

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

EXAMINATION PERIOD
MAY 2020

CYFNOD ARHOLIADAU
MAI 2020

SOLUTIONS

MODULE CODE: M5X00927

ELECTRICAL POWER

TIME: 2 HOURS

ANSWER ALL QUESTIONS

Equipment or materials required – Calculator

Question One (40marks)

- a) For the Y-Y three phase systems shown in Figure 1 below, $V_{AB} = 200\angle 0^\circ V$ Find:
- The line voltages V_{BC} and V_{CA} [5]
 - The phase voltages V_{AN} , V_{BN} and V_{CN} [5]
 - The phase currents I_{an} , I_{bn} and I_{cn} [5]
 - The line currents I_a , I_b and I_c [5]

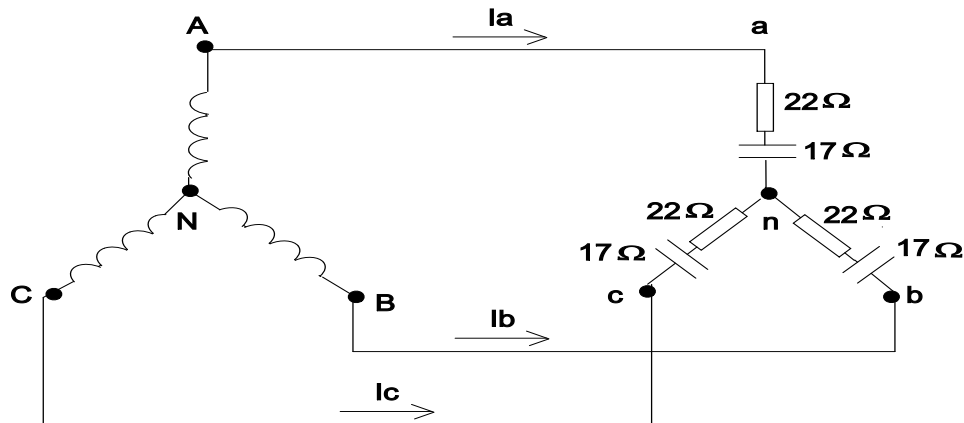


Figure 1

Solutions

i)

The line voltages

$$V_{AB} = 200 \angle 0^\circ \text{ Volt}$$

$$V_{BC} = 200 \angle -120^\circ \text{ Volt}$$

$$V_{CA} = 200 \angle 120^\circ \text{ Volt}$$

ii)

The phase voltages

$$V_{AB} = \sqrt{3} V_{AN} \angle 30^\circ$$

$$V_{AN} = \frac{V_{AB}}{\sqrt{3} \angle 30^\circ}$$

$$V_{AN} = \frac{200 \angle 0^\circ}{\sqrt{3} \angle 30^\circ}$$

$$V_{AN} = 115 \angle -30^\circ \text{ volt}$$

$$V_{BN} = V_{AN} \angle (\emptyset - 120^\circ)$$

$$V_{BN} = 115 \angle (-30^\circ - 120^\circ)$$

$$V_{BN} = 115 \angle -150^\circ \text{ volt}$$

$$V_{CN} = V_{AN} \angle (\emptyset + 120^\circ)$$

$$V_{CN} = 115 \angle (-30^\circ + 120^\circ)$$

$$V_{CN} = 115 \angle 90^\circ \text{ volt}$$

iii)

$$I_{an} = \frac{V_{an}}{Z_{an}}$$

$$I_{an} = \frac{115 \angle -30^\circ}{22 - j15}$$

$$I_{an} = \frac{115 \angle -30^\circ}{27.80 \angle -37.69^\circ}$$

$$I_{an} = 4.13 \angle 7.70^\circ \text{ A}$$

$$I_{bn} = I_{an} \angle (\emptyset - 120^\circ)$$

$$I_{bn} = 4.13 \angle (7.70^\circ - 120^\circ)$$

$$I_{bn} = 4.13 \angle -112.3^\circ \text{ A}$$

$$I_{cn} = I_{an} \angle (\emptyset + 120^\circ)$$

$$I_{cn} = 4.13 \angle (7.70^\circ + 120^\circ)$$

$$I_{cn} = 4.13 \angle 127.7^\circ \text{ A}$$

iv)

$$I_a = I_{an} , \quad I_b = I_{bn} \quad \text{and} \quad I_c = I_{cn}$$

b) Figure 2 below shows a balanced Y- connected source with $V_{an} = 120 \angle 20^\circ V$ is connected to a Δ -connected balanced load $Z_\Delta = 12 + j8 \Omega$ per phase. Calculate:

