Homework 8

Page 161. Chinese textbook

Question 6.1

A lamp is supplied by a single-phase AC voltage controller. Suppose this lamp is a resistor load, the output power reaches maximum value when α=0. Try to find the delay angle α when the output power is 80% and 50% of maximum output power.

Question 6.2

An AC voltage controller is supplied by a 50Hz-220V voltage source, and its load is serried resistor and inductor where $R = 0.5\Omega$ and L=2mH. Try to derive:

① Available range of delay angle α,
② Maximum value of RMS value of load current,
③ Maximum value output power together with power factor on the source side,
④ When $\alpha=\pi/2$, the RMS value of current in the thyristor, the conduction angle of thyristor and power factor on the source side.

Question 6.4

What is the highest output frequency of an AC-AC converter? Which factor limits the output frequency?

Answer 6.1

When phase angle $\alpha = 0°$, the output voltage is at its maximum value.

$$U_{o\max} = \sqrt{\frac{1}{\pi}\int_0^{\pi} \sqrt{2}U_1 \sin\omega t \, d(\omega t)} = U_1$$

Meanwhile, the current of load is at its maximum value.

$$I_{o\max} = \frac{U_{o\max}}{R} = \frac{U_1}{R}$$

Therefore, the maximum value of the output power is

$$P_{\max} = U_{o\max} I_{o\max} = \frac{U_1^{\ 2}}{R}$$

When the output power is 80%,

$$U_o = \sqrt{0.8}\,U_1 = U_1\sqrt{\frac{\sin 2\alpha}{2\pi} + \frac{\pi - \alpha}{\pi}}$$

The solution is

$$\alpha = 60.54°$$

When the output power is 50%,

$$U_o = \sqrt{0.5}\,U_1 = U_1\sqrt{\frac{\sin 2\alpha}{2\pi} + \frac{\pi - \alpha}{\pi}}$$

The solution is

$$\alpha = 90°$$

Answer 6.2

(1)

$$\varphi = \arctan\frac{\omega L}{R} = \arctan\frac{2\pi \times 50 \times 2 \times 10^{-3}}{0.5} = 0.898637$$

The solution is

$$0.898637 \leqslant \alpha \leqslant \pi$$

(2)

When the phase angle $\alpha = \varphi$, the current is continuous at its maximum and the conduction angle $\theta = \pi$.

$$I_o = \frac{U_o}{Z} = \frac{220}{\sqrt{0.5^2 + (2\pi \times 50 \times 2 \times 10^{-3})^2}} A = 273.978A$$

(3)

$$P = U_o I_o = U_1 I_o = 220 \times 274W = 60280W$$

$$\cos\lambda = \frac{P}{S} = \frac{U_o}{U_1} = 1$$

(4)

When the phase angle $\alpha = \frac{\pi}{2}$,

$$\cos(\theta - \varphi) = e^{-\frac{\theta}{\tan\varphi}}\cos\varphi$$

The derivation of the above formula is

$$-\sin(\theta-\varphi)=-\frac{1}{\tan\varphi}e^{-\frac{\theta}{\tan\varphi}}\cos\varphi$$

With the above two equations, sum of square of each of them are

$$\left(\frac{1}{\tan^2\varphi}+1\right)e^{-\frac{2\theta}{\tan\varphi}}\cos^2\varphi=1$$

Then we get the value of θ

$$\theta=-\tan\varphi\ln(\tan\varphi)=136°$$

The RMS value of current in the thyristor is

$$I_{VT}=\frac{U_1}{\sqrt{2\pi}Z}\sqrt{\theta-\frac{\sin\theta\cos(2\alpha+\varphi+\theta)}{\cos\varphi}}=123A$$

The power factor on the source side is

$$\cos\lambda=\frac{U_oI_o}{U_1I_o}=\sqrt{\frac{\theta}{\pi}-\frac{\sin2\alpha-\sin(2\alpha+2\theta)}{\pi}}=0.66$$

Answer 6.4

The more pulse AC to AC converter has, the higher frequency of output signal has. For the 6-pulse 3-phase bridge converter, the maximum frequency is below 1/3~1/2 of the grid frequency. When the grid frequency is 50Hz, the maximum value of output frequency is about 20Hz.

When the output frequency increases, the number of grid voltage segments decreases in the single cycle of output voltage, so the waveform distortion is serious. And the waveform distortion of voltage and the waveform distortion of current due to the waveform distortion of voltage is the main reason to limit the output frequency.