19/9/20

AC Voltage Controllers

Fixed AC $\longrightarrow$ Variable AC.

$\nearrow V_o$

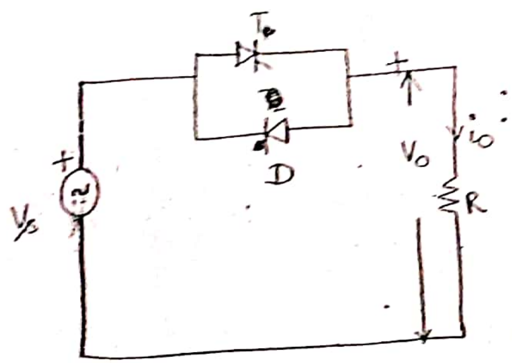
(f = const)

Types

1. phase controlled regulators
2. Integral cycle control (ON/OFF)

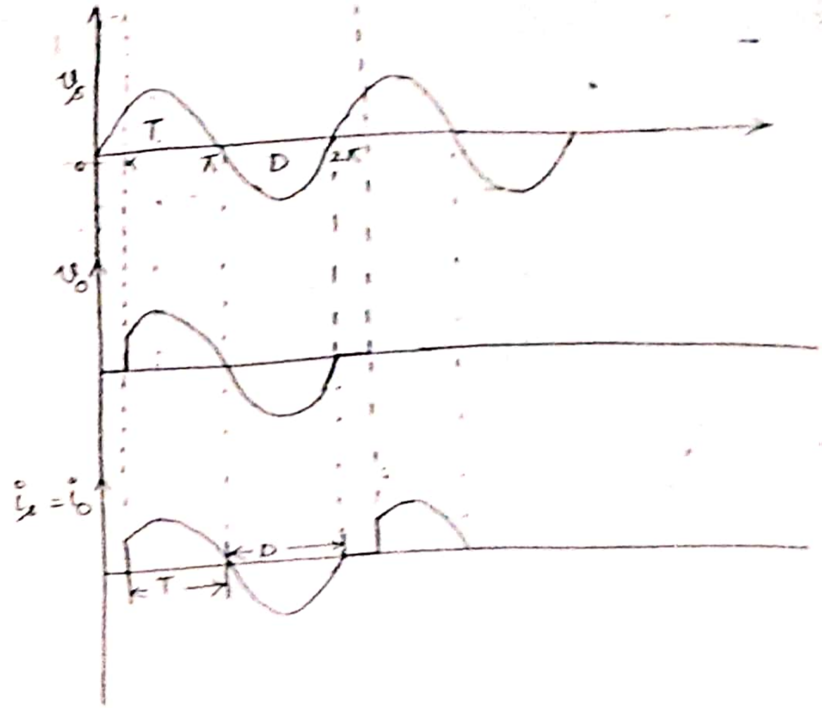
Phase Controlled Regulator

1. 1-ϕ half controlled regulators:



T is FB in +ve cycle $\rightarrow I_g(\alpha, 2\pi+\alpha, \cdots)$

D " " " -ve cycle.



$$V_o = \frac{1}{2\pi}\left[\int_{\alpha}^{2\pi} V_m \sin\omega t \; d(\omega t)\right]$$

$$= \frac{V_m}{2\pi}\left[\cos\alpha - 1\right]$$

$$I_s = I_o = \frac{V_o}{R} = \frac{V_m}{2\pi R}\left[\cos\alpha - 1\right]$$

Here, the source current contains the DC component & saturates the supply T/F core. Hence, it is not generally preferred for applications.

$$V_{or}^2 = \frac{1}{2\pi}\int_{\alpha}^{2\pi} V_m^2 \sin^2\omega t \cdot d(\omega t)$$

$$= \frac{V_m^2}{2\pi}\int_{\alpha}^{2\pi}\left[\frac{1-\cos 2\omega t}{2}\right] d(\omega t)$$

$$= \frac{V_m^2}{4\pi}\left[2\pi - \alpha + \frac{1}{2}(\sin 2\alpha - 0)\right]$$

$$V_{or} = \frac{V_m}{2\sqrt{\pi}}\left[(2\pi-\alpha) + \frac{1}{2}\sin 2\alpha\right]^{1/2}$$

$$P_{in} = V_{sr} I_{sr} \cos\phi$$

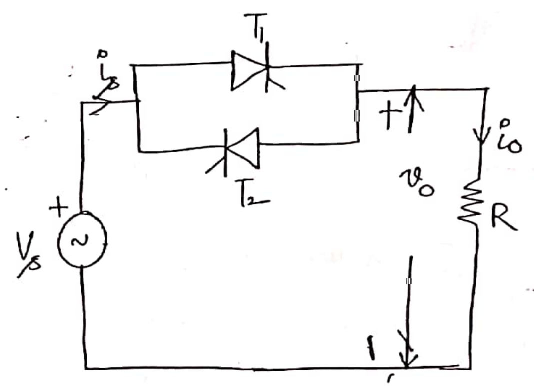
$$P_{out} = V_{or} \cdot I_{or}$$

$$P_{in} \simeq P_{out}$$

$$\Rightarrow \boxed{\cos\phi = \frac{V_{or} I_{or}}{V_{sr} I_{sr}} = \frac{V_{or}}{V_{sr}}}$$

