Dynamic Stability Enhancement of Power System using Fuzzy Logic Based Power System Stabilizer

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***Abstract*— The power system is a dynamic system and it is constantly being subjected to disturbances. It is important that these disturbances do not drive the system to unstable conditions. For this purpose, additional signal derived from deviation, excitation deviation and accelerating power are injected into voltage regulators. The device to provide these signals is referred as power system stabilizer.**

The use of power system stabilizer has become very common in operation of large electric power systems. The conventional PSS which uses lead-lag compensation, where gain setting designed for specific operating conditions, is giving poor performance under different loading conditions. Therefore, it is very difficult to design a stabilizer that could present good performance in all operating points of electric power systems. In an attempt to cover a wide range of operating conditions, Fuzzy logic control has been suggested as a possible solution to overcome this problem, thereby using linguist information and avoiding a complex system mathematical model, while giving good performance under different operating conditions.

Keywords- Generator Excitation System, Synchronous Machine Model, Automatic Voltage Regulator (AVR), Power System Stabilizer, Fuzzy Logic Controller (FLC), PID, Controller Design, Robust control.

I. INTRODUCTION

The power system is a dynamic system. It is constantly being subjected to disturbances, according to which generator voltage angle changes. When these disturbances removed, a new corrective steady state operating condition is reached. It is important that these disturbances do not drive the system to unstable condition. The disturbances may be of local mode having frequency range of 0.7 to 2 Hz or of inter area modes having frequency range in 0.1 to 0.8 Hz, these swings are due to the poor damping characteristics caused by modern voltage regulators with high gain. A high gain regulator through excitation control has an important effect of eliminating synchronizing torque but it affects the damping torque negatively. To compensate the redundant effect of the voltage regulators in the excitation system, additional signals are proposed as a input signal in the feedback for the voltage regulators. The additional signals are mostly derived from excitation system deviation, speed deviation or accelerating power. This is accomplished by inserting a stabilizing signal into the excitation system voltage reference summing point junction. The device arrangement is to provide the signal is called “power system stabilizer”.

Excitation control is well known as one of the effective means to enhance the overall stability of electrical power systems. Present day excitation systems predominantly constitute the fast acting AVRs. A highly response excitation system is useful in increasing the synchronizing torque, thus improving the transient stability of the system i.e. to hold the generator in synchronism with power system during large transient fault condition. However, it produces a negative damping especially at high values of external system reactance and high generator outputs. Generator excitation controls have been installed and made faster to improve stability. PSS have been added to the excitation systems to improve the oscillatory instability it is used to provide a supplementary signal to excitation system. The basic function of PSS is to extend the stability limit by modulating generator excitation to provide the positive damping torque to power swing modes.

II. SYSTEM MODELING

The Mathematical Models needed for small signal analysis of Synchronous Machines, Excitation System and lead-lag power system stabilizer are briefly reviewed. The Guidelines for the selection of Power System Stabilizer parameters are also presented.

A. Synchronous Machine Model

The synchronous machine is vital for power system operation. The general system configuration of synchronous machine connected to infinite bus through transmission network can be represented as the mathematical models needed for small signal analysis of synchronous machine; excitation system and the lead-lag power system stabilizer are briefly reviewed. The guidelines for the selection of power system stabilizer parameters are also presented. The Thevenin’s equivalent circuit shown in Fig. 1.1

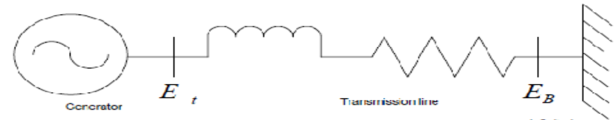

Fig. 1.1The equivalent circuit of synchronous machine connected to infinite bus.

B. Classical System Model

The generator is represented as the voltage E' behind Xd' as

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shown in Fig. 1.2. The magnitude of E' is assumed to remain constant at the pre-disturbance value. Let d be the angle by which E' leads the infinite bus voltage E_B. The d changes with rotor oscillation. The line current is expressed as –

$$I_t = \frac{E'\angle 0^0 - E_B\angle -\delta}{jX_T} = \frac{E' - (E_B\cos\delta - j\sin\delta)}{jX_T}$$

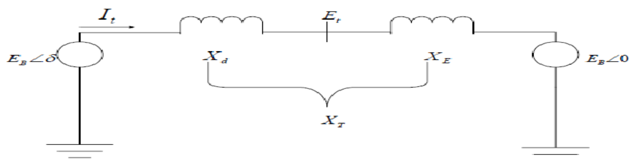

Fig. 1.2: Classical model of generator

$$S = P + jQ = \frac{E' E_B \sin\delta}{X_T} + j\frac{E'(E' - E_B\cos\delta)}{X_T}$$

With stator resistance neglected, the air-gap power (Pe) is equal to the terminal power (P). In per unit, the air-gap torque is equal to the air gap power.