- The phase voltages V_{an}, V_{bn}, V_{cn} [5]
- The line voltages V_{ab}, V_{bc}, V_{ca} [5]
- The phase currents I_{AB}, I_{BC}, I_{CA} [5]
- The line currents I_a, I_b, I_c [5]

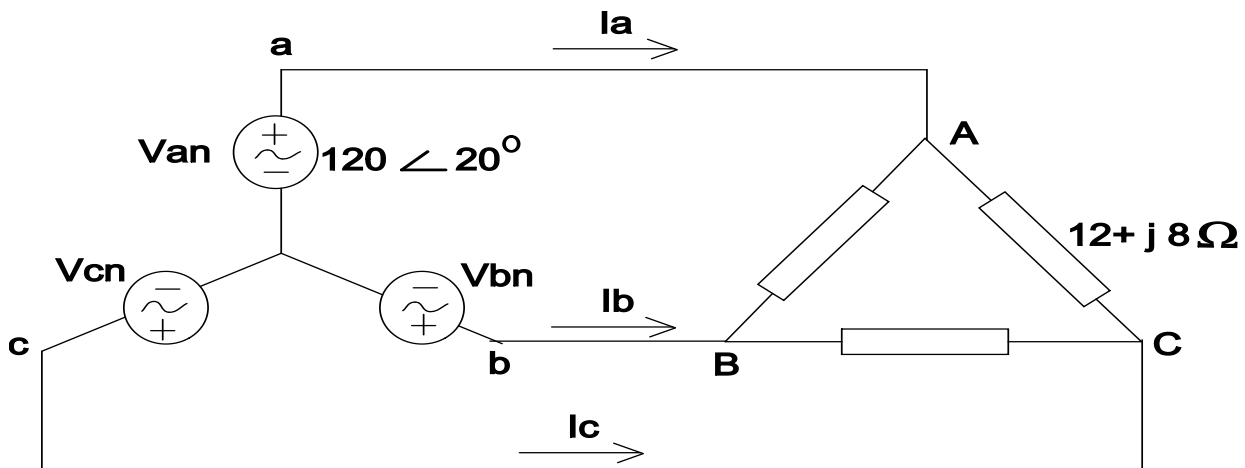


Figure 2

i)

$$V_{an} = V_{an} \angle 0^\circ$$

$$V_{bn} = V_{an} \angle -120^\circ$$

$$V_{cn} = V_{an} \angle +120^\circ$$

$$V_{an} = 120 \angle 20^\circ V$$

$$V_{bn} = 120 \angle 20^\circ - 120^\circ V = 120 \angle -100^\circ V$$

$$V_{cn} = 120 \angle 20^\circ + 120^\circ V = 120 \angle 140^\circ V$$

ii)

If the phase voltage $V_{an} = 120 \angle 20^\circ V$, the line voltage is

$$V_{ab} = V_{an}\sqrt{3}\angle 30.0^\circ = 120\sqrt{3}\angle(20 + 30)^\circ = 207.85\angle 50.0^\circ$$

$$V_{bc} = V_{an}\sqrt{3}\angle -120.0^\circ = 120\sqrt{3}\angle(50 - 120)^\circ = 207.85\angle -70.0^\circ$$

$$V_{ca} = V_{an}\sqrt{3}\angle +120.0^\circ = 120\sqrt{3}\angle(50 + 120)^\circ = 207.85\angle +170.0^\circ$$

iii)

The load impedance is $Z_\Delta = 12 + j8 = 14.22\angle 33.69^\circ \Omega$

If the phase voltage $V_{an} = 120 \angle 20^\circ V$, the line voltage is

$$I_{AB} = \frac{V_{AB}}{Z_\Delta} = \frac{V_{ab}}{Z_\Delta} = \frac{207.85\angle 50.0^\circ}{14.22\angle 33.69^\circ} = 14.616\angle 16.31^\circ A$$

$$I_{BC} = \frac{V_{BC}}{Z_\Delta} = \frac{V_{bc}}{Z_\Delta} = \frac{207.85\angle -70.0^\circ}{14.22\angle 33.69^\circ} = 14.616\angle -103.69^\circ A$$

$$I_{CA} = \frac{V_{CB}}{Z_\Delta} = \frac{V_{ca}}{Z_\Delta} = \frac{207.85\angle 170.0^\circ}{14.22\angle 33.69^\circ} = 14.616\angle 136.31^\circ A$$

iv)

$$I_a = I_{AB}\sqrt{3} \angle -30^\circ$$

$$I_a = 14.616\sqrt{3} \angle 16.31^\circ - 30^\circ$$

$$I_a = 25.315\angle -13.69^\circ A$$

$$I_b = I_{BC}\sqrt{3} \angle -30^\circ$$

$$I_b = 14.616\sqrt{3} \angle -103.69^\circ - 30^\circ$$

$$I_b = 25.315\angle -133.69^\circ A$$

$$I_c = I_{CA}\sqrt{3} \angle -30^\circ$$

$$I_c = 14.616\sqrt{3} \angle 136.31^\circ - 30^\circ$$

$$I_b = 25.315\angle 106.69^\circ A$$

Question two (40marks)

a) Figure 3 below shows RC load being fed by a voltage source 240 V through RL short transmission line. Calculate:

- The apparent, real and reactive power absorbed by the source. [5]
- The apparent, real and reactive power absorbed by the line. [5]
- The apparent, real and reactive power absorbed by the load. [5]
- The total apparent power and the power factor of the circuit. [10]

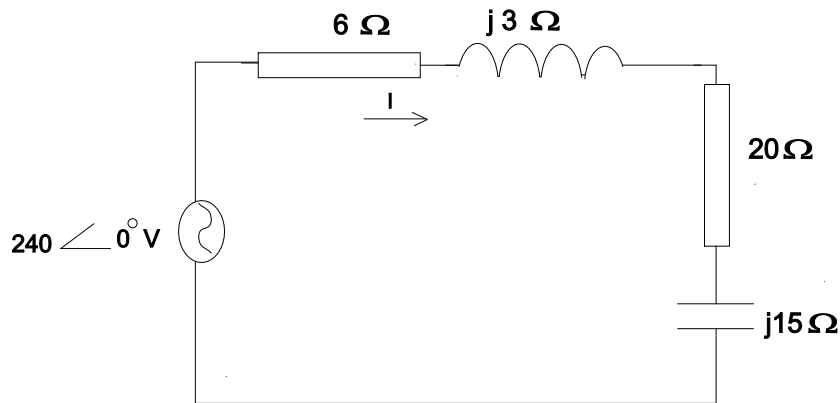


Figure 3

$$Z = (6 + j3) + (20 - j15) = 26 - j12 = 28.635 \angle -24.77^\circ$$

$$I = \frac{V_s}{Z} = \frac{240 \angle 0^\circ}{28.635 \angle -24.77^\circ} = 8.38 \angle 24.77^\circ \text{ A}$$

$$S_s = VI^* = 240 \angle 0^\circ \times 8.38 \angle -24.77^\circ = 2011.2 \angle -24.77^\circ = 1826.16 - j842.65 \text{ VA}$$

$$\text{Real power} = 1826.16 \text{ W}$$

$$\text{Reactive power} = 842.65 \text{ VAR} \quad \text{leading}$$

$$V_{line} = (6 + j3) \times I = 6.708 \angle 26.56^\circ \times 8.38 \angle 24.77^\circ = 56.21 \angle 51.33^\circ \text{ V}$$

$$\begin{aligned} S_{line} &= V_{line} I^* = 56.21 \angle 51.33^\circ \times 8.38 \angle -24.77^\circ = 471.04 \angle 26.56^\circ \\ &= 421.33 + j210.62 \text{ VA} \end{aligned}$$

$$\text{Real power} = 421.33 \text{ W}$$

$$\text{Reactive power} = 210.62 \text{ VAR} \quad \text{lagging}$$

$$V_{load} = (20 - j15) \times I = 25.0\angle -36.87^\circ \times 8.38\angle 24.77^\circ = 209.5\angle -12.1^\circ V$$

$$S_{load} = V_{load}I^* = 209.5\angle -12.1^\circ \times 8.38\angle -24.77^\circ = 1755.61\angle -36.87^\circ \\ = 1404.486 - j1053 \text{ VA}$$

$$\text{Real power} = 1404.5 \text{ W}$$

$$\text{Reactive power} = 1053 \text{ VAR leading}$$

The total real power $P_T = P_{line} + P_{load}$

$$P_T = 421.33 + 1404.5$$

$$P_T = 1825.8 \text{ W}$$

The total reactive power $Q_T = Q_{line} + Q_{load}$

$$Q_T = 210.62 - 1053$$

$$Q_T = -842.38 \text{ VAR}$$

The total apparent power in the circuit is

$$S_T = P_T + jQ_T = 1825.8 - j842.38 = 2010\angle -24.76^\circ$$

The power factor of the circuit is

$$PF_T = \frac{P_T}{S_T} = \frac{1825.8}{2010} = 0.917 \text{ Leading}$$

b) Equivalent circuit of a medium single-phase transmission line is shown in Figure 4. The series inductance L per kilometre is 1.400 mH/km. the shunt capacitance C per kilometre of the line is 8.4 nF/km, and the resistivity of the line at 20° C will be $2.95 \times 10^{-8} \Omega\text{m}$. If the length l of the 50Hz transmission line is 60 km with a radius of 3 cm calculate:

- i. The series resistance per kilometre of this line [5]
- ii. The total series impedance of this line [5]
- iii. The total shunt reactance of this line [5]

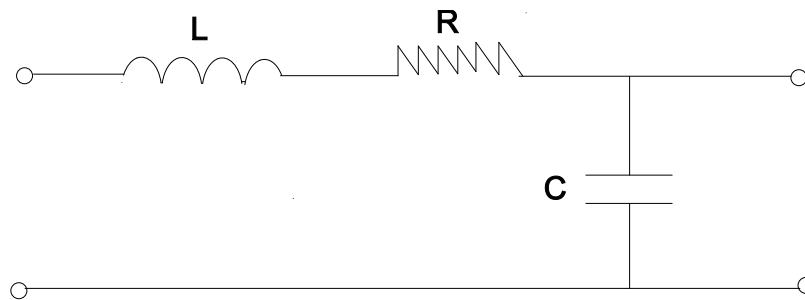


Figure 4

i)

The resistance per kilometre of the line is

$$R = \frac{\rho l}{A}$$

$$R = \frac{2.75 \times 10^{-8} \times 1000}{\pi \times 0.03^2}$$

$$R = 0.0104 \Omega/\text{km}$$

ii)

The series impedance per kilometre of the transmission line is

$$z_{eq} = R + jx_L$$

$$z_{eq} = 0.0104 + j \times 2 \times \pi \times 50 \times 1.4 \times 10^{-3}$$

$$z_{eq} = 0.0104 + j0.236 \Omega/\text{km}$$

The total series impedance of the line is

$$Z_{eq} = (R + jx_L)l$$

$$Z_{eq} = (0.0104 + j0.236) \times 60$$

$$Z_{eq} = 0.626 + j14.137 \, \Omega$$

iii)

The shunt reactance per kilometre X_C of the transmission line is

$$X_C = \frac{1}{j\omega C}$$

$$X_C = \frac{1}{j2\pi \times 50 \times 8.4 \times 10^{-9}}$$

$$X_C = -j3.79 \times 10^5 \frac{\Omega}{km}$$

The total shunt reactance of this line

$$X_{CT} = \frac{X_C}{l}$$

$$X_{CT} = \frac{-j3.79 \times 10^5}{60} = -j6.316k\Omega$$

Question Three (20marks)

A single phase motor connected to 500V, 60 Hz main supply, the motor is taking a current $I_m = 28.5 \text{ A}$ with a power factor of 0.75 lagging.

- i. Determine the active and the reactive components of the motor current I_m [6]
- ii. Calculate the supply current I , when the power factor corrected to 0.95 lagging. [6]
- iii. Calculate the capacitance required in parallel with the motor to improve the power factor to 0.95 lagging. [8]

i)

$$\text{power factor} = \cos \phi_m = 0.75$$

$$\phi_m = \cos^{-1} 0.75 = 41.41^\circ$$

The active component of I_m

$$I_m \cos \phi_m = 28.5 \times 0.75 = 21.375 \text{ A}$$

The reactive component of I_m

$$I_m \sin(41.41) = 28.5 \times 0.661 = 18.85 \text{ A}$$

ii)

$$\text{The new power factor} = \cos \phi = 0.95$$

$$\phi = \cos^{-1} 0.95 = 18.19^\circ$$

The active power remains unchanged due to power factor correction.

The active component of $I =$

$$I \cos \phi = I \times 0.95 = 21.375 \text{ A}$$

The new supply current

$$I = \frac{21.375}{0.95} = 22.5 \text{ A}$$

iii)

The current taken by the capacitor I_C in parallel with the motor is the difference between the reactive components of I_m and I

The reactive component of I

$$I \sin \phi = 22.5 \sin(18.19) = 7.026A$$

The reactive component of $I_C =$ reactive component of I_m - reactive component of I

$$I_C = 18.85 - 7.026$$

$$I_C = 11.824A \text{ leading}$$

$$I_C = \frac{V}{X_C} = 2\pi f C V$$

$$C = \frac{I_C}{2\pi f V} = \frac{11.824}{500 \times 2\pi \times 60} = 62.73 \mu F$$

The effect of connecting a 62.73 μF capacitor in parallel with the motor is to reduced the current taken from supply 28.5A to 22.5A without altering the power taken by the motor