practice, two or more first–order blocks may be used to achieve the desired phase compensation. Normally the frequency range of interest is 0.1 to 2.0 Hz, and the phase lead network should provide compensation over this entire frequency range. The phase characteristic to be compensated changes with system conditions, therefore a compromise is made and a characteristic acceptable for different system conditions is selected.

4) Input Signals

The input signals that have been identified as valuable include deviations in the rotor speed ($\Delta\omega$), the frequency (Δf), the electrical power (ΔPe) and the accelerating power (ΔPa). Since the main action of the PSS is to control the rotor oscillations, the input signal of rotor speed has been the most frequently advocated in the literature.

5) Limiter

The output of the power system stabilizer is required to be limited in order to prevent conflicts with AVR actions during load rejection.

B. Tuning techniques

A wide spectrum of PSS tuning approaches has been proposed. These approaches have included pole placement, damping torque concepts, $H\infty$ and LQG/LTR, nonlinear and variable structure and the different optimization and artificial intelligence techniques. Some of the proposed PSS are analog and others are digital. Self-tuning PSSs have been proposed along with fixed parameter PSSs. The conventional and widely used PSS structure is the lead lag compensator. However, state feedback and PID controllers are also being used. [5]

III.PID CONTROLLER DESIGN

Designing and tuning a proportional – integral – derivative (PID) controller appears to be conceptually intuitive, but can be hard in practice, if multiple (and often conflicting) objectives such as short transient and high stability are to be achieved. A PID controller may be considered as an extreme form of a phase lead-lag compensator with one pole at the origin and the other at infinity. Similarly, its cousins, the PI and the PD controllers, can also be regarded as extreme forms of phase lag and phase – lead compensators, respectively. A standard PID controller is also known as the "three-term" controller, whose transfer function is generally written in the "parallel form" given by or the ideal form

$$
\begin{aligned}
G(s) &= Kp + Ki\,(1/s) + Kds \\
&= Kp\,(1+1/T1s + Tds)
\end{aligned}
$$

Where Kp is the proportional gain, Ki is the integral gain, Kd is the derivative gain, T1 the integral time constant. The individual effects of KP, Ki, Kd on the closed loop performance are summarized in Table I. This table serves as a guide for stable open loop plants only. For optimum performance, Kp, Ki and Kd are mutually dependent in tuning

A. Tuning methods for PID controllers

With tuning objectives, the tuning methods for PID controllers can be grouped according to their nature and usage as follows:

1) Analytical methods

PID parameters are calculated from analytical or algebraic relations between a plant model and an objective (such as an internal mode control (IMC) or lambda tuning). These can lead to an easy-to-use formula and can be suitable for use with online tuning, but the objective needs to be in an analytical form and the model must be accurate.

2) Heuristic methods

These are evolved from practical experience in manual tuning (such as the Z-N tuning rule) and from artificial intelligence (including expert systems, fuzzy logic and neural networks).Again, these can serve in the form of a formula or a rule base for online use, often with tradeoff design objectives.

3) Frequency response methods

Frequency characteristics of the controlled process are used to tune the PID controller (such as loop-shaping). These are often offline and academic methods, where the main concern of design is stability robustness.

4) Optimization methods

These can be regarded as a special type of optimal control, where PID parameters are obtained ad hoc using an offline numerical optimization method for a single composite objective or using computerized heuristics or an evolutionary algorithm for multiple design objectives. These are often time-domain methods and mostly applied offline.

5) Adaptive tuning methods

These are for automated online tuning, using one or a combination of the previous methods based on real-time identification.

IV. SYSTEM DATA

The following are the nominal parameters of the system and the operating conditions used for the sample problem investigated. All data are given in the per units of value except H and time constants are in seconds.

Table I Generator parameters

Parameters	Values
H	4
Xd	1.81
Xq	1.76
Xd'	0.3
Td0'	8

Table II Excitation System with PSS parameters

Parameters	Values
K_{stab}	9.5
T_w	1.4
T_1	0.154
T_2	0.033
T_3	2.3576
Ka	200
T_R	0.02

