Sri Vidya College of Engineering And Technology
Virudhunagar – 626 005
Department of Electrical and Electronics Engineering

SHORT QUESTIONS AND ANSWERS

Year/ Semester/ Class : III/ V/ EEE Academic Year: 2017-2018
Subject Code/ Name: EE6501/ Power System Analysis

UNIT V STABILITY ANALYSIS
PART – A

1. **Define infinite bus in a power system.**
A bus is called infinite bus if its voltage remains constant and does not altered by any changes in generator excitation.

2. **Define stability.**
The stability of a system is defined as the ability of power system to return to stable (synchronous) operation when it is subjected to a disturbance.

3. **Define steady state and transient state stability.**
The steady state stability of a system is defined as the ability of power system to remain stable (without loosing synchronism) for small disturbances.
The transient stability of a system is defined as the ability of power system to remain stable (without loosing synchronism) for large disturbances.

4. **Define power angle.**
The power angle (or torque angle) is defined as the angular displacement of the rotor from synchronously rotating reference frame.

5. **What is power system stability?**
Power system stability is the property of the system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.

6. **State equal area criterion.**
The equal area criterion for stability states that the system is stable if the area under P_a- δ curve reduces to zero at some value of δ .This is possible if the positive (accelerating) area under Pa- δ curve is equal to the negative (decelerating) area under Pa- δ curve for a finite change in δ .Hence the stability criterion is called equal area criterion.

7. **Write the swing equation used for stability analysis of power system.**
The swing equation is given below

$$\left[\left(\frac{H}{\Pi f}\right)\left(\frac{d^2\delta}{dt^2}\right)\right] = P_m - P_e$$

M in p.u.= $\frac{H}{\Pi f}$,we can write

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

Where,
H-Inertia constant in MW-s/MVA
f- Frequency in Hertz
M- Inertia constant in p.u.
P_m-Mechanical power input to the system (neglecting mechanical losses) in p.u.
P_e-Electrical power output of the system (neglecting electrical losses) in p.u.

8. Write the swing-equation for a single synchronous machine connected to an infinite bus

The swing equation is given below

$$\left[\left(\frac{H}{\Pi f}\right)\left(\frac{d^2\delta}{dt^2}\right)\right] = P_m - P_e$$

M in p.u.= $\frac{H}{\Pi f}$,we can write

$M_{eq}\Pi f \frac{M_{eq}\Pi f}{S_b}$

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

Where,
H-Inertia constant in MW-s/MVA
f- Frequency in Hertz
M- Inertia constant in p.u.
P_m-Mechanical power input to the system (neglecting mechanical losses) in p.u.
P_e-Electrical power output of the system (neglecting electrical losses) in p.u.

9. Write the concept of critical clearing angle.

The critical clearing angle, δ_{cc} is the maximum allowable change in the power angle δ before clearing the fault, without loss of synchronism. The time corresponding to this angle is called critical clearing time, t_{cc}.

10. Define steady state stability limit.

The steady state stability limit is the maximum power that can be transmitted by a machine (or transmitting system) to a receiving system without loss of synchronism. In steady state the power transferred by synchronous machine (or power system) is always less than the steady state stability limit.

11. State equal area criterion.

The equal area criterion for stability states that the system is stable if the area under P_a- δ Curve reduces to zero at some value of δ .

This is possible only if the positive (accelerating) area under P_a- δ curve is equal to the negative (deceleration) area under P_a- δ curve for a finite change in δ .Hence this stability criterion is called equal area criterion.

12. In a 3-machine system having ratings S1 S2 and S3 and inertia constants M1 M2 and M3, what is inertia constant M and H of the equivalent system?

$M_{eq}=M_1S_1/S_b+ M_2S_2/S_b+ M_3S_3/S_b$

Where, S_1, S_2, S_3=MVA ratings of machines 1, 2, 3 respectively.

S_b =Base MVA or MVA rating of system.

$$H_{eq} = \frac{M_{eq}\Pi f}{S_b}$$

13. List any two methods of improving the transient stability limit of power system.

The following are the methods used to improve the transient stability of a system.

- Increase of system voltage and use of AVR (Automatic Voltage Regulation).
- Use of high speed excitation systems.
- Reduction in system transfer reactance.
- Use of high speed reclosing breakers.

14. Define swing curve. What is the use of swing curve?

The swing curve is the plot or graph between the power angle δ and time t.

It is usually plotted for a transient state to study the nature of variation in δ for a sudden large disturbance. From the nature of variation of δ the stability of the system for any disturbance can be determined.

15. Write the power-angle equation of a synchronous machine connected to an infinite bus and also the expression for maximum power transferable to the bus.

