1-3 Methods for Improving Steady State Stability Limit

1. Use of higher excitation voltages, thereby increasing the value of Eg.

2. Reducing the reactance between the generator and the motor. The reactance X = Xg + Xm + Xe is called the transfer reactance between the two machines and this has to be brought down to the possible extent.

Synchronizing Power Coefficient

We have $$P = \frac{E_g\ E_m}{X} \sin\delta$$

The quantity $$\frac{dP}{d\delta} = \frac{E_g\ E_m}{X} \cos\delta$$

is called Synchronizing power coefficient or stiffness.

For stable operation dP/dδ, the synchronizing coefficient must be positive.

Transient Stability

Steady state stability studies often involve a single machine or the equivalent to a few machines connected to an infinite bus. Undergoing small disturbances. The study includes the behavior of the machine under small incremental changes in operating conditions about an operating

point on small variation in parameters.

When the disturbances are relatively larger or faults occur on the system, the system enters transient state. Transient stability of the system involves non-linear models. Transient internal voltage E_g' and transient reactances Xd' are used in calculations.

The first swing of the machine (or machines) that occur in a shorter time generally does not include the effect off excitation system and load-frequency control system. The first swing transient stability is a simple study involving a time space not exceeding one second.

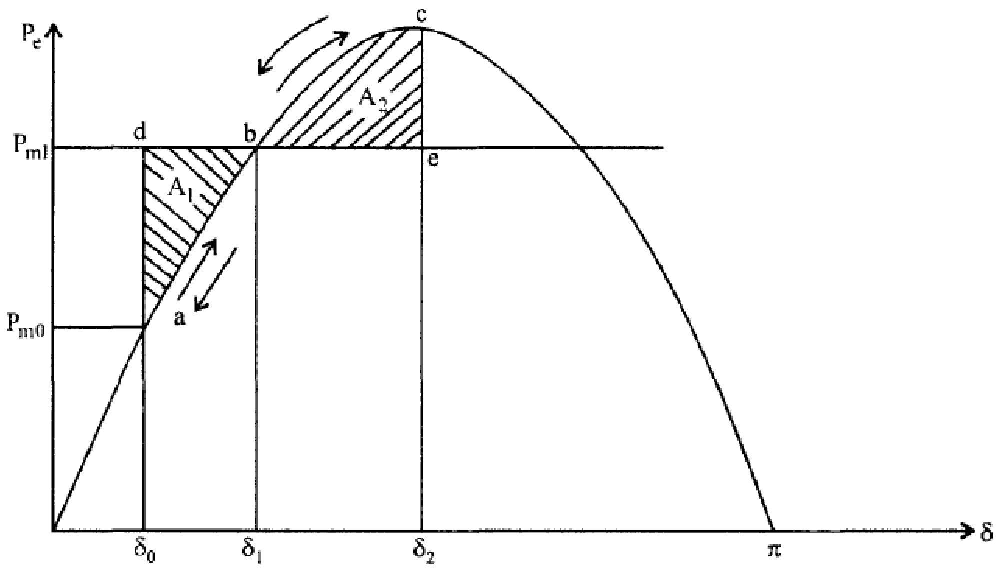
If the machine remains stable in the first second, it is presumed that it is transient stable for that disturbances. However, where disturbances are larger and require study over a longer period beyond one second, multi swing studies are performed taking into effect the excitation and turbine-generator controls. The inclusion of any control system or supplementary control depends upon the nature of the disturbances and the objective of the study.

Stability of a Single Machine Connected to Infinite Bus:

Consider a synchronous motor connected to an infinite bus. Initially the motor is supplying a mechanical load P_{mo} while operating at a power angle δo, The speed is the synchronous speed *W*s' Neglecting losses power in put is equal to the mechanical load supplied. If the load on the motor is suddenly increased to P_{m1}' this sudden load demand will be met by the motor by giving up its stored kinetic energy and the motor, therefore, slows down. The torque angle δ increases from δo to δ1 when the electrical power supplied equals the mechanical power demand at b as shown in Fig.3. Since, the motor is decelerating, the speed, however, is less than Ns at b. Hence, the torque 'angle δ' increases further to δ2 where the electrical power P_e is greater than P_{ml} , but N = Ns at point c. At this point c further increase of δ is arrested as $P_e > P_{ml}$ and N = Ns. The torque angle starts decreasing till δ1 is reached at b but due to the fact that till point b is reached Pe is still greater than P_{m1} speed is more than Ns. Hence, δ decreases further till point **a** is reacted where N = Ns but

P_{ml} > Pe . The cycle of oscillation continues. But, due to the damping in the system that includes friction and losses, the rotor is brought to the new operating point b with speed N = Ns.

