22/08/17

Unit-4

Power system Steady state stability Analysis

* A power system consists of synchronous machine operating in synchronism under all conditions when the system is subjected to some form of disturbance there is a tendency for the system to develop restoring force to bring it to normal (or) stable condition.

* The Ability of the system to reach normal (or) stable condition after being disturbed is called "stability".

* Power system stability is that the property of a power system which ensures that the operation of the system is with in the specified limits of voltage and power angle during normal and abnormal changes in operating conditions.

* If the system is unable to develop the restoring forces after the disturbance then that system is referred to unstable and its tendency is known as "Instability".

* There are two forms of Instability in the power systems

① Loss of synchronism b/n synchronous machines

② Stalling of Asynchronous loads.

Types of stability:-

* Stability is categorised into 3 types depends upon the magnitude of disturbance. They are

① Steady state
② Transient state
③ Dynamic state.

① Steady state stability

* It is the Ability of the system to bring it to stable condition after a small disturbance occured.

* It is basically concerned with the effect of Gradual variation of load.

② Transient state stability

* It is the Ability of the system to bring it to a stable condition after a long disturbance is occured

* It is concerned with sudden and large changes in the network conditions.

* The large disturbances can occure due to sudden load change, switching operation, and faults with subsequent circuit isolation.

③ Dynamic state stability

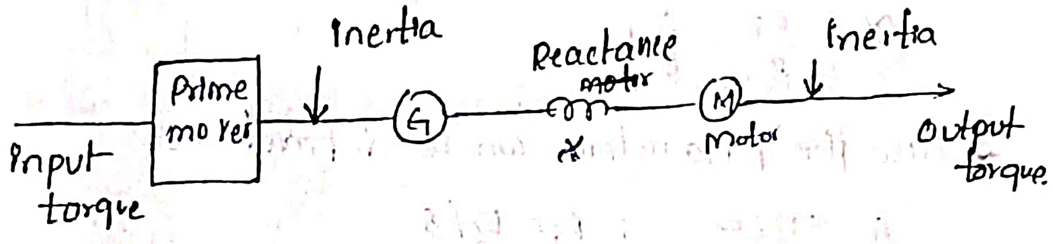
* It is an extension of steady state stability which is concerned with small disturbances lasting for long time with the inclusion of Automatic control devises. The stability can be significant improved through the use of power system stabilizer

* The steady state stability can and Dynamic stability can be differentiated between operations with and without automatic control devices such as Governers, voltage reggulators.

Stability Limits :-

* The stability limit is the Maximum power that can be transferred in the network between sources and & loads without loss of synchronism.
* It is the Maximum power that can be transferred without the system becoming unstable when a small disturbance occurs in the power system network
* The Validity of on the Application of large disturbance is responsible for the Loss of stability otherwise It may be possible to maintain stability if the same large load is applied gradually.
* Thus & transient stability limits is lower than the steady state stability limits.

Essential factors in the stability Problem :-



There are two types of factors.

* Mechanical factor:
  a) Prime Over i/p Torque
  b) Inertia of prime & mover & generator
  c) Inertia of motor shaft load
  d) shaft load output torque.

* Electrical factors:

a) Internal voltage of synchronous generator
b) Reactance of a system including generator line and motor
c) Internal voltage of synchronous motor

Expression for steady state power:

* The expression for steady state power which can be received (or) transmitted in terms of receiving end and sending end voltages line constants.

* The Network equation in terms of ABCD parameters are given by

$$E_s = AE_r + BI_r$$

$$I_s = CE_r + DI_r$$

$$\therefore I_r = \frac{E_s}{B} - \frac{A}{B}E_r$$

* Now the parameters can be defined as

$A = |A|\angle\alpha$; $E_s = E_s\angle\delta$

$B = |B|\angle\beta$; $E_r = E_r\angle 0$

$$\therefore I_r = \left|\frac{E_s}{B}\right|\angle\delta-\beta - \left|\frac{A}{B}E_r\right|\angle\alpha-\beta$$

* Conjugate of receiving end current, I_r is

$$I_r^* = \frac{E_s}{B}\angle\beta-\delta - \frac{A}{B}E_r\angle\beta-\alpha$$

* The complex power at receiving end is given by

$$S_r = P_r + jQ_r$$

$$= E_r \cdot I_r^*$$

$$= E_r \angle 0 \left[\frac{E_s}{B} \angle \beta - \delta - \frac{A}{B} E_r \angle \beta - \alpha \right]$$

$$S_r = \frac{E_s E_r}{B} \angle \beta - \delta - \frac{A}{B} E_r^2 \angle \beta - \alpha$$