The power-angle equation of a machine connected to an infinite bus is given by,

$P_e = P_{max} \sin\delta$

Where, $P_{max} = |E||V| / X$

$|E|$=Magnitude of internal E.M.F of generator.

$|V|$ = Magnitude of infinite bus voltage.

X =Transfer reactance between generator and infinite bus.

δ =Power angle or torque angle.

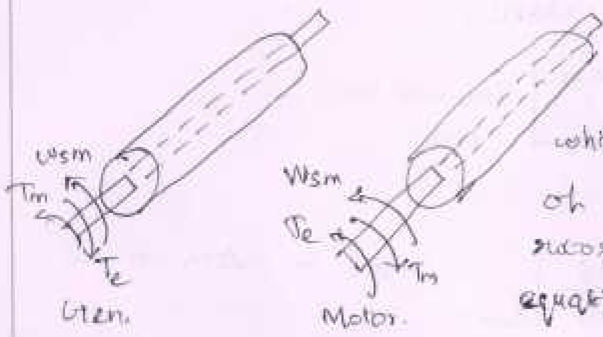
16. Define critical clearing time and critical clearing angle.

The critical clearing angle, δ_{cc} is the maximum allowable change in the power angle δ before clearing the fault, without loss of synchronism. The time corresponding to this angle is called critical clearing time, t_{cc}.

The critical clearing time, t_{cc} can be defined as the maximum time delay that can be allowed to clear a fault without loss of synchronism.

Part B

1. Derive swing equation used for stability studies in power system.



The fundamental eqn which governs the dynamics of the synchronous machine rotor is known as swing equation.

$$T_a \propto \frac{d^2\theta_m}{dt^2}$$

$$\frac{d^2\theta_m}{dt^2} = \frac{d^2\delta_m}{dt^2}$$

$$J\frac{d^2\delta_m}{dt^2} = T_m - T_e$$

$$J\omega_{sm}\frac{d^2\delta_m}{dt^2} = P_{m\,act} - P_{e\,act}$$

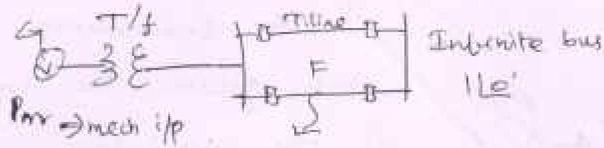
$$J\omega_{sm} = \frac{2HS}{\omega_{sm}}$$

$$\frac{HS}{\pi f}\frac{d^2\delta}{dt^2} = P_{m\,act} - P_{e\,act}$$

$$\frac{H}{\pi f} \cdot \frac{d^2\delta}{dt^2} = \frac{P_{m\,act}}{S} - \frac{P_{e\,act}}{S}$$

$$\boxed{\frac{H}{\pi f}\frac{d^2\delta_m}{dt^2} = P_m - P_e}$$

2. Explain the modified Euler method of analysing multi machine power system for stability with a neat flow chart.



I Estimates :

$$k_1 = \left.\frac{d\delta}{dt}\right|_{\Delta\omega_1} \times \Delta t = \Delta\omega_i \times \Delta t$$

$$l_1 = \left.\frac{d\Delta\omega}{dt}\right|_{\delta_1} \times \Delta t$$

$$= \frac{\pi f}{H}\left[P_m' - P_e(\delta_i)\right] \times \Delta t$$

II Estimates :

$$k_2 = \left[\Delta\omega_i + \frac{l_1}{2}\right]\Delta t$$

$$l_2 = \frac{\pi f}{H}\left[P_m' - P_e\left(\delta_i + (k_1/2)\right)\right]\Delta t$$

III Estimates :-

$$k_3 = \left[\Delta\omega_i + \frac{l_2}{2}\right]\Delta t$$

$$l_3 = \frac{\pi f}{H}\left[P_m' - P_e\left(\delta_i + (k_2/2)\right)\right]\Delta t$$

Find estimates at $t = t_1$

$$\delta_{i+1} = \delta_i + \frac{1}{6}\left[k_1 + 2k_2 + 2k_3 + k_4\right]$$

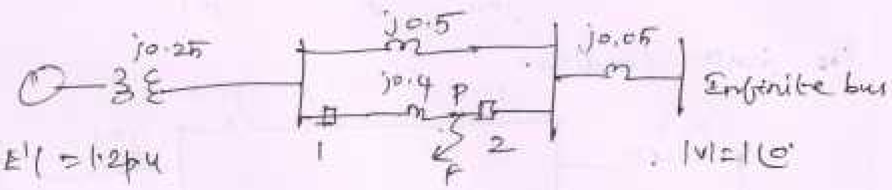
$$\Delta\omega_{i+1} = \Delta\omega_i + \frac{1}{6}\left[l_1 + 2l_2 + 2l_3 + l_4\right]$$

