UNIT IV

STABILITY ANALYSIS

Rotor Angle Stability

- It is the ability of interconnected synchronous machines of a power system to maintain in synchronism. The stability problem involves the study of the electro mechanical oscillations inherent in power system.

- Types of Rotor Angle Stability

  1. Small Signal Stability (or) Steady State Stability

  2. Transient stability

Voltage Stability

- ❖ It is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance.

- ❖ The major factor for instability is the inability of the power system to meet the demand for reactive power.

- Mid Term Stability

It represents transition between short term and long term responses.

Typical ranges of time periods.

1. Short term : 0 to 10s
2. Mid Term : 10 to few minutes
3. Long Term : a few minutes to 10's of minutes

- Long Term Stability

  Usually these problem be associated with

  1. Inadequacies in equipment responses.
  2. Poor co-ordination of control and protection equipment.
  3. Insufficient active/reactive power reserves.

Compute the change in state vector

$$\Delta\delta^k = \frac{\left(K_1^k + 2K_2^k + 2K_3^k + K_4^k\right)}{6}$$

$$\Delta\omega^k = \frac{\left(l_1^k + 2l_2^k + 2l_3^k + l_4^k\right)}{6}$$

Evaluate the new state vector

$$\delta^{k+1} = \delta^k + \Delta\delta^k$$

$$\omega^{k+1} = \omega^k + \Delta\omega^k$$

Evaluate the internal voltage behind transient reactance using the relation

$$E_p^{k+1} = \left|E_p^k\right| \cos\delta_p^{k+1} + j\left|E_p^k\right| \sin\delta_p^{k+1}$$

Check if $t<t_c$ yes K=K+1

Check if j=0,yes modify the network data and obtain the new reduced admittance matrix and set j=j+1