IV. SIMULATION OF MODEL & RESPONSE

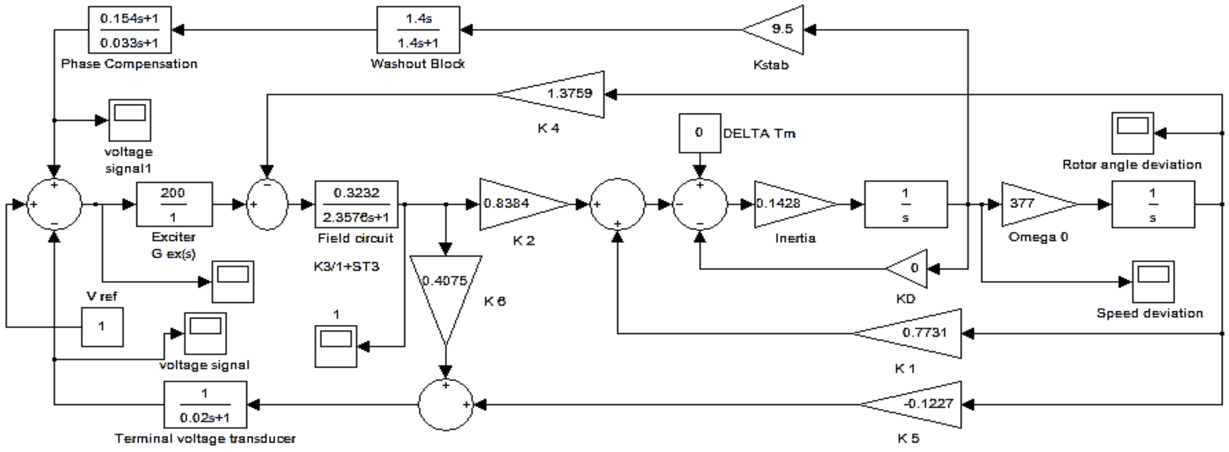

Fig:-3 Simulation of Heffron –Philips model with AVR and PSS

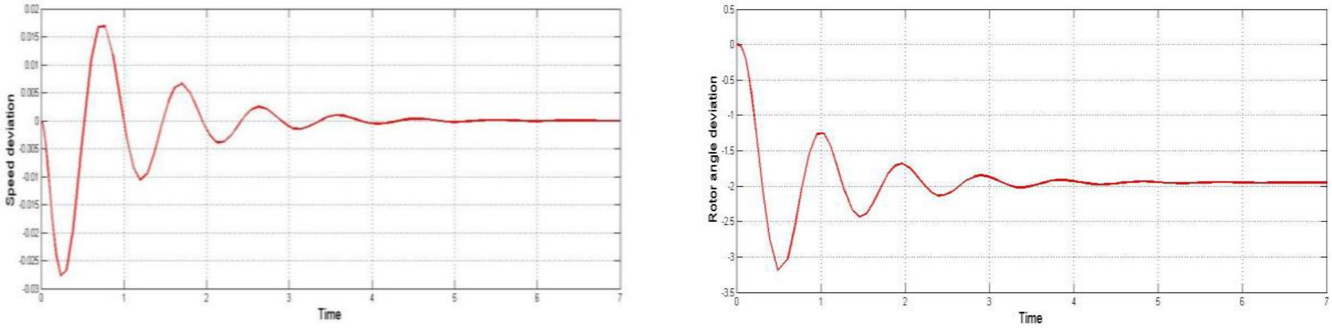

Fig: - 4 Simulation result of H-P model with AVR and PSS for deviation in Rotor speed and Rotor Angle

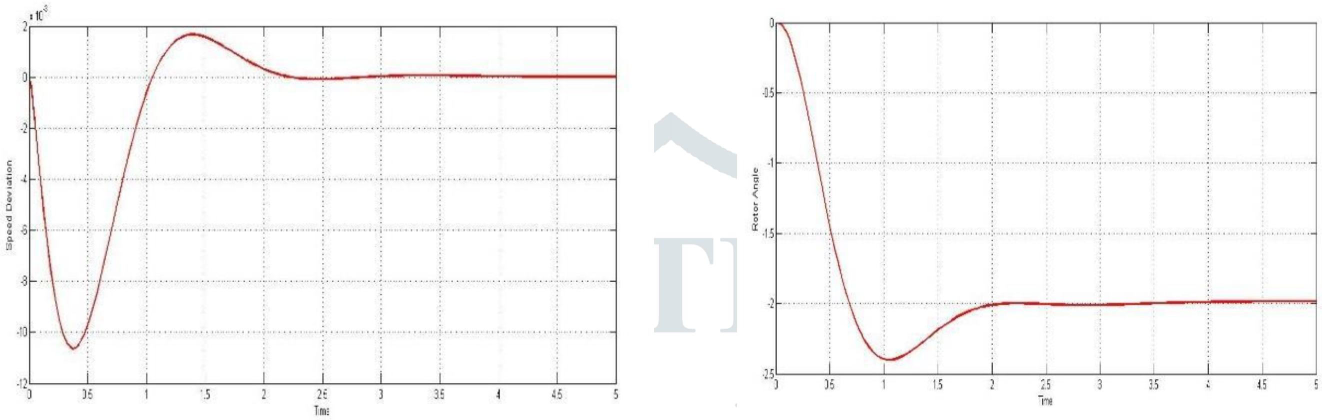

Fig: - 5 Simulation result of H-P model with AVR and PSS for deviation in Rotor speed and Rotor Angle

