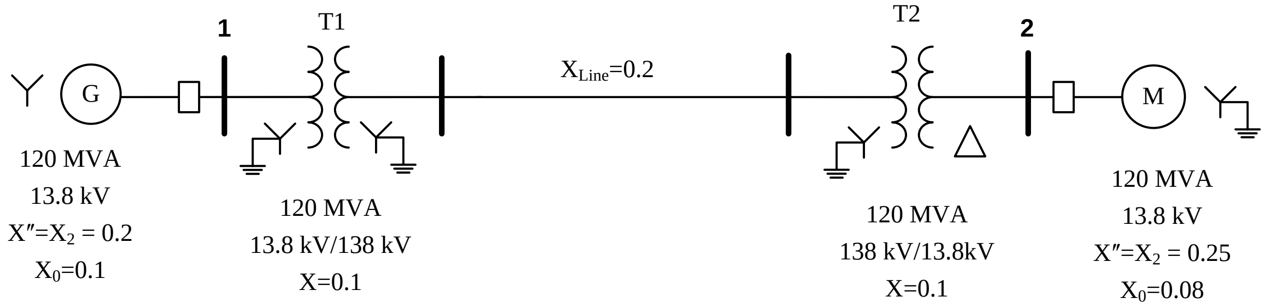
Power System Analysis II Sample problems with answers

P1 The synchronous generator in the figure below is operating at the rated power, at unity power factor and at the rated voltage when a bolted three-phase short circuit occurs at bus **1**. All the impedance values are in per-unit and the system base values are 120 MVA and 13.8 kV at the generator side. Ignore the transformer phase shifts. Assume a balanced three-phase system.

a) Calculate the subtransient fault current using bus impedance matrix $\bar{Z}_{bus}$.
b) Find the subtransient generator current including the prefault current.
c) Find the bus voltages at the fault instant.



a) $I_F'' = I_F''^{(1)} = -j6.5385$ pu

b) $\bar{I}_g'' = 1.0 + 4.97\angle{-90^\circ} = 5.1\angle{-78.7^\circ}$

c) $V_2 = -0.3845 + 1.0 = 0.6155$ pu

P2 The following unbalance voltages are applied to a balanced line and a load given below.

$$\begin{bmatrix} \bar{V}_{ag} \\ \bar{V}_{bg} \\ \bar{V}_{cg} \end{bmatrix} = \begin{bmatrix} 220\angle 0^\circ \\ 130\angle -110^\circ \\ 200\angle +120^\circ \end{bmatrix} \text{Volts}$$

The balance line has an impedance of $2.5\angle 90^\circ\ \Omega$ per phase, and the load is a balanced-Y load connected in parallel with a balanced-Δ load. The Y-load has an impedance of $3\angle 90^\circ\ \Omega$ per phase with an ungrounded neutral, and the Δ-load has $15\angle -90^\circ\ \Omega$ per phase.

a) Draw the sequence networks.
b) Calculate the sequence currents.
c) Calculate the line currents ($\bar{I}_a$, $\bar{I}_b$ and $\bar{I}_c$)

b) $\bar{I}_0 = 0$ (4)

$\bar{I}_1 = \dfrac{182.83\angle 2.36}{10\angle 90^\circ}$

$\bar{I}_1 = 18.283\angle{-87.64^\circ}$ A (5)

