AC Voltage Controller

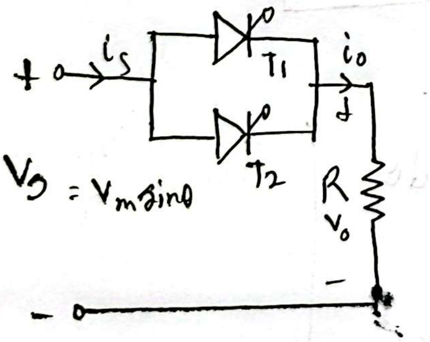
If a thyristor switch is connected between ac supply and load, the power flow can be controlled by varying the rms value of ac voltage applied to the load; this type of power circuit is known as an ac voltage ~~source~~ controller.

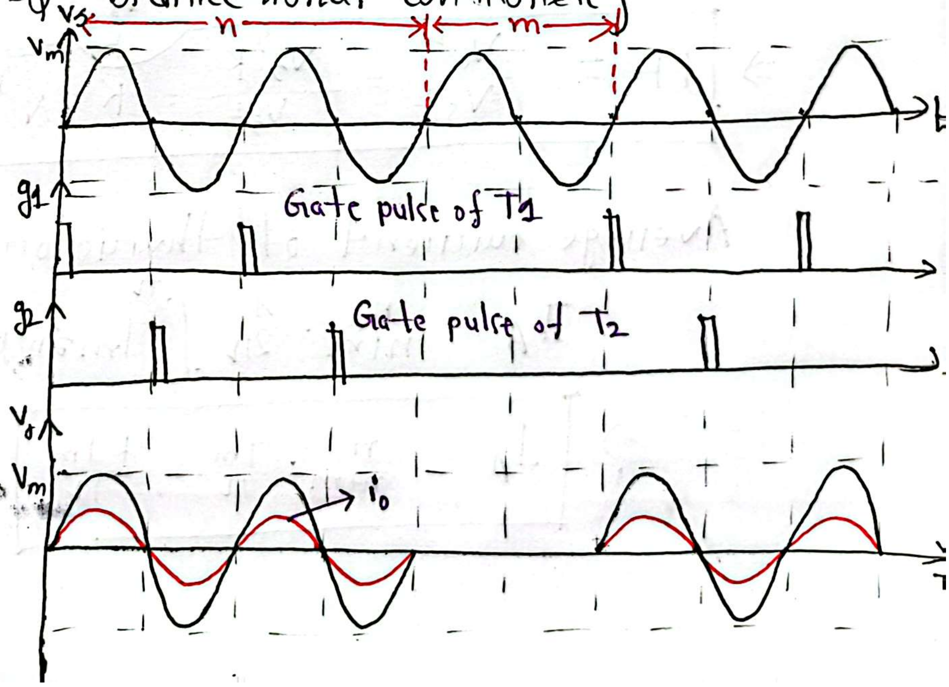
For power transfer, two types of controllers are used:

1. On-off controller: Thyristor switches connect the load to the ac source for a few cycles of input voltage and then disconnect it for another few cycles.

2. Phase controller: Thyristor switches connect to the load to the ac source for a portion of each cycle of input voltage. Types:
   - i) Single phase unidirectional controller
   - ii) Single phase bidirectional controller
     } 1ϕ
   - iii) 3-ϕ unidirectional controller
   - iv) 3-ϕ bidirectional controller
     } 3-ϕ

On-off controller:





RMS output voltage:

$$V_0 = \cancel{\pi} \sqrt{\frac{1}{T}\int_0^T V_s^2 \, d\theta}$$

$$= \left[\frac{n}{n+m} \cdot \frac{1}{2\pi}\int_0^{2\pi} V_m^2 \sin^2\theta \, d\theta\right]^{1/2}$$

$$= \left[\frac{n}{n+m} \cdot \frac{V_m^2}{4\pi}\int_0^{2\pi} (1-\cos 2\theta)\, d\theta\right]^{1/2}$$

$$= \left[\frac{n}{n+m} \cdot \frac{V_m^2}{4\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{2\pi}\right]^{1/2}$$

$$= \left[\frac{n}{n+m} \cdot \frac{V_m^2}{4\pi}(2\pi - 0)\right]^{1/2}$$

$$= \left[\frac{n}{n+m} \cdot \frac{V_m^2}{4\pi} \cdot 2\pi\right]^{1/2}$$

$$= \sqrt{\frac{n}{n+m}} \cdot \frac{V_m}{\sqrt{2}}$$

$$\boxed{V_0 = \sqrt{K} \cdot V_s}$$ [K = duty cycle] $K = \frac{n}{n+m}$

$$PF = \frac{P_0}{VA} = \frac{\frac{V_0^2}{R}}{V_s I_0} = \frac{\frac{V_0^2}{R}}{\frac{V_s^2}{R}}$$

$$\Rightarrow \boxed{PF = \frac{V_0^2}{V_s^2} = \frac{V_s^2 K}{V_s^2} = K = \cancel{\sqrt{\pi}}\frac{n}{n+m}}$$

Average current of thyristor:

$$I_A = \frac{n}{n+m} \cdot \frac{1}{2\pi}\int_0^{\pi} I_m \sin\theta \, d\theta$$

$$I_m = \frac{V_m}{R} = \frac{\sqrt{2}V_s}{R}$$

$$\Rightarrow \boxed{I_A = \frac{n}{n+m} \cdot \frac{I_m}{\pi} = \frac{K I_m}{\pi}}$$

RMS current of thyristor:

$$I_R = \left[\frac{n}{n+m} \cdot \frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2\theta \, d\theta\right]^{1/2}$$

$$\Rightarrow \boxed{I_R = \frac{I_m\sqrt{K}}{2} = \frac{\sqrt{K}}{2} \cdot \frac{V_m}{R} = \sqrt{\frac{K}{2}} \cdot \frac{V_s}{R}}$$

Example 11.1: A ac voltage controller has a resistive load of $R = 10\,\Omega$ and the rms input voltage is $V_s = 120V$, 60Hz The thyristor switch is on for $n = 25$ cycles and is off for $m = 75$ cycles. Determine the (a) rms output voltage V_o; (b) input power factor, PF; and (c) average and rms current of thyristors.

Soln: given that, $R = 10\Omega$, $n = 25$ & $m = 75$, $V_s = 120V$

(a)
rms output voltage,

$$V_o = V_s \cdot \sqrt{K} = V_s\sqrt{\frac{n}{n+m}}$$

$$= 120 \cdot \sqrt{\frac{25}{25+75}}$$

$$= 60\,V$$

(b) $PF = \frac{P_o}{VA} = \frac{\frac{V_o^2}{R}}{V_s I_o} = \frac{\frac{V_o^2}{R}}{\frac{V_s^2}{R}}$ $\quad [I_o = \frac{V_s}{R}]$

$$= \frac{V_o^2}{V_s^2} = \sqrt{K} = \frac{n}{n+m} = \sqrt{\frac{25}{100}} = \sqrt{0.25} = 0.5$$

(c) $I_m = \frac{V_m}{R} = \frac{\sqrt{2}V_s}{R} = \frac{\sqrt{2}.120}{10} = 12\sqrt{2}$

$\therefore$ Average current $I_A = \frac{K I_m}{\pi} = \frac{0.25 \times 12\sqrt{2}}{\pi} = 1.35A$

$\therefore$ rms current $I_R = \frac{I_m\sqrt{K}}{2} = \sqrt{\frac{K}{2}} \cdot \frac{V_s}{R} = \sqrt{\frac{0.25}{2}} \cdot \frac{120}{10} = 4.24A$