5.2 Generators

Friday, 11 February 2022 3:47 PM

Q1 $P = 6$, $F = 50\text{Hz}$.

$n_s = ?$

$$n_s = \frac{120\,F}{P}$$

$$= \frac{120 \times 50}{6} = 1000 \text{ rpm}$$

Q2 2500 kVA, 6.6kV, 3Ø, WYE, $x = j4$, $R = 0$

a) Full load, 0.9 lag.

↳ $\theta = 25.84°$

$$V = \frac{6600}{\sqrt{3}} \angle 0°$$

$$|S_{load}| = 2500 \times 10^3 \text{ VA}$$

$$= 3\,|V_{ph}|\,|I_{ph}|$$

$$|I_{ph}| \quad \frac{2500 \times 10^3}{3 \times \frac{6600}{\sqrt{3}}} = 218.69\text{A}$$

$$I = 218.69 \angle -25.84° \text{ A}$$

→ $E = V + I(jX)$

$$= \frac{6600}{\sqrt{3}} \angle 0 + 218.69 \angle -25.84 (j4)$$

$$= 4265.08 \angle 10.64° \text{ V}$$

$(|E| \text{ was } - |V|) > 0$ [over excited]

↳ $Q > 0$

$$4265.08\cos(10.64) - \frac{6600}{\sqrt{3}} > 0$$

Overexcited.

b) Full load @ 0.9 leading.

$$I' = 218.69\angle 25.84^\circ A$$

$$E' = V + I' jX$$

$$= \frac{6600}{\sqrt{3}} + 218.69\angle 25.84\,(j4)$$

$$= 3518.45\angle 12.93^\circ V$$

$$|E'|\cos\delta' - |V| = 3518.45\cos 12.93 - \frac{6600}{\sqrt{3}} < 0$$

→ Underexcited generator

Q3 1MVA, 11kV, 3Φ, WYE, $X = j5$, $R = 0\Omega$

- Rated load @ 0.9 p.f lagging

$|S_{load}| = 1MVA$

$$V_{ph} = \frac{11000}{\sqrt{3}}\angle 0^\circ = 6350.85\angle 0^\circ V$$

$$|I_{ph}| = \frac{1\times 10^6}{3\times\frac{11000}{\sqrt{3}}} = 52.49A.$$

$I = 52.49\angle -25.84^\circ$ A

$E = V + I j X$

$= 6350.85\angle 0^\circ + 52.49\angle -25.84 (j5)$

$= 6469.55\angle 2.09^\circ$ V

$|E| = 6469.55$ V

$\delta = 2.09^\circ$

→ Keep $|E|$ unchanged

$P_{new} = \frac{1}{2} P_{old}$.

$P_{old} = S_{old} \times \cos\theta_{old}$

$= 1\times10^6 \times 0.9 = 900$ KW

$P' = P_{new} = \frac{900}{2}$ MW $= 450$ KW

$= \frac{3|V||E|}{|X|} \sin\delta'$

$\sin\delta' = \frac{450\times10^3 \times 5}{3 \times 6469.55 \times 6350.85}$

$\delta' = 1.046^\circ$

$\delta' < \delta$

$P' < P_{old}$

$I' = \frac{|E|\angle\delta' - |V|\angle 0}{jX}$

$= \frac{6469.55\angle 1.046 - 6350.85\angle 0}{j5}$

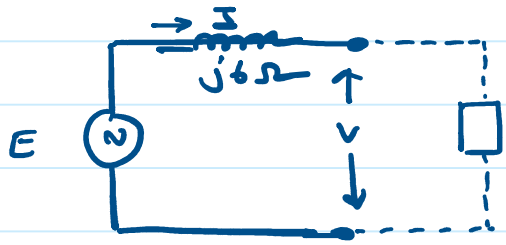
$= 33.34\angle -44.88^\circ$ A

$|I'| = 33.34\,A$

$\cos\theta' = 0.71$ lagging.

