Example 3.10: Four-bus three-phase electrical power system is shown in the figure. Answer the following questions:

a) Draw one-line impedance diagram showing all impedances in per unit on a 100 MVA base. Choose 20 kV as the voltage base for generator.

b) The motor is drawing 45 MVA at 0.8 PF lagging at a line-to-line terminal voltage of 18 kV. Determine the terminal voltage and the internal emf of the generator in per unit and in kV.

\[
G_1 = 60 \text{ MVA} \quad 20 \text{ kV} \quad X = 9%
\]
\[
T_1 = 50 \text{ MVA} \quad 20/200 \text{ kV} \quad X = 10%
\]
\[
T_2 = 50 \text{ MVA} \quad 200/20 \text{ kV} \quad X = 10%
\]
\[
M = 43.2 \text{ MVA} \quad 11 \text{ kV} \quad X = 8%
\]
\[
\text{Line} = 200 \text{ kV} \quad Z = 120 + j200 \Omega
\]

\[
Z_{pu} = Z_{pu, old} \frac{S_B, new}{S_B, old} \frac{V_B, old^2}{V_B, new^2}
\]

- \[
G_1_{pu}(\text{new}) = (0.09)(\frac{100}{60})(\frac{20^2}{30^2}) = 0.0666 \text{ pu}
\]
- \[
T_1_{pu}(\text{new}) = (0.1)(\frac{100}{50})(\frac{20^2}{30^2}) = 0.0888 \text{ pu}
\]
- \[
T_2_{pu}(\text{new}) = (0.1)(\frac{100}{50})(\frac{200^2}{300^2}) = 0.0888 \text{ pu}
\]
- \[
M_{pu}(\text{new}) = (0.08)(\frac{100}{43.2})(\frac{18^2}{30^2}) = 0.0666 \text{ pu}
\]

\[
Z_{\text{line}} = \frac{200^2}{100} = 400 \Omega
\]
\[
\frac{Z_{\text{line}}(\text{pu})}{400} = \frac{0.583095 + j0.036}{400} \rightarrow I = 0.0888 \text{ pu}
\]

Line: \[
0.0888 \text{ pu} \quad \frac{18}{30} \quad 2 \text{ kV}
\]

Motor: \[
0.0666 \text{ pu} \quad 59.036 \text{ pu}
\]
\( U_2 = 0.670^\circ + (I)(j0.0888) \) = 
\[
\{ \\
V_1 = U_2 + I \cdot Z_{line}(pm) = \\
V_g = V_1 + (j0.0888)(I) = \\
I = ? \rightarrow \text{per unit current of the motor.}
\}
\
I_{line} = \frac{45 \times 10^6}{\sqrt{3} \times 18000} = 1.415 A,
\]
I_{basemotor} = \frac{100 \times 10}{\sqrt{3} \times 35000} = 1924.5 A
\
I_{motor(pu)} = \frac{1.415}{1924.5} = 0.7498 \rightarrow 36.87^\circ pu
\
E_g = V_g + (\frac{1}{50.0666})(I)
\
E_m = U_m - (\frac{1}{50.0666})(I)

Last modified: Aug 4, 2020