IV Estimates

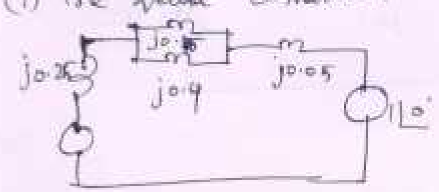
$$k_4 = (\Delta\omega_i \times l_3)\,\Delta t$$

$$l_4 = \frac{\pi f}{H}\left[P_m' - P_e(\delta_i + (k_3))\right] \times \Delta t$$

3. Find the critical clearing angle for clearing the fault with simultaneous opening of the CB 1&2. The reactance values of various components are indicated on the dia. The generator is delivering 1 p.u power at the instant preceding the fault. The fault occurs at point P.



(i) Pre fault condition

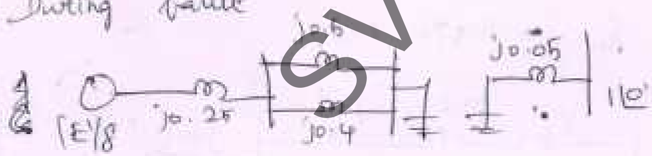


$X_1 = 0.522$ pu

$P_{e1} = 2.3 \sin\delta$

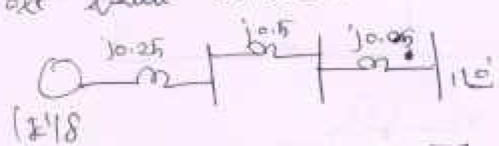
$\delta_0 = 0.45$ radians

(ii) During fault



$P_{e2} = 0$

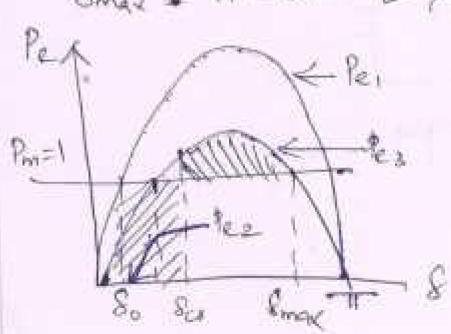
(iii) Post fault condition



$X_{III} = 0.8$

$P_{e3} = 1.5 \sin\delta$

$\delta_{max} = \pi - \sin^{-1}\left[P_m / P_{max3} \right] = 2.41$ rad.

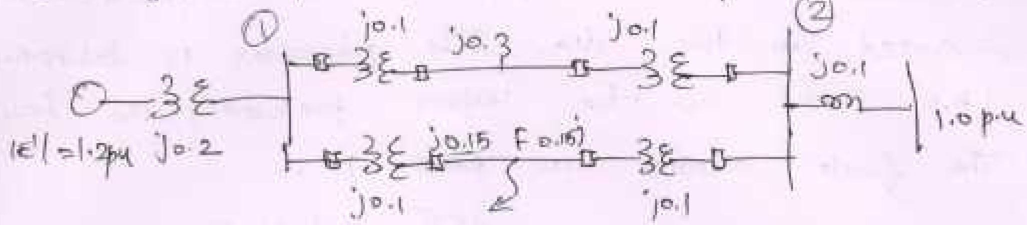


$\delta_{cr} - 0.45 = A_1$

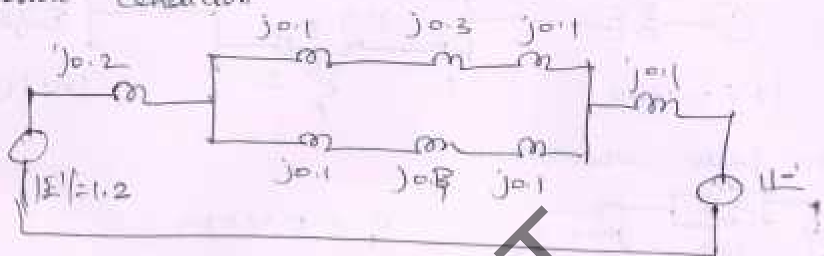
$A_2 = -1.293 + 1.1 \cos\delta_{cr} + \delta_{cr}$

$\Rightarrow \delta_{cr} = 55.8°$

4. A 3ϕ fault occurs at point F. Det. the critical clearing angle for the system. The generator is delivering 1.0 pu power under prefault condition.



