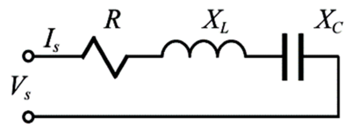
Single-Phase AC Circuits and Phasors

You will need to use a calculator that can handle complex numbers, or you can directly use MATLAB.

1) Assume a serious connection of resistor, inductor, and capacitor (i.e. RLC) elements connected to a AC 60Hz voltage source $V_s = 10V$ rms, as shown on the figure below:



Sketch a qualitative phasor diagram (approximately to scale) and show the current and voltage drops on each element (similar to what we did in class) for the following scenarios:

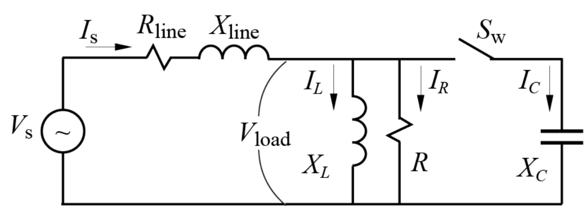
a) For the values: $R = 1\Omega$; $X_L = 1\Omega$; $X_C = 1\Omega$.

b) For the values: $R = 1\Omega$; $X_L = 2\Omega$; $X_C = 1\Omega$.

c) For the values: $R = 1\Omega$; $X_L = 1\Omega$; $X_C = 2\Omega$.

d) Using a calculator that handles complex numbers, calculate and label the rms values of current and all voltage drops on each of the diagrams.

2) Assume an RL load defined by $R = 10\Omega$ and $X_L = 10\Omega$ is fed from a AC 60Hz source $V_s = 120V$ rms through a line (cable) with impedance $R_{line} = 1\Omega$ and $X_{line} = 1\Omega$, as depicted on the figure below. There is also an option to connect a power factor compensating capacitor X_C when needed using the switch S_w.



a) Assume S_w is open (no compensation). Calculate the voltage that appears across the load V_{load}, source current I_s, real reactive power P, power factor PF, apparent power S, and reactive power Q delivered to the load. Also calculate the loss of real power P_{loss} in the line (cable) that is supplying the load. Draw approximate qualitative phasor diagram for this case depicting respective voltages and currents.

b) Now assume that you have a partial power factor correction (S_w is closed) using the additional capacitor $X_C = 20\Omega$. Repeat all calculations done in part a). Make observations and conclusions about the real power consumed by the load and the losses in the line.

c) Now assume that you have a full power factor correction using the additional capacitor $X_C = 10\Omega$. Repeat all calculations done in part a). Draw approximate qualitative phasor diagram for this case depicting respective voltages and currents. Make observations and conclusions about the real power consumed by the load and the losses in the line.

d) Implement this system using MATLAB/Simulink toolbox **Simscape Electrical** and reproduce the studies in parts a) through c). Plot load voltage V_{load} and source current I_s for each case and discuss/conclude the effect of power factor correction.

Three-Phase AC Circuits and Phasors

3) Assume that you have three voltage sources with magnitude 120 V rms, and shifted by 120 degrees, respectively, so that they can form a balanced and symmetric three-phase system. You also have three identical loads (resistor and inductor connected in series) with the total impedance of each $Z_{load} = 5 + j5$ Ohms. You have learned in class, that you can connect your sources and loads in Y and/or Δ arrangements, respectively. Perform the following tasks for each of the cases described below. For each case, also sketch a circuit diagram, label all sources and loads, voltages and currents, etc.

a) (Y-Y) Assume your source is Y-connected, and the load is also Y-connected. Calculate the phase currents, power factor, power factor angle, real, apparent, and reactive power delivered to your load. Sketch a corresponding qualitative phasor diagram.

b) (Y-Δ) Assume your source is Y-connected, and the load is Δ-connected. Calculate the phase currents, power factor, power factor angle, real, apparent, and reactive power delivered to your load. Sketch a corresponding qualitative phasor diagram.

c) (Δ-Y) Assume your source is Δ-connected, and the load is Y-connected. Calculate the phase currents, power factor, power factor angle, real, apparent, and reactive power delivered to your load. Sketch a corresponding qualitative phasor diagram.

d) (Δ-Δ) Assume your source is Δ-connected, and the load is also Δ-connected. Calculate the phase currents, power factor, power factor angle, real, apparent, and reactive power delivered to your load. Sketch a corresponding qualitative phasor diagram.

e) Prepare a table in which you compare the values of line-to-line voltages, line currents, and total real power delivered to your load as you have found it for each case a) through d). Briefly explain the results in this table.

f) Implement cases a) through d) using MATLAB/Simulink toolbox **Simscape Electrical** and reproduce the studies in each part. Comment if your results agree with your previous calculations?

