

PER UNIT QUANTITIES

Tuesday 28/11/1427

$$\text{p.u. value} = \frac{\text{actual value in any unit}}{\text{base or reference value in the same unit}} \quad (9.1)$$

For a single-phase system, the following formulas relate the various base quantities [1]:

$$\text{Base current} = \frac{\text{base kVA}_{1\phi}}{\text{base voltage, kV}_{\text{LN}}} \quad (\text{A}) \quad (9.2)$$

$$\text{Base impedance} = \frac{\text{base voltage, V}_{\text{LN}}}{\text{base current, A}} \quad (\Omega) \quad (9.3)$$

$$\text{Base impedance} = \frac{(\text{base voltage, kV}_{\text{LN}})^2}{\text{MVA}_{1\phi}} \quad (\Omega) \quad (9.4)$$

For a three-phase system, the relations among various base quantities are as follows:

$$\text{Base current} = \frac{\text{base kVA}_{3\phi}}{\sqrt{3} \times \text{base voltage, kV}_{\text{LL}}} \quad (\text{A}) \quad (9.5)$$

$$\text{Base impedance} = \frac{(\text{base kV}_{\text{LL}} / \sqrt{3})^2 \times 1000}{\text{base kVA}_{3\phi} / 3} \quad (\Omega) \quad (9.6)$$

$$\text{Base impedance} = \frac{(\text{base kV}_{\text{LL}})^2}{\text{MVA}_{3\phi}} \quad (\Omega) \quad (9.7)$$

It is clear that equations (9.4) and (9.7) are identical and we do not need to carry the subscripts to distinguish single and 3-phase cases, provided that we:

- Use line-to-line kilovolts with three-phase megavoltamperes, and
- Use line-to-neutral kilovolts with megavoltamperes per phase.

For both single and three phase systems

$$\text{Base KW (or MW)} = \text{Base kVA (or MVA)} \quad (9.8)$$

$$\text{p.u. Z on new base} = \text{p.u. Z on given base} \left(\frac{\text{Base kV}_{\text{given}}}{\text{Base kV}_{\text{new}}} \right)^2 \left(\frac{\text{Base kVA}_{\text{new}}}{\text{Base kVA}_{\text{given}}} \right) \dots (9-10)$$

Example 9.4:

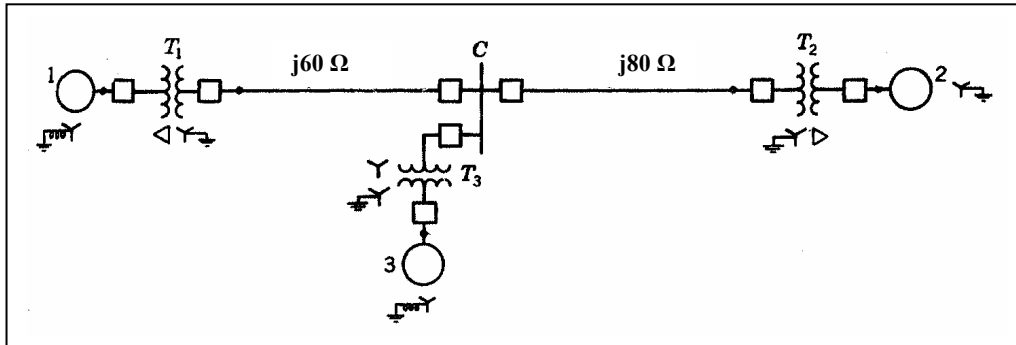


Figure
(e9.4)

The
single-
line

diagram of a power system is shown in Fig. (e9.4) [1]. Reactances of the transmission line are shown on the diagram. The generators and transformers are rated as follows:

Generator 1: 25 MVA, 13.8 kV, $X = 0.25$ p.u.

Generator 2: 28 MVA, 18 kV, $X = 0.20$ p.u.

Generator 3: 30 MVA, 20 kV, $X = 0.23$ p.u.

