Three-Phase Half-Wave Controlled Rectifier - 1 (PE_rectifier_5.sqproj)

Question: For the three-phase half-wave controlled rectifier 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 average output voltage (V_{out}) and conduction period of thyristors (T_{on}) in degrees for a firing angle $\alpha = 15°$.

(b) Find the average output voltage (V_{out}) and conduction period of thyristors (T_{on}) in degrees for a firing angle $\alpha = 60°$.

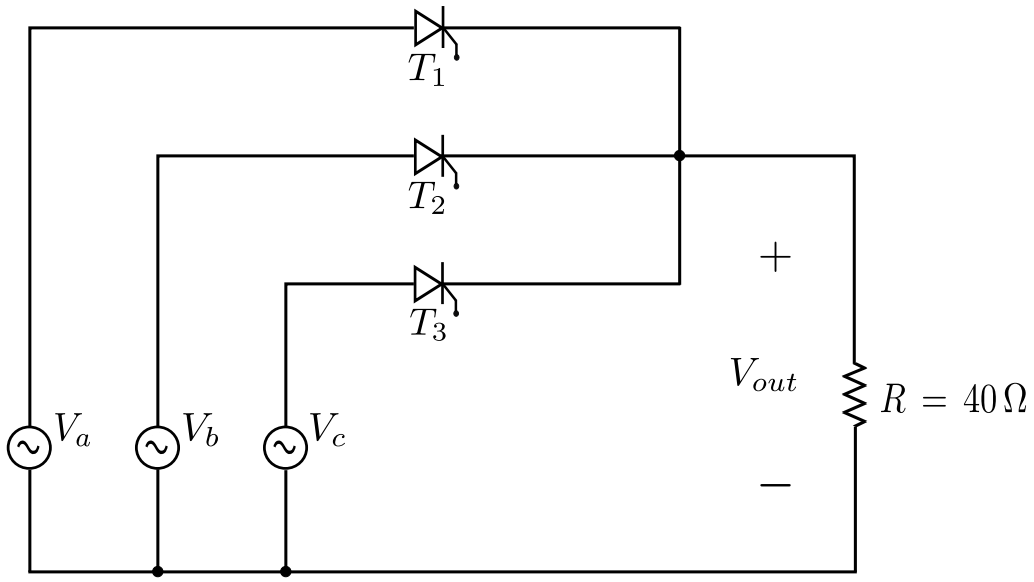

Figure 1: Three phase half-wave controlled rectifier with R load.

Solution:

(a) For a 3 - phase half-wave controlled rectifier shown in Fig. 1, the input phase voltages V_a, V_b, V_c have same amplitude and frequency with 120° phase shift as shown in Fig.2.

Thyristor T_1 is forward biased when phase voltage V_a is greater than the other phase voltages. Thyristor T_1 should be fired in this period to conduct. Similarly for thyristors T_2 and T_3, phase volatges V_b and V_c respectively should be greater than other two phase voltages. Output voltage waveform is identical to the input phase voltage corresponding to the thyristor conducting at the time. The output voltage waveforms are as shown in Fig. 2. From Fig. 2, we can infer that for α up to 30°, V_{out} is continuous. Thus for $0° < \alpha < 30°$, the average value of output voltage,

$$V_{out} = \frac{3}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} V_{mp} \sin(\omega t)\, d(\omega t) = \frac{3\sqrt{3}}{2\pi} V_{mp} \cos\alpha \tag{1}$$

For $\alpha = 15°$,

$$V_{out} = \frac{3\sqrt{3}}{2\pi} 230\sqrt{2} \cos 15° = 260\,\mathrm{V} \tag{2}$$

The three thyristors conduct for same time period in a complete cycle and as the conduction is continuous in the load, the conduction period,

$$T_{on} = \frac{360}{3} = 120° \tag{3}$$

(b) For $\alpha > 30°$, V_{out} is discontionuous for a resistive load as shown in Fig. 2. The average value of output voltage,

$$V_{out} = \frac{3}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\pi} V_{mp} \sin(\omega t)\, d(\omega t) = \frac{3}{2\pi} V_{mp} \left[1 + \cos\left(\alpha + \frac{\pi}{6}\right)\right] \tag{4}$$