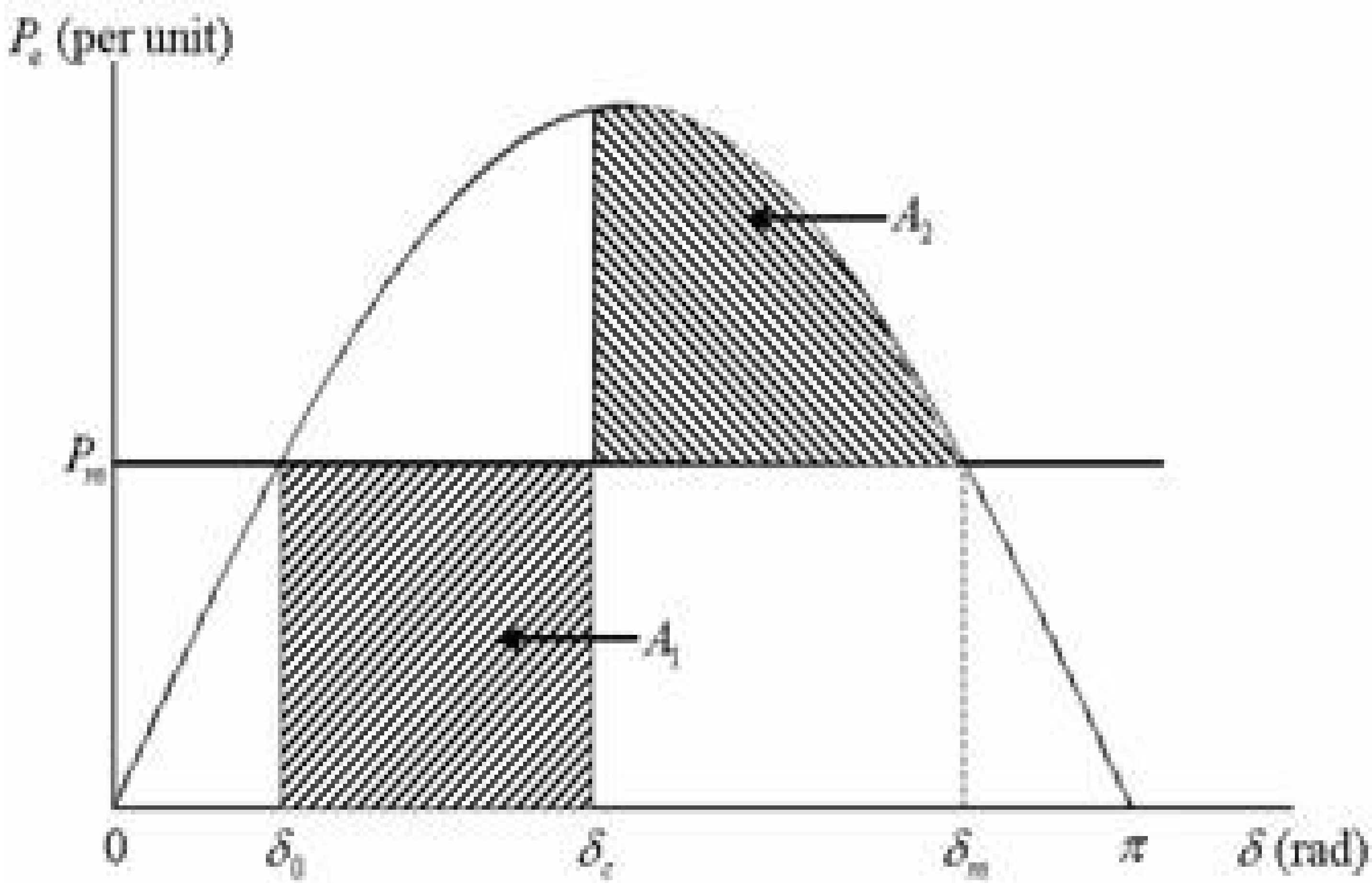
set K=K+1

Check if K<Kmax, yes start from finding 8 constants

Equal Area Criterion

- This is a simple graphical method to predict the transient stability of two machine system or a single machine against infinite bus. This criterion does not require swing equation or solution of swing equation to determine the stability condition.

- The stability conditions are determined by equating the areas of segments on power angle diagram.



Power-angle curve for equal area criterion

multiplying swing equation by $d\delta/dt$ on both sides

$$\frac{H}{\omega_s}\frac{d}{dt}\left(\frac{d\delta}{dt}\right)^2 = (P_m - P_e)\frac{d\delta}{dt}$$

$$\frac{d}{dt}\left(\frac{d\delta}{dt}\right)^2 = 2\left(\frac{d\delta}{dt}\right)\left(\frac{d^2\delta}{dt^2}\right)$$

Multiplying both sides of the above equation by *dt* and then integrating between two arbitrary angles δ_0 and $\delta_{c.}$

$$\frac{H}{\omega_s}\left(\frac{d\delta}{dt}\right)^2\Bigg|_{\delta_0}^{\delta_c} = \int_{\delta_0}^{\delta_c}(P_m - P_e)\,d\delta$$

Once a fault occurs, the machine starts accelerating. Once the fault is cleared, the machine keeps on accelerating before it reaches its peak at δ_c , The area of accelerating A1

$$A_1 = \int_{\delta_0}^{\delta_c} (P_m - P_e)\, d\delta = 0$$

The area of deceleration is given by A_2

$$A_2 = \int_{\delta_c}^{\delta_m} (P_e - P_m)\, d\delta = 0$$

If the two areas are equal, i.e., $A_1 = A_2$, then the power system will be stable

Critical Clearing Angle (δ_{cr}) maximum allowable value of the clearing time and angle for the system to remain stable are known as critical clearing time and angle.

δ_{cr} expression can be obtained by substituting $\delta_c = \delta_{cr}$ in the equation A1 = A2

$$\int_{\delta_0}^{\delta_{cr}} (P_m - P_e) d\delta = \int_{\delta_{cr}}^{\delta_m} (P_e - P_m) d\delta$$

Substituting P_e = 0 in swing equation

$$\frac{d^2\delta}{dt^2} = \frac{\omega_s}{2H} P_m$$

Integrating the above equation

$$\frac{d\delta}{dt} = \int_0^t \frac{\omega_s}{2H} P_m dt = \frac{\omega_s}{2H} P_m t$$

$$\delta = \int_0^t \frac{\omega_s}{2H} P_m t \, dt = \frac{\omega_s}{4H} P_m t^2 + \delta_0$$

Replacing δ by δ_{cr} and t by t_{cr} in the above equation, we get the critical clearing time as

$$t_{cr} = \sqrt{\frac{4H}{\omega_s P_m}\left(\delta_{cr} - \delta_0\right)}$$

Factors Affecting Transient Stability

- Strength of the transmission network within the system and of the tie lines to adjacent systems.

- The characteristics of generating units including inertia of rotating parts and electrical properties such as transient reactance and magnetic saturation characteristics of the stator and rotor.

- Speed with which the faulted lines or equipments can be disconnected.

Thank you