Three Phase Full Wave Controlled Rectifier - 2 (PE_rectifier_7.sqproj)

Question: For the circuit shown in Fig. 1, the input supply is balanced three phase with line-to-line voltage rating of 400 V, 50 Hz.

(a) Find the firing angle (α) if the average output current $I_{out} = 10\,\text{A}$.

(b) Find the input power factor in the above case.

(Assume that the inductance L is large enough to ensure a constant current in the load in steady state.)

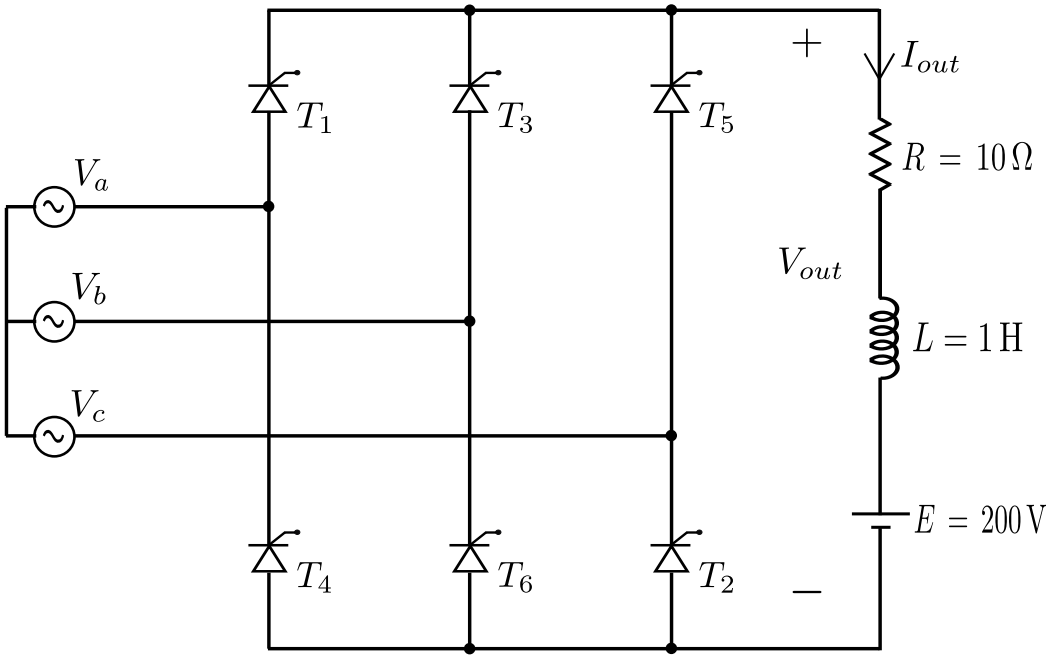

Figure 1: Three-phase fully controlled rectifier with RLE load.

Solution:

(a) For a 3 - phase full wave controlled rectifier shown in Fig. 1, the output voltage is always difference between two phase voltages. At any instant of time two thyristors of different legs conduct. Let us consider the instant at which T_1 and T_6 conduct. Solving KVL, the output voltage V_{out} is equal to the difference between V_a and V_b. Similarly this applies for every other combination of conduction of thyristors. The output waveform for continuous conduction is shown in Fig. 2.

