2.52 A three-phase generator step-up transformer is rated 26-kV:345-kV, 850 MVA and has a series impedance of 0.0025 + j0.057 per unit on this base. It is connected to a 26-kV 800-MVA generator, which can be represented as a 2.12 Problems 121 voltage source in series with a reactance of j1.28 per unit on the generator base.

a. Convert the per unit generator reactance to the step-up transformer base.

b. The system is supplying 750 MW at 345 kV and 0.90 power factor leading to the system at the transformer terminals. Draw a phasor diagram for this condition, using the transformer high-side voltage as the reference phasor.

c. Calculate the generator terminal voltage and internal voltage behind its reactance in kV for the conditions of part (b). Find the generator output power in MW and the power factor.

Solution

Given Data:

Transformer: $S_{Base} = 850\,MVA$, $V_{HV} = 345\,kV$, $V_{LV} = 26\,kV$

Transformer Impedance: $Z = 0.0025 + j0.057\,pu$.

Generator: $S_{gen} = 800\,MVA$, $V_{gen} = 26\,kV$, $X_d = j \cdot 1.28\,pu$

Load: $P_{load} = 750\,MW$, $V_{load} = 345\,kV$, $PF = 0.90$ (leading)

Part (a): On the transformer base, the per-unit generator reactance is

$$X_g = 1.28\left(\frac{Z_{base,g}}{Z_{base,t}}\right) \qquad Z_{base,t} = \frac{26^2}{850} = 0.795\,\Omega$$

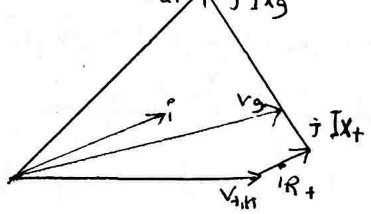
$$Z_{base,g} = \frac{26^2}{800} = 0.845\,\Omega$$

$$X_g = 1.28\left(\frac{0.845}{0.795}\right) = 1.36 \text{ perunit}$$

Part (b): Phasor Diagram

* Since the power factor is 0.9 leading, the current leads the voltage.

* Diagram description: V_H on the real axis. The current I points upwards with a positive angle. The voltage drop across the transformer adds to V_H to find the terminal voltage V_t. The drop across the generator reactance adds to V_t to find the internal voltage E_{int}. Because of the leading current and large inductances, E_{int} will likely be shifted but may not drop as much in magnitude.



Part(c) : In per-unit on the transformer base,

Current = $S_{load,pu} = \frac{750MW}{850MVA} \times \frac{1}{0.9PF} = 0.9804\,pu$

$$|I| = \frac{S_{pu}}{V_{pu}} = \frac{0.9804}{1.0} = 0.9804\,pu$$

Angle $\phi = \arccos(0.9) = 25.84^\circ$ (Positive because leading)

$$I = 0.9804\angle 25.84^\circ\,pu \;//$$

Generator Terminal Voltage (V_t) = $V_t = V_{grid} + I \cdot Z_{xfm}$

$$V_t = 1.0\angle 0^\circ + (0.9804\angle 25.84^\circ)\cdot(0.0025 + j0.057)$$

$$V_t \approx 0.979 + j0.051\,pu \Rightarrow |V_t| = 0.980\,pu$$

$$V_{t,actual} = 0.980 \times 26kV = 25.48kV \;//$$

Internal Voltage (E_{int}) = $E_{int} = V_t + I\cdot(j X_{gen\,new})$

$$E_{int} = (0.979 + j0.051) + (0.9804\angle 25.84^\circ)\cdot(j1.36)$$

$$E_{int} \approx 0.398 + j1.25pu \Rightarrow |E_{int}| = 1.313\,pu$$

$$E_{int,actual} = 1.313 \times 26kV = 34.14kV \;//$$

Generator Output Power = Generator supplies the load power (750MW) plus the losses (I^2R)

$$P_{loss} = |I|^2 \times R_{xfm} = (0.9804)^2 \times 0.0025 = 0.0024\,pu$$

$$P_{loss} = 0.0024 \times 850\,MVA = 2.04\,MW$$

$$P_{gen} = 750 + 2.04 = 752.04\,MW \;//$$

Generator Power Factor =

PF Angle = Angle of current − Angle of voltage terminal

$$PF\ Angle = 25.84^\circ - 3.0^\circ = 22.84^\circ$$

$PF = \cos(22.84) = 0.92$ leading