* Seperating the real & reactive powers

$$P_r = \frac{E_s E_r}{B} \cos(\beta - \delta) - \frac{A E_r^2}{B} \cos(\beta - \alpha) \quad \text{— ①}$$

$$Q_r = \frac{E_r E_s}{B} \sin(\beta - \delta) - \frac{A E_r^2}{B} \sin(\beta - \alpha)$$

* Neglecting the resistance of the line values of ABCD

$A = 1\angle 0$; $C = 0$

$B = X\angle 90°$; $D = 1\angle 0°$

* The receiving end power is given as

$$P_r = \frac{E_r E_s}{X} \cos(90 - \delta)$$

$$= \frac{-E_r^2}{X} \cos(90 - \delta)$$

$$P_r = -\frac{E_r E_s}{X} \sin \delta$$

* So the power can be transmitted depending upon the reactance of the system the angle b/n two rotors

$\delta = 90°$

$P_r = P_{max}$

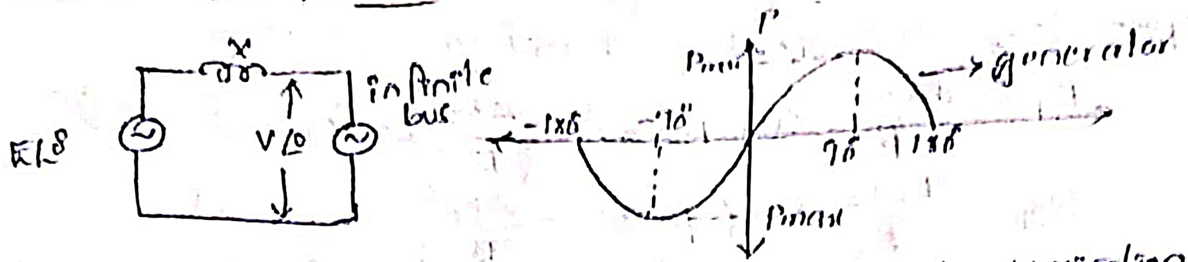
* The maximum value of 'δ' for maximum power transfer is $90°$.

* In actual practice 'δ' is maximum power tran kept around $30°$ to $45°$

$\therefore P = P_{max} \sin\delta$

* The total reactance 'X' which directly connects the two EMF sources is known as transfer reactance and has an important effect on power angle curve

Power Angle Curve:-



* Consider the steady state real angle variation with both generator and motor for constant values of 'E','V' and 'X' as shown in the figure.
* power angle 'δ' is +ve' i.e., E leads 'V' for generator action and -ve E lags V' for motoring action.
* Assume that the generator is working under the steady state condition i.e., $\delta = \delta_0$.
* Let the power angle 'δ' increase by a small amount of $\Delta\delta$. Therefore the increase in synchronous power o/p is

$$\Delta P = \frac{dP}{d\delta} \Delta\delta$$

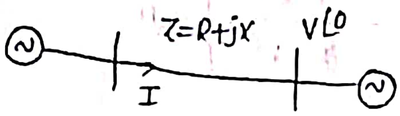
$$P_E = \frac{EV}{X} \sin\delta$$

$$P_{sy} = \frac{dP}{d\delta} = \frac{EV}{X} \cos\delta$$

$$\therefore \Delta P = P \sin\Delta\delta$$

* The Quantity P_{sy} is known as synchronising power co-efficient (or) stiffness co-efficient of Machine. An increase in power angle will results in increase in power i.e, for $\delta<0, \delta>90°$ the system is unstable. It is going to be stable when δ lies b/n 0 & 90° i.e., $0 \le \delta \le 90°$. The Max value of δ for sucessful operation is 90°

Power Transfer through Impedence :-



$$|Z| = \sqrt{R^2+X^2}$$

$$\theta = Tan^{-1}\left(\frac{R}{Z}\right)$$

$$= Tan^{-1}\left(\frac{R}{\sqrt{R^2+X^2}}\right)$$

$$I = \frac{E\angle\delta - V\angle 0}{Z\angle\theta}$$

$$= \frac{E}{Z}\angle\delta-\theta - \frac{V}{Z}\angle-\theta$$

$$I^* = \frac{E}{Z}\angle\theta-\delta - \frac{V}{Z}\angle\theta$$

$$S = P+jQ = VI^*$$

$$= V\angle 0^\circ \times \left[\frac{E}{Z}\angle\theta-\delta - \frac{V}{Z}\angle\theta\right]$$

$$S = \frac{EV}{Z}\angle\theta-\delta - \frac{V^2}{Z}\angle\theta$$

By separating real & imaginary parts as separate

$$P = Real\ (S)$$

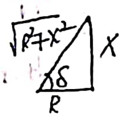
$$= \frac{EV}{Z}\cos(\theta-\delta) - \frac{V^2}{Z}\cos\theta$$