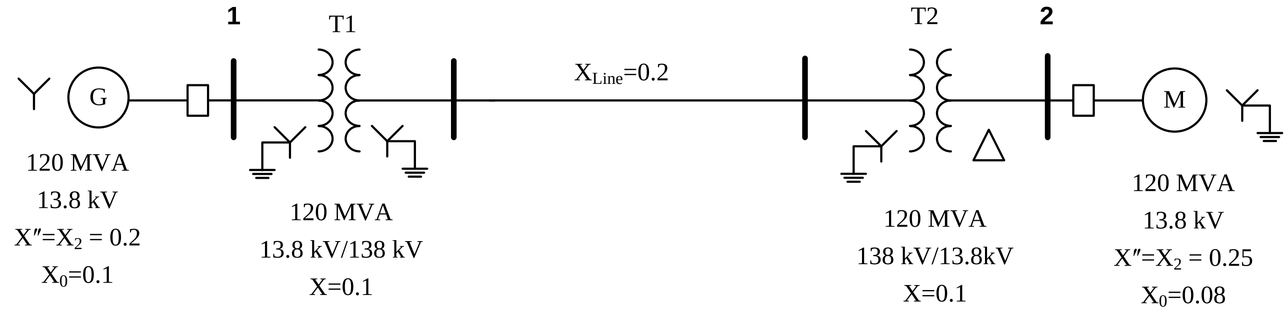
$\bar{I}_2 = \dfrac{27.4\angle{-63.67^\circ}}{10\angle 90^\circ} = 2.74\angle{-153.67^\circ}$ A (2)

$19.55\angle{-95^\circ}$ A

$15.56\angle 153.42^\circ$ A

$= 20.\angle 38.7^\circ$ A

P3 Draw the zero-sequence, positive-sequence, and negative-sequence networks for the power system given below. All the impedance values are in per-unit and the system base values are 120 MVA and 13.8 kV at the generator side. Assume a balanced three-phase power system.



Problem 2) (35 pts)

A 1500-MVA 20-kV, 60-Hz three-phase generator is connected through a 1500-MVA 20-kV Δ/500-kV Y transformer to a 500-kV circuit breaker and a 500-kV transmission line. The generator reactances are $X''_d = 0.17$, $X'_d = 0.30$, and $X_d = 1.5$ per unit, and its time constants are $T''_d = 0.05$, $T'_d = 1.0$, and $T_A = 0.10$ s. The transformer series reactance is 0.10 per unit; transformer losses and exciting current are neglected. A three-phase short-circuit occurs on the line side of the circuit breaker when the generator is operated at rated terminal voltage and at no-load. The breaker interrupts the fault 3 cycles after fault inception. Determine (a) the subtransient current through the breaker in per-unit and in kA rms; and (b) the rms asymmetrical fault current the breaker interrupts, assuming maximum dc offset. Neglect the effect of the transformer on the time constants.

TABLE 7.2

Short-circuit current—unloaded synchronous machine*

Component	Instantaneous Current (A)	rms Current (A)
Symmetrical (ac)	(7.2.1)	$I_{ac}(t) = E_g\left[\left(\frac{1}{X''_d} - \frac{1}{X'_d}\right)e^{-t/T''_d} + \left(\frac{1}{X'_d} - \frac{1}{X_d}\right)e^{-t/T'_d} + \frac{1}{X_d}\right]$
Subtransient		$I'' = E_g/X''_d$
Transient		$I' = E_g/X'_d$
Steady-state		$I = E_g/X_d$
Maximum dc offset	$i_{dc}(t) = \sqrt{2}I''e^{-t/T_A}$	
Asymmetrical (total)	$i(t) = i_{ac}(t) + i_{dc}(t)$	$I_{rms}(t) = \sqrt{I_{ac}(t)^2 + i_{dc}(t)^2}$ with maximum dc offset: $I_{rms}(t) = \sqrt{I_{ac}(t)^2 + [\sqrt{2}I''e^{-t/T_A}]^2}$

