Problem 1: Design of a PI current controller

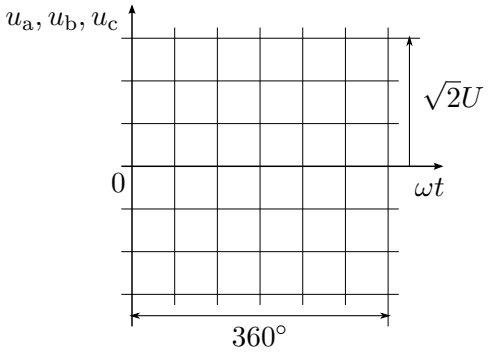
The parameters of a DC motor are $R_\mathrm{a} = 0.87\ \Omega$ and $L_\mathrm{a} = 16$ mH. An ordinary PI current controller is used. The current-control bandwidth is required to be $\alpha_\mathrm{c} = 2\pi \cdot 300$ rad/s.

(a) Derive the expressions for the controller gains according to the principle of internal model control.

(b) Derive the expressions for the controller gains by cancelling the pole of the open-loop system and by requiring that the 0-dB crossover angular frequency of the loop transfer function is α_c.

Problem 2: Waveforms in a balanced three-phase system

Sketch the waveforms of balanced three-phase voltages on the squared paper (or the grid below).



Hint: It is convenient to use a 6×6 grid to draw these waveforms. You can fist mark the points corresponding to zero crossings and peak values. It is also worth noticing that $\sin(\pi/6) = 1/2$ and mark these points on the grid.

Problem 3: Power in single-phase and three-phase systems

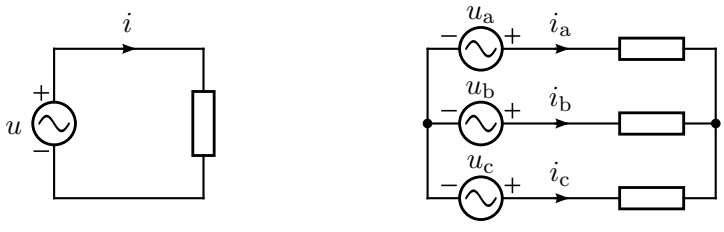
The purpose of this problem is to demonstrate that the instantaneous power in a balanced three-phase system is constant in steady state.

(a) A single-phase load is fed with the voltage $u(t) = \sqrt{2}U\sin(\omega t)$ and it draws the current $i(t) = \sqrt{2}I\sin(\omega t - \varphi)$. Derive the expressions for the instantaneous power and the average power.

Hint: The trigonometric product-to-sum identity may be useful:

$$\sin\alpha\sin\beta = \frac{1}{2}\left[\cos(\alpha-\beta) - \cos(\alpha+\beta)\right]$$

(b) A balanced three-phase load is fed with balanced three-phase voltages. Derive the expressions for the instantaneous power and the average power.



(a) (b)

Problem 4: Transmission losses

The figure below shows two different configurations to feed the same power to the resistive load:

(a) The balanced three-phase supply feeds the three resistors R_{load}. The resistance of the transmission wires is R.

(b) The single-phase supply, taken from one phase of the previous three-phase supply, feeds the load resistor $R_{\text{load}}/3$. The same transmission wires are also used as in the previous case.

The resistance R of the wires can be assumed to be much smaller than the resistance R_{load}. Compare the transmission losses in these two cases.