The above equation to describe small-signal performance is represented in schematic Fig. 1.3.

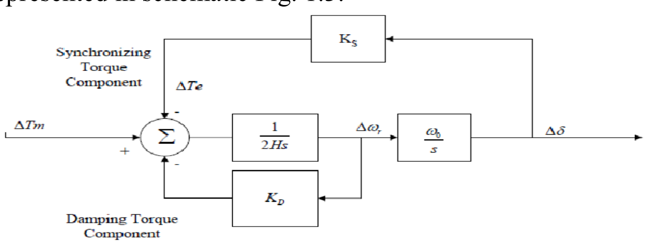

Fig. 1.3: Block diagram of single machine infinite bus system with classical model

From the block diagram we have:

$$\Delta\delta = \frac{\omega_0}{s}\left(\frac{1}{2Hs}\ (-K_s\Delta\delta - K_D\Delta\omega_r + \Delta T_M)\right)$$

$$= \frac{\omega_0}{s}\left(\frac{1}{2Hs}\ (-K_s\Delta\delta - K_D\frac{\Delta\delta}{\omega_0}s + \Delta T_M)\right)$$

Solving the block diagram we get the characteristics equation:

$$s^2 + \frac{K_D}{2H}s + \frac{K_s\omega_0}{2H} = 0$$

Comparing it with general form, the undamped natural frequency ω_n and damping ratio ξ are expressed as –

$$\omega_n = \sqrt{\frac{K_s\omega_0}{2H}}$$

$$\xi = \frac{1}{2}\frac{K_D}{\sqrt{K_s 2H\omega_0}}$$

III. POWER SYSTEM STABILISER

The basic function of power system stabilizer is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signals. For provide damping signal the stabilizer must produce a component of electrical torque in phase with rotor speed deviation. The Power System Stabilizer with the aid of block diagram as shown in Fig. 1.4

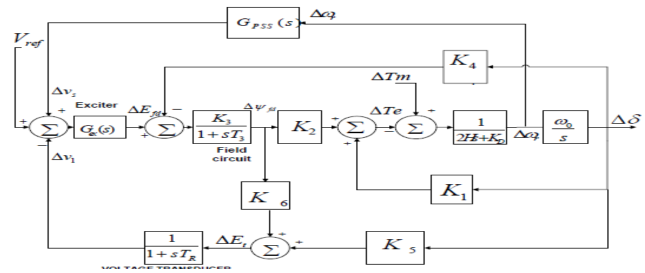

Fig. 1.4: Block diagram representation with AVR and PSS

Since the purpose of PSS is to introduce a damping torque component. A logical signal is use for controlling generator excitation is the speed deviation $\Delta\omega_r$. The PSS transfer function GPSS(s), should have appropriate Gain, Washout signals and Phase Compensation circuits to compensate for the phase lag between exciter input and electrical torque. The following is a brief description of the basis for the PSS configuration and consideration in selection of parameters.

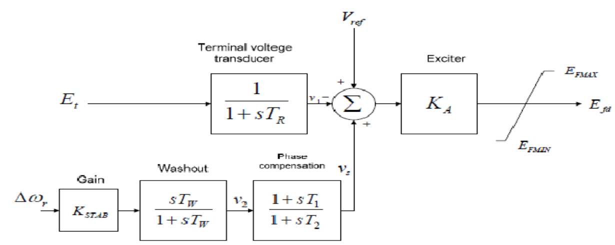

Fig. 1.5: Thyristor excitation system with AVR and PSS

III. FUZZY CONTROLLER

The fuzzy control systems are rule-based systems in which a set of fuzzy rules represent a control decision mechanism to adjust the effects of certain system stimuli. With the help of effective rule base, fuzzy control systems can replace a skilled human operator. The fuzzy logic controller provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy. The Fig. 1.6 illustrates the schematic design of a fuzzy logic controller which consists of a fuzzification interface, a knowledge base, control system (process), decision making logic, and a defuzzification interface.

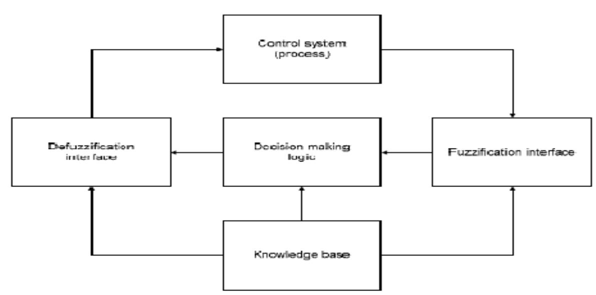

Fig. 1.6: The principle design of fuzzy logic controller