For $\alpha = 60°$, average output voltage,

$$V_{out} = \frac{3 \times 230\sqrt{2}}{2\pi} \left[1 + \cos\left(\frac{\pi}{3} + \frac{\pi}{6}\right)\right] = 155\,\mathrm{V} \tag{5}$$

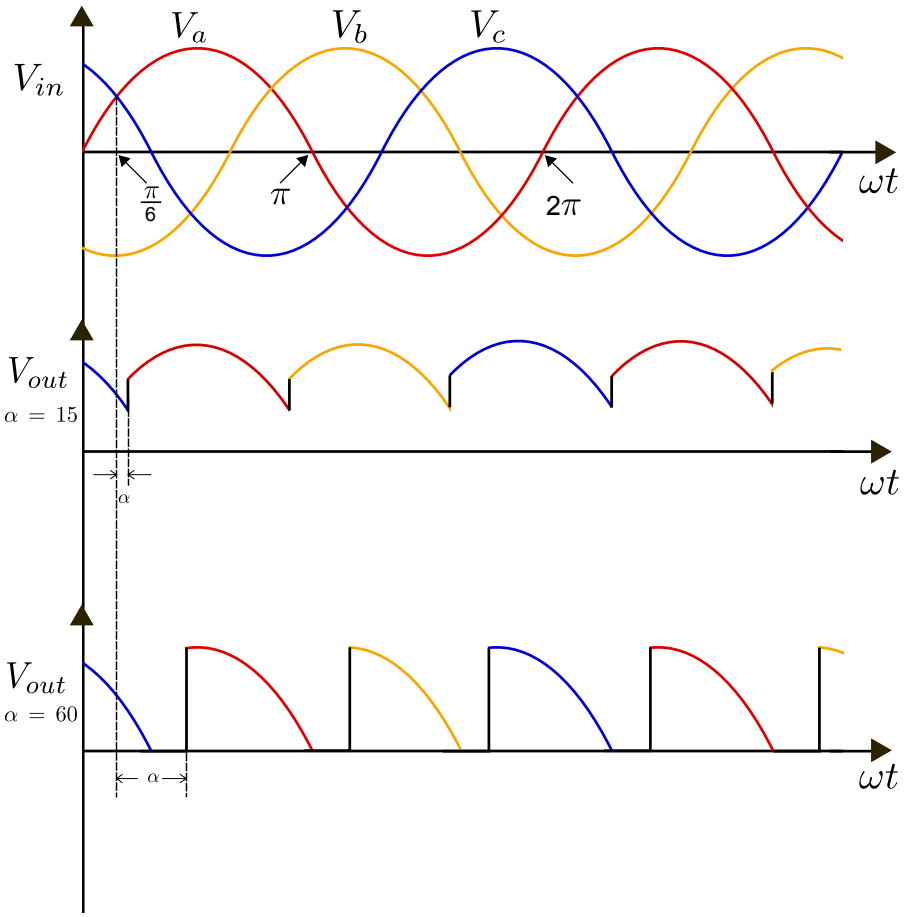

Figure 2: Output voltage waveform of 3 phase half-wave controlled rectifier

In this case, the three thyristors conduct for the same time duration, but the conduction is discontinuous in the load. Thyristor T_1 conducts from 90°to 180°.

$$T_{on} = 90° \tag{6}$$

SequelApp Exercises:

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

(a) The firing angle (α) and the conduction time (T_{on}) of the thyristor to get an average output voltage, $V_{out} = 240\,\text{V}$.

(b) The firing angle (α) and the conduction time (T_{on}) of the thyristor to get an average output voltage, $V_{out} = 120\,\mathrm{V}$.

Verify your answers using SequelApp.