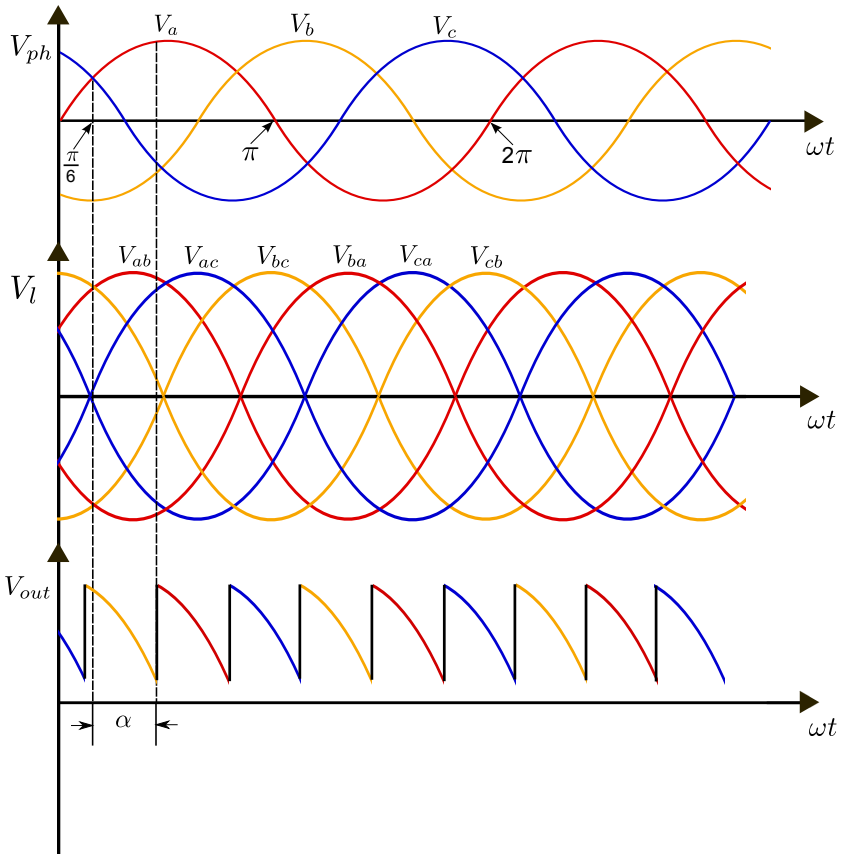

Figure 2: Output voltage waveform of 3-phase full-wave controlled rectifier

From the waveforms, the average value of output voltage,

$$V_{out} = \frac{3}{\pi} \int_{\frac{\pi}{6}+\alpha}^{\frac{\pi}{2}+\alpha} \sqrt{3} \times V_{mp} \sin(\omega t + 30^\circ)\, d(\omega t) = \frac{3\sqrt{3}}{\pi} V_{mp} \cos\alpha \tag{1}$$

Applying KVL in load side, the average output voltage,

$$V_{out} = E + I_{out}R = 200 + 10 \times 10 = 300\,\text{V} \tag{2}$$

From Eqns. (1) and (2),

$$\alpha = \cos^{-1}\left(\frac{300\,\pi}{3\sqrt{2} \times 230\sqrt{3}}\right) = 56^\circ \tag{3}$$

(b) For constant current of $I_{out} = 10\,\text{A}$, the supply current I_a is a rectangular wave of amplitude 10 A. It is also seen that this current flows for 120° in a half cycle of 180°. The RMS value of source current,

$$I_{sr} = 10 \times \sqrt{\frac{120}{180}} = 8.16\,\text{A} \tag{4}$$

RMS value of output current, $I_{or} = 10\,\text{A}$.

Power delivered to load,

$$P = EI_{out} + I_{or}^2 R = 200 \times 10 + 10^2 \times 10 = 3\,\text{kW} \tag{5}$$

Power delivered from one source, $P_s = 1\,\text{kW}$, which is equal to $V_{sr}I_{sr}\cos\phi$.

The input power factor,

$$\cos\phi = \frac{1000}{230 \times 8.16} = 0.53\,\text{lag} \tag{6}$$

SequelApp Exercises:

For the circuit shown in Fig. 1, find the following:

(a) The firing angle (α) to get an average output current $I_{out} = 15\,\text{A}$.

(b) The firing angle (α) to get an average output current $I_{out} = 10\,\text{A}$, if the battery voltage is changed to $E = 180\,\text{V}$.

(c) Find the input power factor in both the cases.

Verify your answers using SequelApp.