Q4) 11KV - 3Φ, wye, $X = j6\,\Omega$, $R = 0\,\Omega$

→ Some field current $E_{ll} = 12KV$ open circuit



$|E|_{line} = V_{line}$

$= 12KV$.

$$|E| = \frac{12000}{\sqrt{3}}$$

→ Max Power. $= \frac{3|V||E|}{|X|}\sin 90°$

$$|V| = \frac{11000}{\sqrt{3}}$$

$$P_{max} = \frac{3 \times \frac{11000}{\sqrt{3}} \times \frac{2000}{\sqrt{3}}}{6}$$

$= 22 \times 10^6\,W$

$= 22\,MW$

→ $\delta \rightarrow 90°$

$$I = \frac{E - V}{jX}$$

$$= \frac{|E| \angle 90° - |V| \angle 0}{j\,?}$$

$$= \frac{|E| \angle 90^\circ - |V| \angle 0}{j6}$$

$$= \frac{\frac{12000}{\sqrt{3}} \angle 90 - \frac{11000}{\sqrt{3}} \angle 0}{j6}$$

$$= 1566.43 \angle 42.51^\circ A$$

$|I| = 1566.43A$

$\cos\theta = 0.74$ leading.

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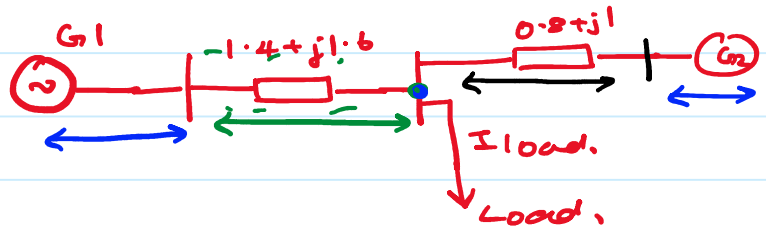


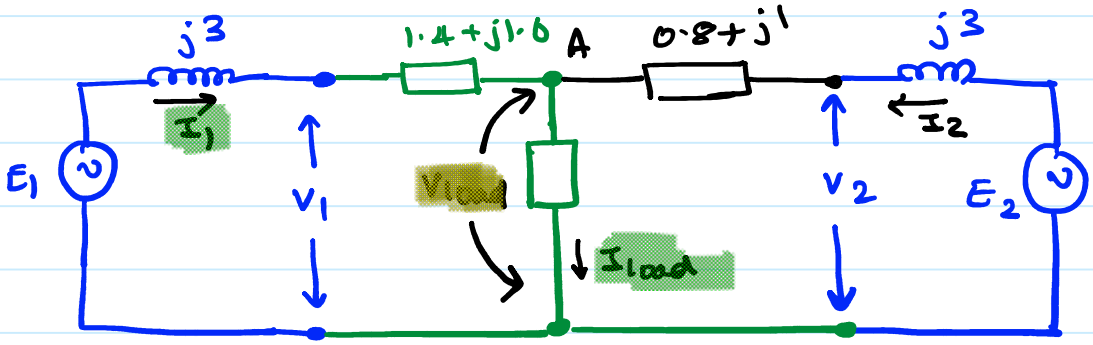
$X_1 = j3\ \Omega$ $X_2 = j3$

$R_1 = 0\ \Omega$ $R_2 = 0\ \Omega$.

Load → 30kW @ 0.8 p.f. lagging.

$V_{line} = 460V$

$$V_1 = \frac{460}{\sqrt{3}} \angle 0^\circ V = 265.58 \angle 0^\circ V$$



★ G1 supplies 15kW @ 0.8 p.f. lag.

$$P_1 = 3|V_1||I_1|\cos\theta_1$$

$$|I_1| = \frac{15\times10^3}{3\times265.58\times0.8} = 23.53A.$$

$$I_1 = 23.53\angle-36.87^\circ A$$

$$E_1 = V_1 + I_1(jX_1)$$
$$= 265.58\angle0^\circ + 23.53\angle-36.87\times j3$$
$$= 313.07\angle10.39^\circ V$$

$$|E_1| = 313.07\,V$$
$$\delta_1 = 10.39^\circ$$

* LOAD → 30KW @ 0.8 p.f lagging.
$\theta \rightarrow 36.87^\circ$

$$P_{load} = 3|V_{load}||I_{load}|\cos\theta_{load}$$

$$V_{load} = V_1 - I_1(1.4 + j1.6)$$
$$= 265.58\angle0^\circ - 23.53\angle-36.87(1.4+j1.6)$$
$$= 216.88\angle-2.74^\circ V$$

