

EE3123 Test 2 (Total 3 questions)

Name:

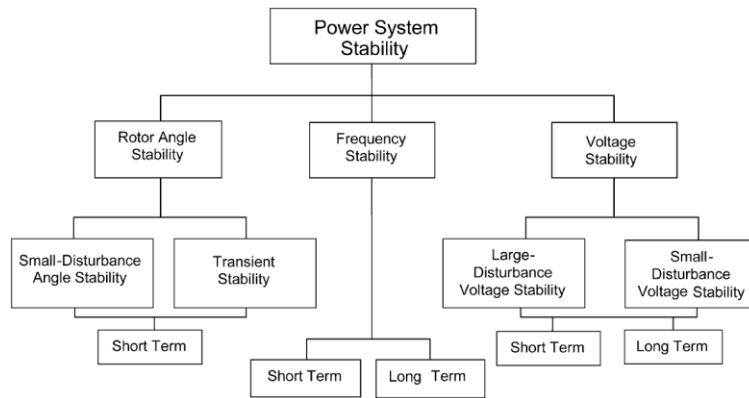
Student No.:

Q1 – Please briefly answer the below questions

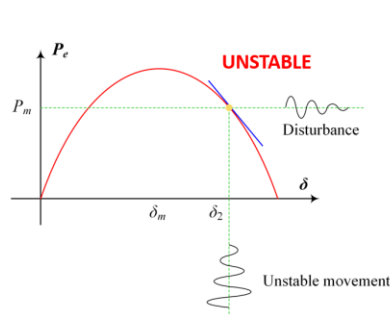
- What is power system stability?
- Why is the system unstable in the rotor angle range $\delta > 90^\circ$ when there is a small disturbance on the rotor angle?
- How would the value of per unit inertia constant H change if a generator's assumed operating frequency is changed from 60 Hz to 55 Hz?

Solution

- Power system stability may be broadly defined as a property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptance state of equilibrium after being subjected to a disturbance.



b)



Scenario 3: $\delta < \delta_2 \Rightarrow P_e > P_m \Rightarrow \frac{d\omega}{dt} < 0$
 (left side of δ_2) $\Rightarrow \omega < \omega_0 \Rightarrow \delta \downarrow \Rightarrow \delta \ll \delta_2$
 moving away from original value

Scenario 4: $\delta > \delta_2 \Rightarrow P_e < P_m \Rightarrow \frac{d\omega}{dt} > 0$
 (right side of δ_2) $\Rightarrow \omega > \omega_0 \Rightarrow \delta \uparrow \Rightarrow \delta \gg \delta_2$
 moving away from original value

c)

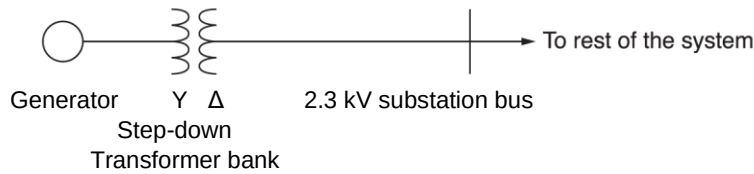
$$H = \frac{\frac{1}{2} J \omega_{m_{syn}}^2}{S_{rated}}; \quad \omega_{m_{syn}} = \frac{2}{p} (2\pi f)$$

$$\text{so } H_{55} = H_{60} \frac{55^2}{60^2}$$

Q2 – Consider the one-line diagram shown below. The three-phase transformer bank (Y-Δ) is made up of three identical single-phase transformers, each specified by $X_l = 0.08 \Omega$ (on the high-voltage side), negligible resistance and magnetizing current, and turns ratio $n = (\text{high-voltage side})/(\text{low-voltage side}) = 10$. The transformer bank is delivering 100 kW at 0.8 p.f. lagging to a substation bus whose voltage is 2.3 kV (line voltage).

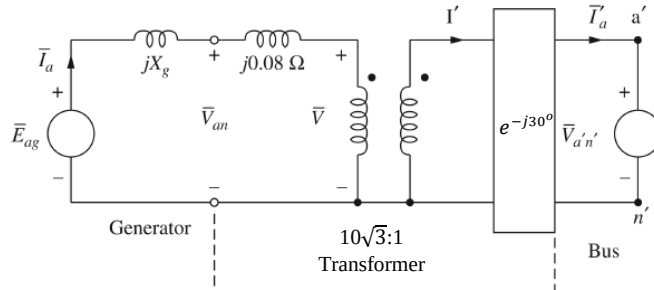
(a) Draw the per-phase diagram and determine the primary current magnitude, primary voltage (line-to-line) magnitude, and the three-phase complex power supplied by the generator. Choose the line-to-neutral voltage at the bus, $V_{a'n'}$ as the reference. Account for the phase shift, and assume positive-sequence operation.

(b) Find the phase shift between the primary and secondary voltages.