V. RESULT

P	**Q**	**Response**	**Settling time**	
			PSS	**PID-PSS**
0.85	**0.3**	**Speed Deviation**	**5.2**	**2.56**
		Rotor Angle	**5.15**	**2.54**
		Controller Output	**5.2**	**4**

VI. CONCLUSION

The results obtained in the presented work indicates that the power system parameters can be fixed through different approaches mentioned in the literature. In the approaches applied in this paper the result obtained for the PSS with manual tuning is best. However this method takes long time. The settling time for step disturbance with PSS are 5.2 sec and for manual tuning PID-PSS is 2.56 sec.

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REFERENCES

[1]. Francisco p. Demello, Charles Concordia, "Concepts of Synchronous Machine Stability as Affected by Excitation Control " IEEE transactions on power apparatus and systems, vol. Pas-88, no. 4, April 1969.

[2]. Kundur P., Klien, M., Rogers, G.J., and Zywno, M.S.: "Application of Power System Stabilizer for the enhancement of overall system stability", IEEE Trans., 1989, PWRS-4, pp. 614-626.

[3]. Balwinder Singh Surjan, Ruchira Garg "Power System Stabilizer Controller Design for SMIB Stability Study "International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-1, October 2012.

[4]. Larsen E.V. and Swann D.A.; "Applying power system stabilizers Part-I", Power Apparatus and Systems, IEEE Transactions, Volume: 100, No. 6, Page(s): 3017-3024, 1981.

[5]. Balwinder Singh Surjan, "Linearized Modeling of Single Machine Infinite Bus Power System and Controllers for Small Signal Stability Investigation and Enhancement "International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 1, Issue 8, October 2012.

[6].N.S. Ab Khalid, M.W. Mustafa and R. Mohamad Idris, "Analysis of Fuzzy Power System Stabilizer using Various Defuzzification Interface for Takagi- Sugeno Fuzzy Logic" IEEE International Power Engineering and Optimization Conference, Melaka, Malaysia: 6-7 June 2012.

[7].Lokman H. Hassan, M. Moghavvemi, Haider A.F. Almurib, K.M. Muttaqi, H. Du. "Damping of low-frequency oscillations and improving power system stability via auto-tuned PI stabilizer using Takagi–Sugeno fuzzy logic" Electrical Power and Energy Systems 38 (2012) 72–83, ELSEVIER

[9] P.Kundur, "Power system stability and control" New York: Tata McGraw-Hill, 1994.

[10] P.M Anderson and A. A. Fouad, "Power System Control and Stability

[11] Larsen E.V. and Swann D.A.; "Applying power system stabilizers Part- II", Power Apparatus and Systems, IEEE Transactions, Volume: 100, No. 6, Page(s): 3025-3033, 1981.

[12] Larsen E.V. and Swann D.A.; "Applying power system stabilizers Part- III", Power Apparatus and Systems, IEEE Transactions, Volume: 100, No. 6, Page(s): 3034-3046, 1981.

[11] Yuan Yih Hsu and Kan Lee Liou, "Design of PID power system stabilizers for synchronous generators" IEEE Trans., 1987, pp. 343-348
.

[12] Peter.W.Sauer, M.A.Pai, "Power System Dynamics and Stability," Published by Pearson Education (Singapore) Pte. Ltd., Indian Branch, 482 F.I.E. Patparganj Delhi, 1st Indian Reprint, 2002.

[13] K.R. Padiyar, "Power System Dynamics: Stability And Control," Interline Publishing Pvt. Ltd Banglore, 1996.

[14] Kiam Heong Ang, Gregory Chong, Student member, IEEE, and Yun Li, Member, IEEE, "PID Control System Analysis, Design and Technology", IEEE Trans. On Control System Technology, Vol.13, No.4 July, 2005.

[15] Wen Tan, Jizhen Liu, Tongwen Chen, Horacio J. Marquez, "Comparison of some well-known PID tuning formulas" Computer & Chemical Engineering 30 (2006) Elsevier, pp1416-1423\