Let $\alpha = 90-\theta$

$\theta = 90-\alpha$

$$= \frac{EV}{Z}\cos(90-\alpha-\delta) - \frac{V^2}{Z}\cos(90-\alpha)$$

$$= \frac{EV}{Z}\sin(\alpha+\delta) - \frac{V^2}{Z}\sin\alpha$$



P is maximum when $\alpha+\delta = 90^\circ = \frac{\pi}{2}$

$\therefore \sin\alpha = \frac{R}{\sqrt{R^2+X^2}}$

$$P_{max} = \frac{EV}{Z} - \frac{V^2}{Z}\sin\alpha = \frac{EV}{\sqrt{R^2+X^2}} - \frac{V^2}{\sqrt{R^2+X^2}} \cdot \frac{R}{\sqrt{R^2+X^2}}$$

If E=V then

is 90°

$$P = \frac{V^2}{\sqrt{R^2+X^2}} - \frac{V^2 R}{R^2+X^2}$$

$\frac{dP}{dX}=0$

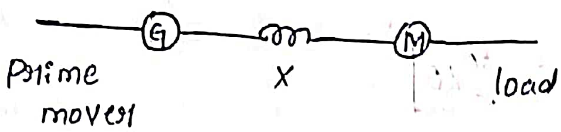
$$\Rightarrow \frac{dP}{dX} = V^2\left[\frac{-\frac{1}{2}(2X)}{(R^2+X^2)^{3/2}} - \frac{R(2X)}{(R^2+X^2)^2}\right] = 0$$

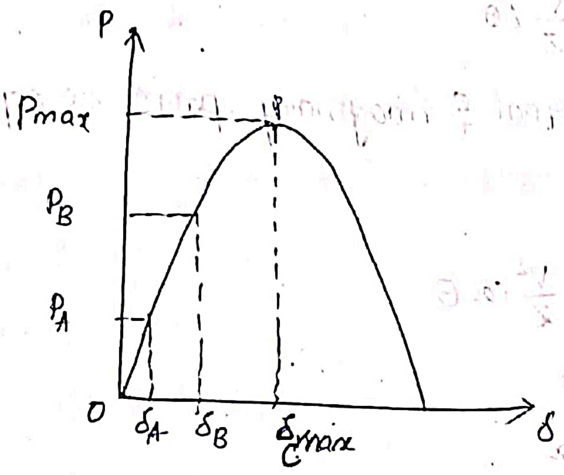
$$= \frac{-X}{(R^2+X^2)^{3/2}} - \frac{2RX}{(R^2+X^2)^2} = 0$$

$$\therefore X = \sqrt{3}R$$

* The finite value of resistance is necessary if $R=0$ then $\alpha=0$

Determination of steady state stability:-





* Consider a 2 machine system consisting of a synchronous generater feeding a synchronous motor through a reactive line as shown in figure.
* Let P_A be the mechanical loss less input to the generator and also the mechanical output from the motor.
* Here the line is loss less

a small increment of shaft load is added to the motor then rotor angle (or) load angle increases, if 'δ' increases which tends the motor to retard and speed decreases temporarily.

* If a increasing 'δ' increases the power input to the motor until the input and output are again in equilibrium and steady operation takes place at a new point 'P'. Thus further gradual increment in shaft load on the motor is acceptable till the point 'c' is reached.

* At this point 'c' the maximum power is transmitted (or) received ~~for there~~ further any kind of addition of load results in increase in load angle 'δ' but reduces the input power to the motor and the motor will go on decelerate & finally it looses the synchronism.

* Thus any attempt to increase the 'δ' angle beyond δ_c results into loss of synchronism. Thus the maximum power P_{max} that can be transmited without loss of synchronism is known as "steady state stability "limit" at the point 'c'

Methods to improve steady state stability:

* ① Reducing the reactance b/n stations which can be done by Adding machines (or) lines in parallel (or) By using machines

of lower inherent impedence.

(2) Optimum conditions of $X = \sqrt{3} R$ for Maximum power transfer is obtained by using series capaci-tors for over head lines and series reactors for underground cables.

(3) Higher Exitations of Generator (or) Motor (or) both to increases their internal E.M.F's.

(4) Quick response exitation system.