Solution

(a) For positive sequence operation and Y-Δ connection, the per-phase diagram is shown as



$$\bar{V}_{a'n'} = \frac{2300}{\sqrt{3}} \angle 0^\circ = 1327.9 \angle 0^\circ \text{ V, choosing that as a reference.}$$

$$\bar{S}' = \frac{100000}{3 \times 0.8} \angle \cos^{-1} 0.8 = 41.67 \angle 36.87^\circ \text{ kVA}$$

$$\bar{I}_a'^* = \frac{\bar{S}'}{\bar{V}_{a'n'}} = \frac{41.67 \times 10^3 \angle 36.87^\circ}{1327.9 \angle 0^\circ} = 31.38 \angle 36.87^\circ \text{ A}$$

$$\bar{I}_a' = 31.38 \angle -36.87^\circ \text{ A}$$

$$\bar{I}_a = \frac{1}{10\sqrt{3}} e^{j30^\circ} \bar{I}_a' = 1.81 \angle -6.87^\circ \text{ A, the primary current magnitude is 1.81 A.}$$

$$\begin{aligned} \bar{V}_{an} &= \bar{V} + j0.08 \bar{I}_a = (10\sqrt{3} \times 1327.9 \angle +30^\circ) + j0.08(1.81 \angle -6.87^\circ) \\ &= 22999.9 \angle 30^\circ + 0.1448 \angle 83.13^\circ \approx 22999.9 \angle 30^\circ \text{ V} \end{aligned}$$

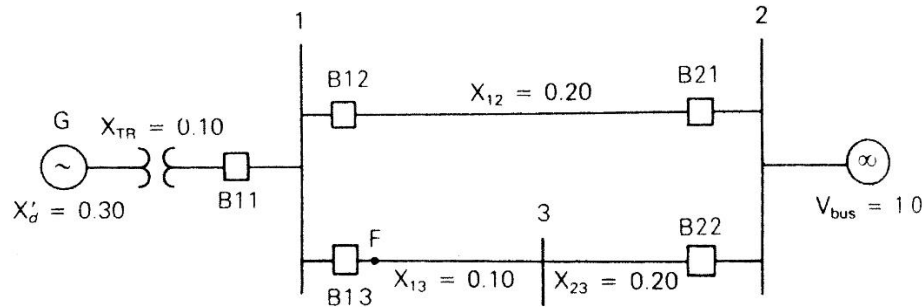
$$\text{Line-to-line primary voltage magnitude} = \sqrt{3}(22999.9) = 39.8 \text{ kV.}$$

Three phase complex power supplied by the generator

$$\bar{S}_{3\phi} = 3\bar{V}_{an} \bar{I}_a'^* = 3(22999.9 \angle 30^\circ)(1.81 \angle 6.87^\circ) = 124889 \angle 36.87^\circ \text{ KVA}$$

(b) The secondary phase lags the primary closely by 30° , as well as for line voltage.

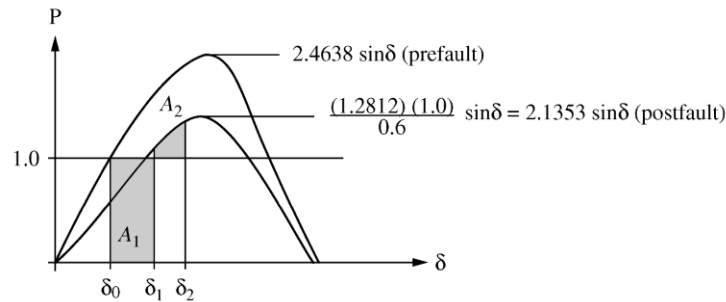
Q3 – The 60-Hz synchronous generator shown below is initially operating in the steady-state condition: the infinite bus receives 1.0 per unit real power at 0.95 p.f. lagging. When there is a temporary three-phase-to-ground short circuit that occurs at point F, breakers B13 and B22 open later than 3 cycles after the fault commences, determine the critical clearing time. ($P_m=1.0$ pu, $H = 3$ pu-s)



Solution

Refer to Tutorial 4 Q4.

The critical clearing time occurs when the accelerating area, A_1 , is equal to the decelerating area, A_2 , in which the maximum value of δ is determined from the post-fault curve.



$$1 - 2.1353 \sin \delta_{\max} = 0 \rightarrow \delta_{\max} = 2.654 \text{ rad} = 152.1^\circ$$

To determine the clearing time, first solve for the critical clearing angle. The post fault curve is the same as

$$\begin{aligned} A_1 &= \int_{\delta_0=0.4179}^{\delta_{cr}} 1.0 d\delta = \int_{\delta_{cr}}^{\delta_{\max}=2.654} (2.1353 \sin \delta - 1.0) d\delta \\ (\delta_{cr} - 0.4179) &= 2.1353 (\cos \delta_{cr} - \cos (2.654)) - (2.654 - \delta_{cr}) \\ 0.3496 &= 2.1353 \cos \delta_{cr} \rightarrow \delta_{cr} = 1.4063 \text{ rad} = 80.58^\circ \end{aligned}$$

Then we can solve for t_{cr} as

$$t_{cr} = \sqrt{\frac{4H}{(2\pi 60)(1.0)}} (1.4063 - 0.4179) = 0.1774 \text{ sec} = 10.6 \text{ cycles}$$

-----The End-----