$$|V_{load}| = 216.88\,V.$$

$$|I_{load}| = \frac{30\times10^3}{3\times216.88\times0.8} = 57.64A$$

$\angle I_{load}$ wrt $\angle V_{load} \rightarrow -36.87^\circ$

$\angle V_{load}$ wrt $\angle V_1 = -2.74^\circ$

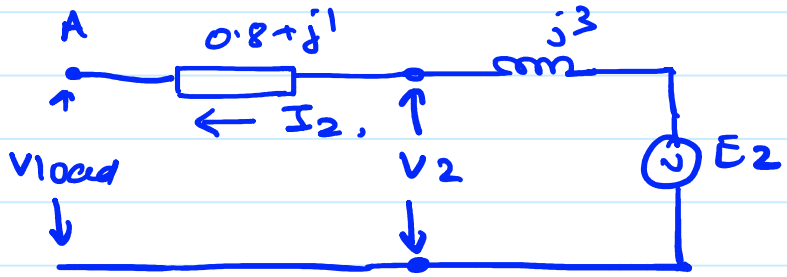
$\angle I_{load}$ wrt $\angle V_1 = -2.74 - 36.87$
$= -39.61^\circ$

$I_{load} = 57.64 \angle -39.61° \text{ A}$

★ Applying KCL @ node A

$$I_1 + I_2 = I_{load}$$

$$I_2 = I_{load} - I_1$$
$$= 57.64 \angle -39.61 - 23.53 \angle -36.87°$$
$$= 34.15 \angle -41.41° \text{ A}$$



$$E_2 = V_{load} + I_2 (0.8 + j1 + j3)$$

$$= 216.88 \angle 2.74 + 34.15 \angle -41.41 (0.8 + j4)$$
$$= 335.73 \angle 12.74° \text{V}$$

$|E_2| = 335.73 \text{ V}$

$\delta_2 = 12.74°$

$$V_2 = E_2 - I_2(jx_2)$$

$$= 335.73 \angle 12.74° - 34.15 \angle -41.41 (j3)$$
$$= 259.76 \angle -0.62 \text{ V}$$

Extra

Find p.f of G_2

$\angle$ of I_2 wrt V_2

$\cos\theta_2 = \cos(40.79)$ lagging.

$= 0.757$ lagging.

$P_2 = 3|V_2||I_2|\cos\theta_2$

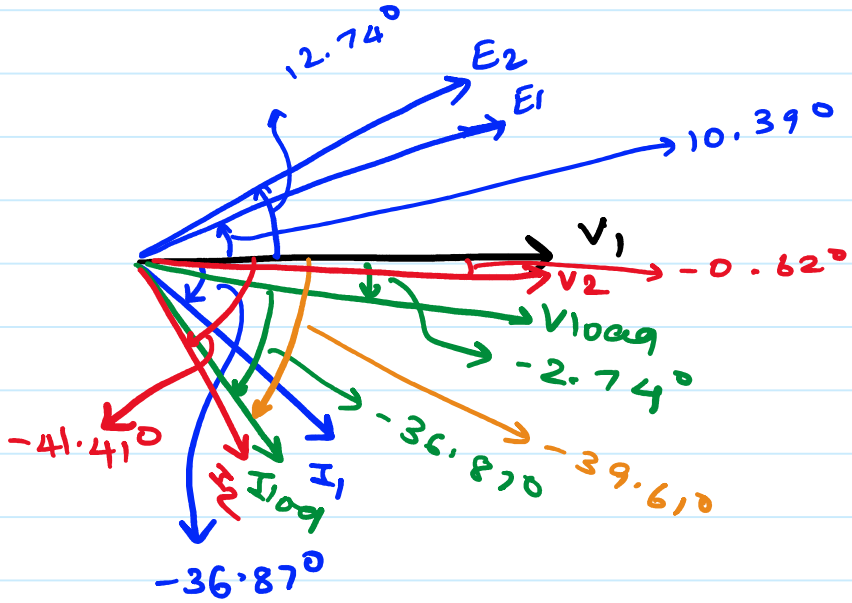
$= 3 \times 259.76 \times 34.15 \times 0.757$

$= 20145.6\,W$

Also $P_2 = \dfrac{3|V_2||E_2|}{|X_2|}\sin\delta_2$

$= \dfrac{3 \times 259.76 \times 335.73}{3}\sin(12.74)$

$= 19232\,W$



$P = 3|V_{ph}||I_{ph}|\cos\theta$

$|I_{ph}| = \dfrac{P}{3|V_{ph}|\cos\theta}$.

$Q = 3|V_{ph}||I_{ph}|\sin\theta$.

$|I_{ph}| = \dfrac{Q}{3|V_{ph}|\sin\theta}$.

$|S| = 3|V_{ph}||I_{ph}| = \sqrt{3}|V_{line}||I_{line}|$