

task_jti0uzudcmg4u22t_with_calculation

Student Group

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complex impedance, exam WS2022

Exercise 1 : Analyzing complex Impedances

(written test, approx. 14% of a 60-minute written test, WS2022)

A circuit with an ideal voltage source ($U=50\text{ V}$, $f=330\text{ Hz}$) and two components (R and X_1) shall be given.

After analysis, the following formula for the impedance was extracted:
$$\underline{Z} = \left(\frac{2}{3+4j} + 5j \right) \Omega$$

1. Calculate the physical values of the two components.

Solution

$$\begin{aligned} \underline{Z} &= \left(\frac{2}{3+4j} + 5j \right) \Omega \quad \&= \left(\frac{2}{3+4j} \cdot \frac{3-4j}{3-4j} + 5j \right) \Omega \quad \&= \\ &= \left(\frac{2}{9+16} \cdot (3-4j) + 5j \right) \Omega \quad \&= (0.24 - 0.32j + 5j) \Omega \quad \&= 0.24 \Omega + j \cdot 4.68 \Omega \quad \&= R + j X_L \end{aligned}$$

With the complex part comes the physical value:
$$X_L = \omega L \quad L = \frac{X_L}{\omega} = \frac{4.68 \Omega}{2\pi \cdot 300 \text{ Hz}} = 2.26 \text{ mH}$$

Final result

$$R = 0.24 \Omega \quad L = 2.26 \text{ mH}$$

2. Calculate the phase and absolute value of complex current $\underline{I}$ through the circuit.

Solution

$$\begin{aligned} \underline{I} &= \frac{\underline{U}}{\underline{Z}} \quad \&= \frac{50 \text{ V}}{0.24 \Omega + j \cdot 4.68 \Omega} \quad \&= \frac{50 \text{ V}}{0.24 \Omega + j \cdot 4.68 \Omega} \cdot \frac{0.24 \Omega - j \cdot 4.68 \Omega}{0.24 \Omega - j \cdot 4.68 \Omega} \quad \&= \\ &= \frac{50 \text{ V}}{(0.24 \Omega)^2 + (4.68 \Omega)^2} \cdot (0.24 \Omega - j \cdot 4.68 \Omega) \end{aligned}$$

The absolute value $|\underline{I}|$ can be calculated as:
$$|\underline{I}| = \frac{|\underline{U}|}{|\underline{Z}|} \quad \&= \frac{50 \text{ V}}{\sqrt{(0.24 \Omega)^2 + (4.68 \Omega)^2}}$$

The phase φ_i can be calculated as
$$\varphi_i = \arctan \left(\frac{\text{Im}(\underline{Z})}{\text{Re}(\underline{Z})} \right)$$

$$\left. \frac{\operatorname{Im}(\cdot)}{\operatorname{Re}(\cdot)} \right) \right) \quad \&= \arctan \left(\frac{-4.68 \, \Omega}{0.24 \, \Omega} \right)$$

Final result

$$\underline{I} \quad \&= 10.67 \, \text{A} \quad \varphi_i \quad \&= -87.06^\circ$$

3. Now an additional component $\underline{X}_2$ shall be added in series to the two components.

This component shall be dimensioned in such a way that the current and voltage are in phase. Calculate these component value!

Solution

The current and voltage are in phase once there is only a pure ohmic (= pure real) resulting impedance $\underline{Z} + \underline{X}_2$.

Therefore, the component must be a capacitor with the same absolute value of impedance:

$$|\underline{X}_C| = |\underline{X}_L| \quad \begin{aligned} \underline{X}_C \quad \&= \frac{1}{\omega \cdot C} \\ C \quad \&= \frac{1}{\omega \cdot X_L} \quad \&= \frac{1}{2\pi \cdot 300 \, \text{Hz} \cdot 4.68 \, \Omega} \end{aligned}$$

Final result

$$C = 103 \, \mu\text{F}$$

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