Pre fault condition

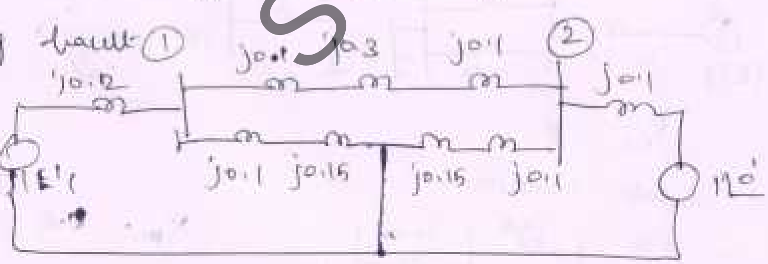


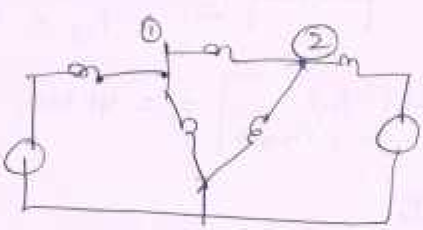
$$Z = j0.55$$

$$P_{e1} = 2.18 \sin \delta$$

$$\delta_0 = 0.476 \text{ rad.}$$

During fault

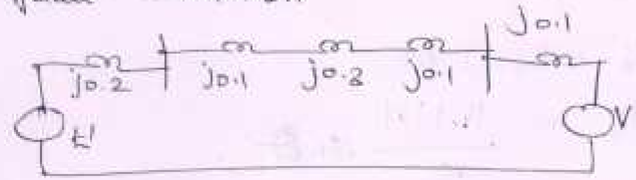




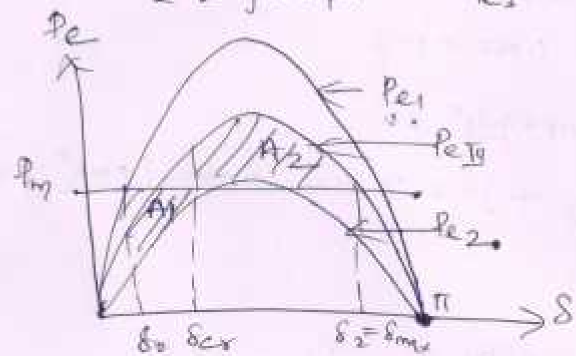
$$Z = j2.34$$

$$P_{e2} = 0.5133 \sin \delta \text{ p.u}$$

Post fault condition



$Z = j0.6\ pu \qquad P_{e_3} = 1.5 \sin\delta$



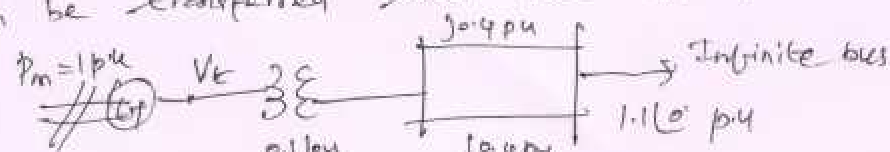
$\delta_{max} = 2.4$ rad

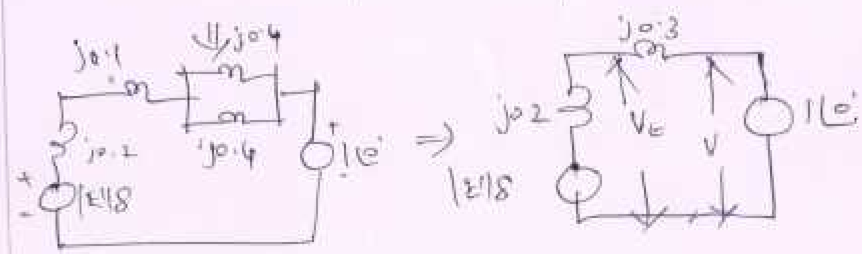
$$A_1 = 1.0\left[\delta_{cr} - 0.476\right] - \int_{\delta_0}^{\delta_{cr}} 0.513 \sin\delta \, d\delta$$

$$A_2 = \int_{\delta_{cr}}^{\delta_{max}} 1.5 \sin\delta \, d\delta - 1.0\,(2.4 - \delta_{cr})$$

$$\Rightarrow \delta_{cr} = 68.°$$

The generator is delivering power to an infinite bus. Take $|V_t| = 1.1$ p.u. Find the max. power that can be transferred when the s/m is healthy.





$X = j0.3$

$P_e = P_m = 1$ pu

$$P_e = \frac{|V_t||V|}{X} \sin\theta$$

$\Rightarrow \theta = 15.827^\circ$

$\therefore V_t = 1.058 + j0.3$

$I = 1.0187 \angle -11^\circ$ pu

$E' = V_t + j0.2 \cdot I = 1.2056 \angle 24.5^\circ$ p.u

Healthy section :

$Z_{12} = j0.5$ pu $\quad X_{12} = 0.5$ pu

$P_{max} = 2.4112$ pu

$P_e = 1$ pu