

BE1M13VES

Manufacturing of Electrical Components

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Overview

1 Impedance

2 Exercises

TOPIC

1 Impedance

2 Exercises

Phasors

Phasor is representation of sinusoidal function by complex number. Transformation can be defined by the equation:

$$u = U_m \cdot \sin(\omega \cdot t + \varphi) = \text{Im} \left\{ U_m \cdot e^{j(\omega t + \varphi)} \right\}$$

Complex number, phasor:

$$\hat{U} = U_m \cdot e^{j\varphi}$$

Rewritten transformation with phasor:

$$u = U_m \cdot \sin(\omega \cdot t + \varphi) = \text{Im} \left\{ \hat{U} \cdot e^{j\omega t} \right\}$$

Phasors - Features

- Part $e^{j\omega t}$ is time dependence of the phasor and its value is the same in a moment for all phasor at the same frequency. Phasors are analyzed, summed and multiplied without considering this part.
- Phasor are time independent in harmonic stable state.
- Time derivations change the value of the phasor by multiplying it by $j\omega$:

$$\frac{\partial u}{\partial t} = \frac{\partial}{\partial t} \text{Im} \left\{ \hat{U} \cdot e^{j\omega t} \right\} = \text{Im} \left\{ j\omega \cdot \hat{U} \cdot e^{j\omega t} \right\}$$

- Time integration change the value of the phasor by dividing it by $j\omega$:

$$\int u dt = \int \text{Im} \left\{ \hat{U} \cdot e^{j\omega t} \right\} dt = \text{Im} \left\{ \frac{\hat{U} \cdot e^{j\omega t}}{j\omega} \right\}$$

Complex Impedance

Complex impedance can be defined only for ideal components where nominal values of resistance R , inductance L and capacitance C are constant.

- Capacitive reactance:

$$i(t) = C \cdot \frac{\partial u(t)}{\partial t} \implies \hat{I} = j\omega C \cdot \hat{U}$$

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

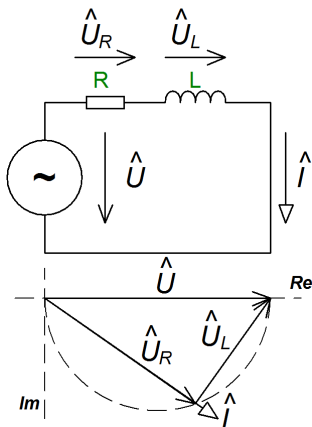
- Inductive reactance:

$$u(t) = L \cdot \frac{\partial i(t)}{\partial t} \implies \hat{U} = j\omega L \cdot \hat{I}$$

$$X_L = j\omega L$$

Phasors and Complex Impedance

Phasors and complex impedance make analysis of circuits in harmonic stable state simple:



According to 2nd Kirchhoff's law:

$$\hat{U} = \hat{U}_R + \hat{U}_L = R \cdot \hat{I} + j\omega L \cdot \hat{I}$$

Complex impedance:

$$\hat{Z} = R + j\omega L$$

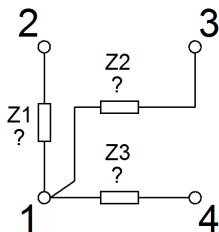
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Behavior of Components at Harmonic Supply

- 1** Identify unknown components in the black-box through their response to a harmonic signal.



Voltage, current and frequency dependency for each component:

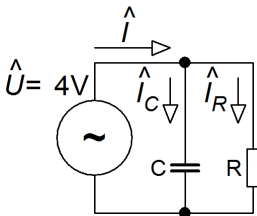
$$\hat{U} = R \cdot \hat{I}$$

$$\hat{U} = X_L \cdot \hat{I} = j\omega L \cdot \hat{I}$$

$$\hat{U} = X_C \cdot \hat{I} = \frac{-j}{\omega C} \cdot \hat{I}$$

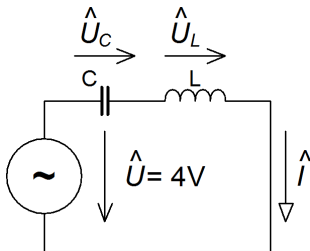
Behavior of Components at Harmonic Supply

- 2** Create parallel connection of capacitor and resistor. Connect the circuit to the voltage source 4 V. Measure the current in each branch.



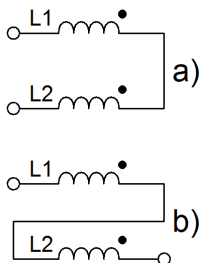
- Do the current values respect 1st Kirchhoffs law?
- Write the measured currents as a phasors (complex numbers).
- Draw a phasor diagram. Think about dissipation factor D , where is angle δ ?

3 Create serial connection of capacitor and inductor. Connect the circuit to the voltage source 4 V. Measure the current and voltage drop over each component.



- Do the voltage values respect 2nd Kirchhoffs law?
- Write the measured voltages as a phasors (complex numbers).
- Draw a phasor diagram. Think about quality factor Q . How can you determine it?

4 Build your own coil with inductance $L = 36 \mu\text{H}$. The second coil build with double core with the same amount of turns. Third coil build with two windings of $N = 10$ turns.



- What value has the magnetic conductance A_L ?
- What difference in inductance is in first and second case coil and why?
- How does the inductance change in case three for circuit a) and b)?

Linearity of an Inductor

- 5 Just see the experiment for the iron powder core.
- Check the maximum current for linear use of the coil sample.
- Check the hysteresis curve and the shape of the excitation and flux signals.