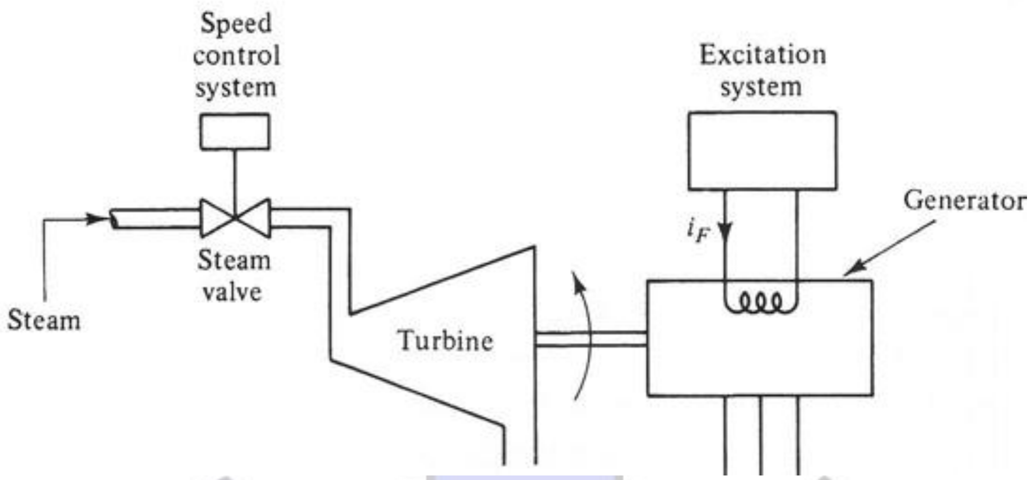
In Fig.3 area 'abd' represents deceleration and area bce acceleration. The motor will reach the stable operating point b only if the accelerating energy A1 represented by bce equals the decelerating energy A2 represented by area abd.



1-3 The Swing Equation

It is the equation governing the motion of the rotor of a synchronous machine.

Consider a generating unit consisting of a three-phase synchronous generator and prime mover, as shown in Figure.



The motion of the synchronous generator's rotor is determined by Newton second law, which is given as:

$J\alpha_m = T_m - T_e = T_a$……………………………………………..1

Where

J = Total moment of inertia of the rotating masses (prime mover and generator) (kgm^2)

α_m = Rotor angular acceleration (rad/s^2)

Tm = Mechanical torque supplied by the prime mover minus the retarding torque due to mechanical losses(e.g. Friction) (Nm)

Te = Electrical torque, accounting for the total three-phase power output and losses (Nm)

Ta= Net accelerating torque (Nm)

The rotor angular acceleration is given by

$\alpha_m = \frac{d\omega_m}{dt} = \frac{d^2\theta_m}{dt^2}$…………………………………………………………2

$\omega_m = \frac{d\theta_m}{dt}$…………………………………………………..3

Where

ω_m = Rotor angular velocity (rad/s)

θ_m= Rotor angular position with respect to a stationary axis (rad)

In steady state conditions the mechanical torque equals the electrical torque and the accelerating torque is zero. There is no acceleration and the rotor speed is constant at the synchronous velocity.

When the mechanical torque is more than the electrical torque then the acceleration torque is positive and the speed of the rotor increases. When the mechanical torque is less than the electrical torque then the acceleration torque is negative and the speed of the rotor decreases.

Since we are interested in the rotor speed relative to the synchronous speed it is convenient to measure the rotor angular position with respect to a synchronously rotating axis instead of a stationary one.

We therefore define:

$\theta_m = \omega_{msyn} t + \delta_m$……………………………..4

ω_{msyn}=Synchronous angular velocity of the rotor, rad/s

δ_m=Rotor angular position with respect to a synchronously rotating reference.