Transformer T_1 : 25 MVA, 220Y / 13.8 Δ kV, $X = 10\%$

Transformer T_2 : made from three single-phase units, each rated 10 MVA, 127 / 18 kV, $X = 10\%$

Transformer T_3 : 35 MVA, 220Y / 22Y kV, $X = 10\%$

SOLUTION

Choose a base of 50 MVA and 13.8 kV in the circuit of generator 1 and find base voltages in the rest of the network.

- New MVA base is 50 MVA for all components.
- New kV base is 13.8 kV for generator 1, 18 kV for generator 2 and 22 kV for generator 3. The base voltages for transmission lines are 220 kV.
- Therefore, new p.u. values of X for

- (1) **generators are:**

$$X \text{ for generator 1} = 0.25 \left(\frac{13.8}{13.8} \right)^2 \left(\frac{50}{25} \right) = 0.5 \text{ p.u.}$$

$$X \text{ for generator 2} = 0.2 \left(\frac{18}{18} \right)^2 \left(\frac{50}{28} \right) = 0.357 \text{ p.u.}$$

$$X \text{ for generator 3} = 0.23 \left(\frac{20}{22} \right)^2 \left(\frac{50}{30} \right) = 0.317 \text{ p.u.}$$

- **(2) Transmission lines**

$$\text{Base impedance for all transmission lines} = \frac{(\text{Base kV})^2}{\text{Base MVA}} = \frac{(220)^2}{50} = 968 \Omega$$

$$\text{p.u. } X \text{ of } 60 \Omega \text{ line} = \frac{60}{968} = 0.0620 \text{ p.u.}$$

$$\text{p.u. } X \text{ of } 80 \Omega \text{ line} = \frac{80}{968} = 0.0826 \text{ p.u.}$$

- (3) for transformers

$$\text{Reactance for transformer } T_1 = 0.1 \left(\frac{220}{220} \right)^2 \left(\frac{50}{25} \right) = 0.2 \text{ p.u.}$$

$$\text{Reactance for transformer } T_2 = 0.1 \left(\frac{127\sqrt{3}}{220} \right)^2 \left(\frac{50}{10 \times 3} \right) = 0.167 \text{ p.u.}$$

$$\text{Reactance for transformer } T_3 = 0.1 \left(\frac{220}{220} \right)^2 \left(\frac{50}{35} \right) = 0.143 \text{ p.u.}$$

The reactance diagram for the system shown by single line diagram of Fig. (e9.4), on a base of 50 MVA and 13.8 kV in the circuit of generator 1 is as shown in Fig. (e9.9). Note that the phase shift caused by Δ -Y or Y- Δ transformers have been ignored here and in the following examples.

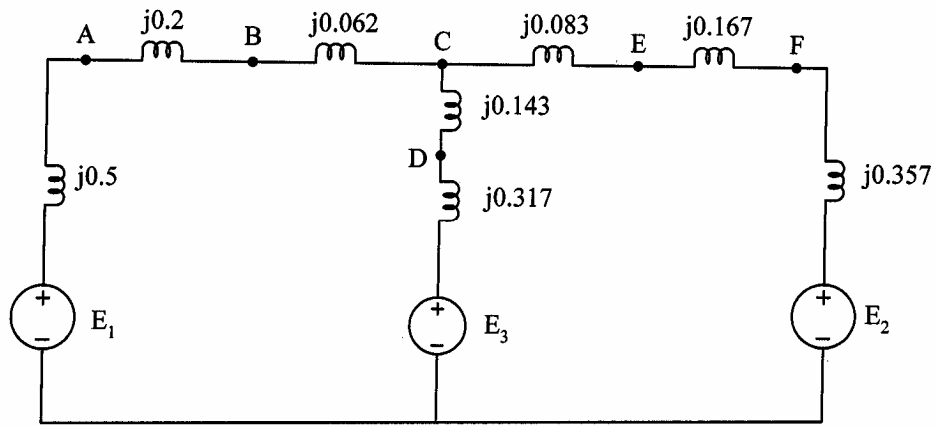


Fig. (e9.9): Reactance diagram for the system of Fig. (e9.4) with all reactances given in p.u. on the base values specified in Example (9.4).