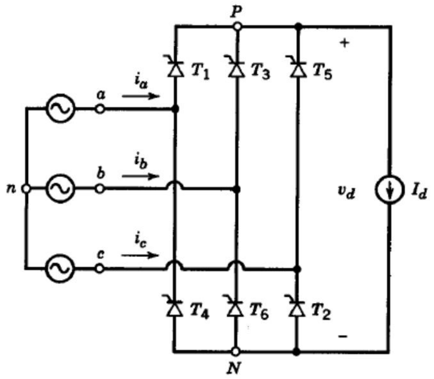
Solution to lecture 4 exercises

4-100



In the ideal three-phase thyristor rectifier circuit, *the firing angle α=30 deg*

a) *Construct the thyristor T_1 voltage and current*
b) *Construct the wave form of the dc-output voltage*
c) *Calculate the average dc-output voltage for V_{LL}=400V*

The thyristor 1 voltage will before turn-on (wt=α=30) follow Uac since T5 is conducting. During T1 conduction (α<wt<α+120deg) the T1 voltage is ideally zero. After turn-off (wt=α+120deg) the voltage is given by Uab since T3 is turning on at this time. After T5 turn on (wt=α+240deg) T1 voltage is given by Uac until T1 again turns on at wt=α+360.

The dc-side voltage is given in the 3rd trace below.

The T1 current is given in the 4th trace below.

Tomas Jonsson

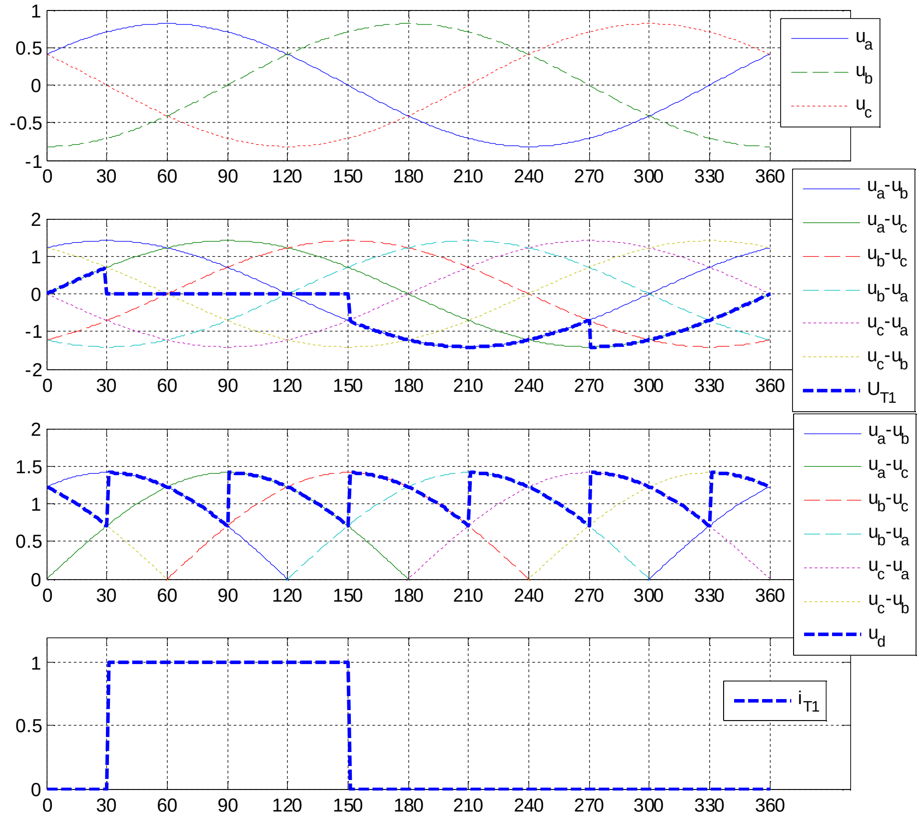


Figure 1

The average dc-side voltage is calculated as: $V_{d\alpha} = \frac{3\sqrt{2}}{\pi} V_{LL} \cos\alpha = 1.35 V_{LL} \cos\alpha = 468\text{V}$

4-101

In the three-phase thyristor rectifier circuit with the following data:
V_{LL} = 400 V at 50 Hz, L_s = 7 mH, I_d = 10A

a) *What firing angle α shall be used to get an average dc-voltage of 500V (rectifier mode)*

b) *What firing angle α shall be used to get an average dc-voltage of -500V (inverter mode)*

c) *Calculate γ. What minimum t_q is required?*

a)

$$V_d = \frac{3\sqrt{2}}{\pi} V_{LL} \cos\alpha - \frac{3\omega L_s}{\pi} I_d$$
$$\Rightarrow \cos\alpha = \frac{\pi}{3} \frac{V_d}{\sqrt{2} V_{LL}} + \frac{\omega L_s}{\sqrt{2} V_{LL}} I_d$$
$$V_d = 500V \Rightarrow \cos\alpha = 0.964$$
$$\Rightarrow \alpha = 15.3\ deg$$

b)

$$V_d = \frac{3\sqrt{2}}{\pi} V_{LL} \cos\alpha - \frac{3\omega L_s}{\pi} I_d$$
$$\Rightarrow \cos\alpha = \frac{\pi}{3} \frac{V_d}{\sqrt{2} V_{LL}} + \frac{\omega L_s}{\sqrt{2} V_{LL}} I_d$$
$$V_d = -500V \Rightarrow \cos\alpha = -0.887$$
$$\Rightarrow \alpha = 152.5\ deg$$

c)

$$\cos(\alpha) - \cos(\alpha + u) = \frac{2\omega L_s}{\sqrt{2} V_{LL}} I_d$$
$$\cos(\alpha + u) = \cos(\alpha) - \frac{2\omega L_s}{\sqrt{2} V_{LL}} I_d$$
$$\cos(\alpha + u) = -0.887 - 0.0778 = -0.965$$
$$\alpha + u = 164.7\ deg$$
$$u = 164.7 - 152.5 = 12.2\ deg$$

$$\gamma = 180 - (\alpha + u) = 15.3\ deg$$
$$t_\gamma = \frac{\gamma}{\omega} = 850\mu s$$
$$t_q < 850\mu s$$