Basic magnetic Circuits

Problems from the Textbook: 1.2; 1.4; 1.7; and 1.14.

1.2 In the magnetic system of Fig. P1.2 two sides are thicker than the other two sides. The depth of the core is 10 cm, the relative permeability of the core $\mu_r = 2000$, the number of turns $N = 300$, and the current flowing through the coil is $i = 1$ A.

(a) Determine the flux in the core.

(b) Determine the flux densities in the parts of the core.

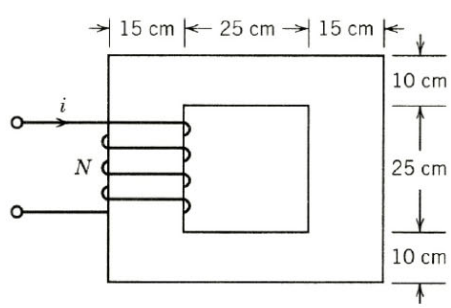


FIGURE P1.2

1.4 Two coils are wound on a toroidal core as shown in Fig. P1.4. The core is made of silicon sheet steel and has a square cross section. The coil currents are $i_1 = 0.28$ A and $i_2 = 0.56$ A.

(a) Determine the flux density at the mean radius of the core.

(b) Assuming constant flux density (same as at the mean radius) over the cross section of the core, determine the flux in the core.

(c) Determine the relative permeability, μ_r, of the core.

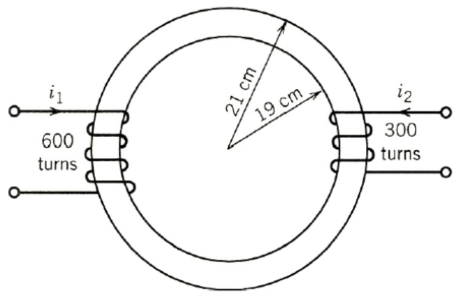


FIGURE P1.4

1.7 A two-pole synchronous machine, as shown in Fig. P1.7, has the following dimensions:

Each air gap length, $l_g = 2.5$ mm

Cross-sectional area of pole face, $A_g = 500\ \text{cm}^2$

$N = 500$ turns

$I = 5$ A

$\mu_c = \text{infinity}$

(a) Draw the magnetic equivalent circuit.

(b) Find the flux density in the air gap.

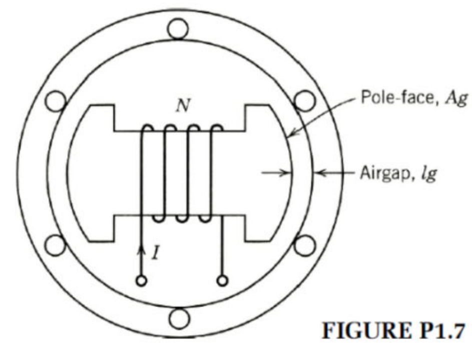


FIGURE P1.7

1.14 An inductor is made of two coils, A and B, having 350 and 150 turns, respectively. The coils are wound on a cast steel core and in directions as shown in Fig. P1.14. The two coils are connected *in series* to a dc voltage.

(a) Determine the two possible values of current required in the coils to establish a flux density of 0.5 T in the air gap.

(b) Determine the self-inductances L_A and L_B of the two coils. Neglect magnetic leakage and fringing.

(c) If coil B is now disconnected and the current in coil A is adjusted to 2.0 A, determine the mean flux density in the air gap.

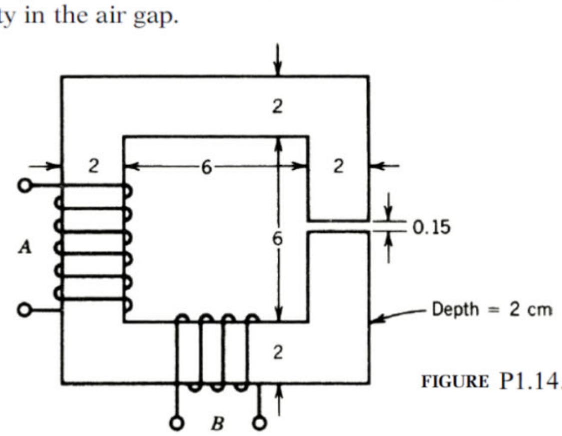


FIGURE P1.14