$\boxed{I'' = 3.704 \text{ pu}}$ $\boxed{I'' = 6.415 \text{ kA}}$

$\boxed{I_{rms}(0.05) = 5.2193 \text{ pu}}$

$I_{ac}(0.05) = 4.141 \text{ pu}$

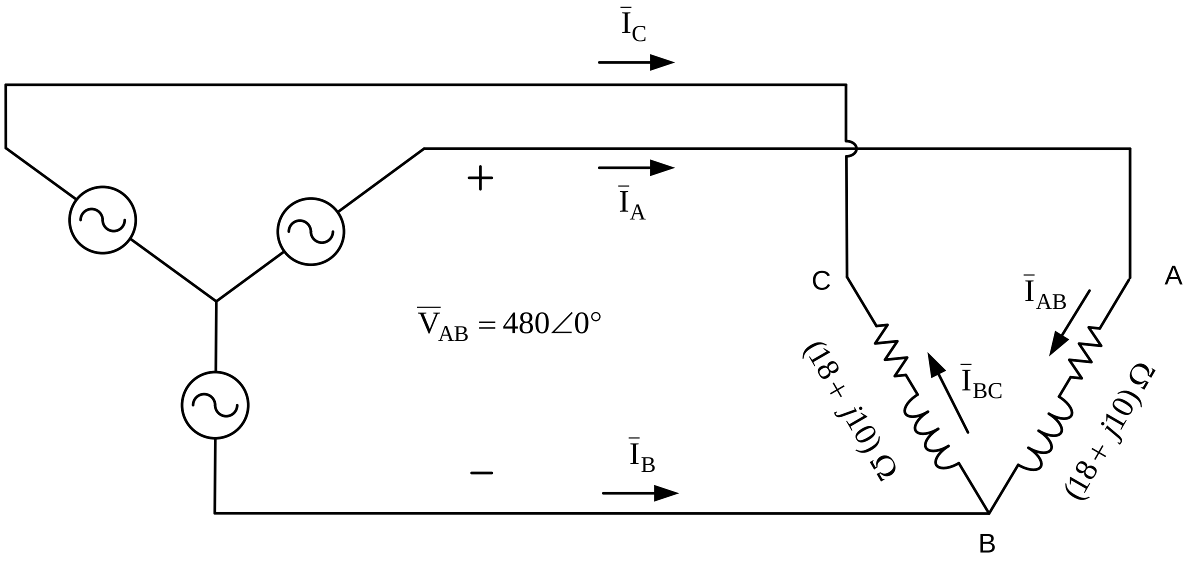
$I_{rms}(0.05) = 9.04 \text{ kA}$

P5 As shown in Figure below, a balanced three-phase, positive-sequence source with $\bar{V}_{AB} = 480\angle 0°$ volts is applied to an unbalanced Δ load. Note that one leg of the Δ is open. Determine:

a) The load currents $\bar{I}_{AB}$ and $\bar{I}_{BC}$

b) The line currents $\bar{I}_A$, $\bar{I}_B$, and $\bar{I}_C$ which feed the Δ load; and

c) The zero-, positive-, and negative-sequence components of the line currents.



a) $\bar{I}_{AB} = \dfrac{480\angle 0°}{18+j10} = 23.312\angle -29°$ A

$\bar{I}_{BC} = \dfrac{480\angle -120°}{18+j10} = 23.312\angle -149.05$ A

$\bar{I}_{CA} = 0$

b) $\bar{I}_A = \bar{I}_{AB} = 23.312\angle -29°$ A

$\bar{I}_B = \bar{I}_{BC} - \bar{I}_{AB} = 40.38\angle 181°$ A

$\bar{I}_C = -\bar{I}_{BC} = 23.312\angle 31°$ A

c)
$$\begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} 23.312\angle -29° \\ 40.38\angle 181° \\ 23.312\angle 31° \end{bmatrix}$$

$\bar{I}_0 = 0$ Since there is no path for the zero-sequence current to flow.

$\bar{I}_1 = 26.92\angle -59°$ A

$\bar{I}_2 = 13.46\angle 61°$ A

$$I_{base} = \frac{S_{base\_1\varphi}}{V_{baseLN}} = \frac{S_{base\_3\varphi}}{\sqrt{3}V_{baseLL}}$$

$$Z_{base} = \frac{V_{baseLN}}{I_{base}} = \frac{{V_{baseLN}}^2}{S_{base_{1\varphi}}} = \frac{{V_{baseLL}}^2}{S_{base_{3\varphi}}}$$

$$\bar{Z}_{new} = \bar{Z}_{old}\left(\frac{V_{base\_old}}{V_{base\_new}}\right)^2\left(\frac{S_{base\_new}}{S_{base\_old}}\right)$$