1- Power System Stability

1-1 Introduction

Maintaining synchronism between the various elements of a power system has become an important task in power system operation as systems expanded with increasing inter connection of generating stations and load centers. The electromechanical dynamic behavior of the prime mover-generator-excitation systems, various types of motors and other types of loads with widely varying dynamic characteristics can be analyzed through somewhat oversimplified methods for understanding the processes involved. There are three modes of behavior generally identified for the power system under dynamic condition. They are

(a) Steady state stability
(b) Transient stability
(c) Dynamic stability

Stability is the ability of a dynamic system to remain in the same operating state even after a disturbance that occurs in the system.

Stability when used with reference to a power system is that attribute of the system or part of the system, which enables it to develop restoring forces between the elements thereof, equal to or greater than the disturbing force so as to restore a state of equilibrium between the elements.

A power system is said to be steady state stable for a specific steady state operating condition, if it returns to the same steady state operating condition following a disturbance. Such disturbances are generally small in nature.

A stability limit is the maximum power flow possible through some particular point in the system, when the entire system or part of the system to which the stability limit refers is operating with stability.

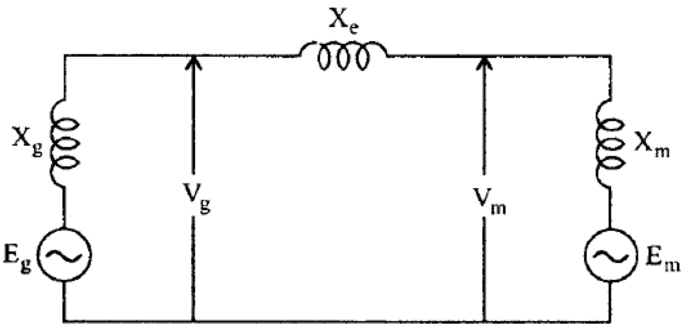
Larger disturbances may change the operating state significantly, but still into an acceptable steady state. Such a state is called a transient state.

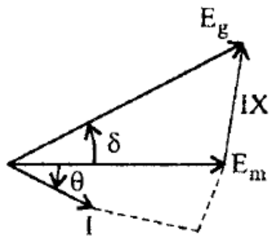
The third aspect of stability viz. Dynamic stability is generally associated with excitation system response and supplementary control signals involving excitation system. This will be dealt with later.

Instability refers to a condition involving loss of 'synchronism' which is also the same as 'falling out of the step' with respect to the rest of the system.

1-2 Illustration of Steady State Stability Concept

Consider the synchronous generator-motor system shown in Fig.1. The generator and motor have reactances Xg and Xm respectively. They ~re connected through a line of reactance Xe' The various voltages are indicated.





From the Fig.

$$E_g = E_m + j \times I;$$

$$I = \frac{E_g - E_m}{jX} \quad \text{where } X = X_g + X_e + X_m$$

Power delivered to motor by the generator is:

$$P = \text{Re}\,[E\, I^*]$$

$$= \text{Re}\,[E_g \angle\delta] \frac{\left[E_g \angle\delta - E_m \angle 0^o\right]}{X \angle -90^o}$$

$$= \frac{E_g^{\,2}}{X} \text{ Cos } 90^o - \frac{E_g\, E_m}{X} \text{ Cos } (90 + \delta)$$

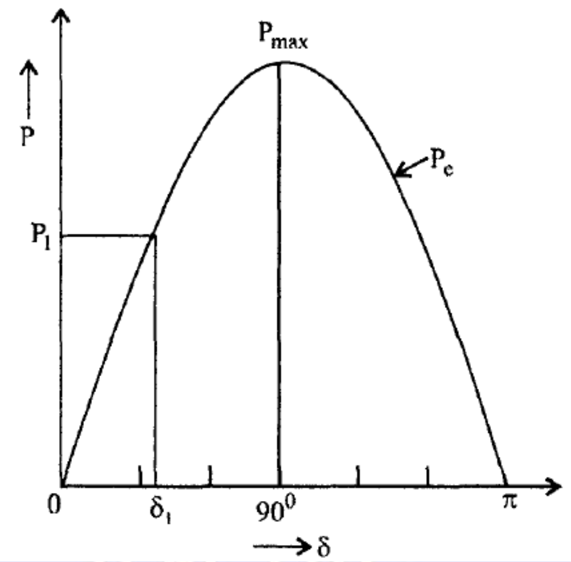
$$P = \frac{E_g\, E_m}{X} \text{ Sin } \delta$$

P is a maximum when $\delta = 90^o$

$$P_{max} = \frac{E_g\, E_m}{X}$$

The graph of P versus δ is called power angle curve and is shown in Fig.2. The system will be stable so long $\frac{dp}{d\delta}$ is positive. Theoretically, if the load power is increased in very small increments from $\delta = 0$ to $\delta = \pi/2$, the system will be stable. At $\delta = \pi/2$.

The steady state stability limit will be reached P_{max} is dependent on Eg, Em and X. Thus, we obtain the following possibilities for increasing the value of P_{max} indicated in the next section.


P
P_{max}
P_e
P_1
0
δ_1
90^0
π
δ