Analysis of electrical power and energy systems

Practical session 2

30 September 2021

1 Exercises[1]

1. A positive sequence (a-b-c), balanced, wye-connected voltage source has the phase-a voltage given as $\overline{V}_a = \sqrt{2} \times 100\angle 30°$V. Obtain the time-domain voltages $v_a(t)$, $v_b(t)$, $v_c(t)$ and $v_{ab}(t)$, and show all of these as phasors.

2. A balanced three-phase inductive load is supplied in steady-state by a balanced, wye-connected, three-phase voltage source with a phase voltage of 120V RMS. The load draws a total of 10kW at a power factor of 0.9. Calculate the RMS value of the phase currents and the magnitude of the per-phase load impedance, assuming a wye connected load. Draw a phasor diagram showing all three voltages and currents.

3. In the per-phase circuit of Figure 1, the power transfer per-phase is 1 kW from side 1 to 2. $V_S = 100$ V, $\overline{V}_R = 95\angle 0°$ V, and $X = 1.5\ \Omega$. Calculate the current, the phase angle of $\overline{V}_S$, and the per-phase Q_R supplied to the receiving end.

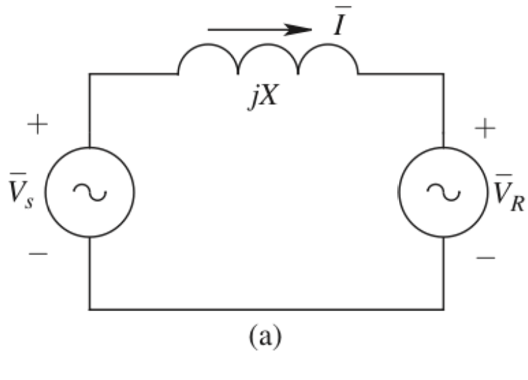

Figure 1: Power transfer between two AC systems.

4. In a radial system represented by the circuit of Figure 1, $X = 1.5\ \Omega$. Consider the source voltage to be constant at $\overline{V}_S = 100\angle 0°$ V. Calculate and plot V_S/V_R if the load varies in a range from 0 to 1 kW at the following three power factors: unity, 0.9 (lagging), 0.9 (leading).

5. In the three-phase circuit of Figure 2, $|Z_L| = 10\ \Omega$, and the per-phase power factor is 0.8 (lagging). Calculate the per-unit values of the per-phase voltage, the load impedance, the load current, and the load real and reactive powers,

   (a) if the line-to-line voltage base value is 208 V (RMS) and the base value of the three-phase power is 3.6 kW.

[1] Exercises 2.11, 2.12, 2.16, 2.17, 2.18, 2.19 and 2.20 from Ned Mohan's book "Electric power systems, a first course"

(b) if the line-to-line voltage base value is 240 V (RMS) and the base value of the three-phase power is 5.4 kW.

(c) if the line-to-line voltage base value is 240 V (RMS) and the base value of the three-phase power is 3.6 kW.

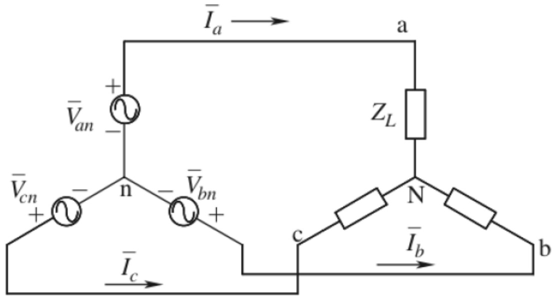

Figure 2: Balanced wye connected, three-phase circuit.

2 Solutions

Link to the python notebook shown during the session: Python Notebook TP2

1. For a frequency of 50 Hz, $v_a(t) = 200\cos(100\pi t + \frac{\pi}{6})$ V, $v_b(t) = 200\cos(100\pi t + \frac{3\pi}{2})$ V, $v_a(t) = 200\cos(100\pi t - \frac{5\pi}{6})$ V, $v_{ab}(t) = \sqrt{3}\,200\cos(100\pi t + \frac{\pi}{3})$ V

2. $I = 30.864$ A, $|Z_L| = 3.888\ \Omega$

3. $\overline{V}_A = 992.428\angle - 0.413°$ V

4. $\overline{I} = 10.82\angle - 13.35°$ A, $\delta = 9.08°$, per phase $Q_R = 237.221$ var supplied to the receiving end

5. The plots will be shown during the practical session.

6. (a) $\overline{V}_{ph} = 1\angle 0°$ pu, $Z_L = 0.832\angle - 36.87°$ pu, $\overline{I}_L = 1.202\angle - 36.87°$ pu, $P_L = 0.961$ pu, $Q_L = 0.721$ pu

   (b) $\overline{V}_{ph} = 1\angle 0°$ pu, $Z_L = 0.937\angle - 36.87°$ pu, $\overline{I}_L = 1.067\angle - 36.87°$ pu, $P_L = 0.853$ pu, $Q_L = 0.64$ pu

   (c) $\overline{V}_{ph} = 1\angle 0°$ pu, $Z_L = 0.625\angle - 36.87°$ pu, $\overline{I}_L = 1.6\angle - 36.87°$ pu, $P_L = 1.28$ pu, $Q_L = 0.96$ pu