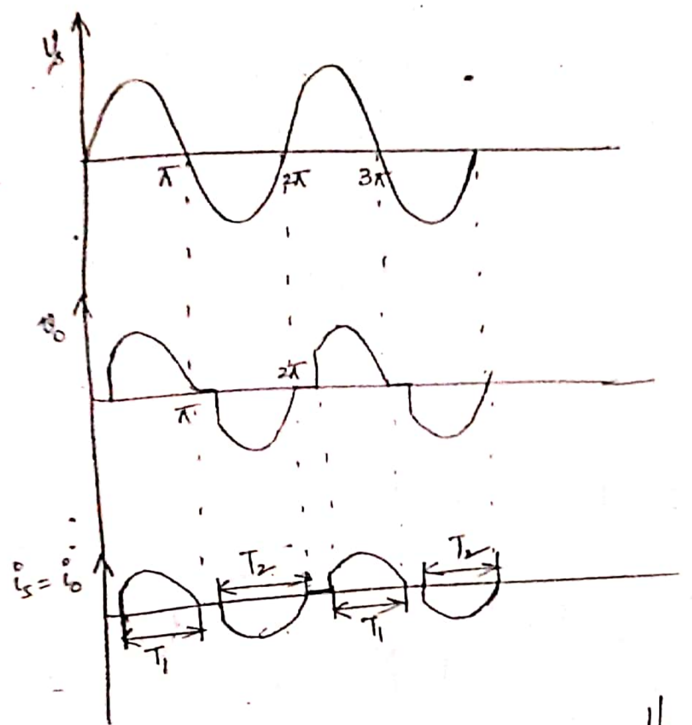
$$\Rightarrow \underset{(IPF)}{\cos\phi} = \frac{1}{\sqrt{2\pi}}\left[\sqrt{(2\pi-\alpha) + \frac{1}{2}\sin 2\alpha}\right]$$

2. 1-ϕ Full controlled regulator:



T_1 is FB in +ve cycle $\rightarrow I_g(\alpha, 2\pi+\alpha, \cdots)$

T_2 is FB in −ve cycle $\rightarrow I_g(\pi+\alpha, 3\pi+\alpha, \cdots)$



$$V_{or} = \left[\frac{1}{\pi} \int_{\alpha}^{\pi} V_m^2 \sin^2 \omega t \, d(\omega t) \right]^{1/2}$$

$$= \frac{V_m}{\sqrt{2\pi}} \sqrt{\left[\pi - \alpha + \frac{1}{2}\sin 2\alpha\right]}$$

$$\Rightarrow \cos\phi = \frac{V_{or}}{V_{sr}}$$

$$= \frac{1}{\sqrt{\pi}} \sqrt{\pi - \alpha + \frac{1}{2}\sin 2\alpha}$$

(D) <u>RL Load</u>

<u>Case 1:</u> $\alpha > \phi$

I_0 lags V_0 by $\tan^{-1}\left(\frac{\omega L}{R}\right)$

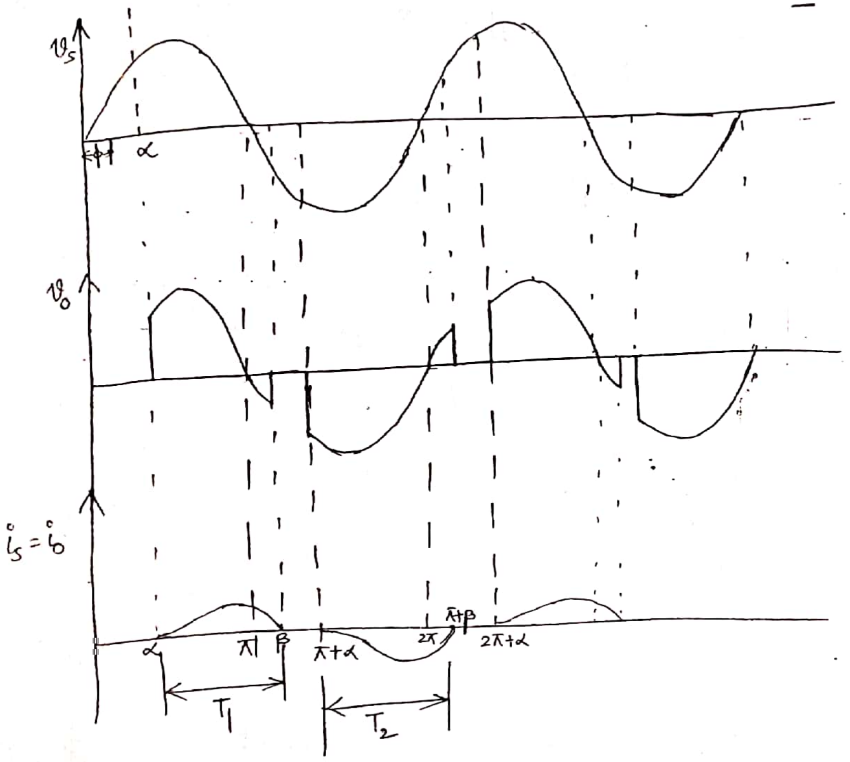
i.e. $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

Here, α should be greater than ϕ for Vg. control in the o/p

$$V_{or}^2 = \frac{1}{\pi} \int_{\alpha}^{\beta} V_m^2 \sin^2 \omega t \, d(\omega t)$$

$$= \frac{V_m^2}{2\pi} \left[\beta - \alpha + \frac{1}{2}(\sin 2\alpha - \sin 2\beta) \right]$$

$$\Rightarrow V_{or} = \frac{V_m}{\sqrt{2\pi}} \left[(\beta - \alpha) + \frac{1}{2}(\sin 2\alpha - \sin 2\beta) \right]^{1/2}$$



$$Pf = \frac{V_{or}}{V_{sr}}$$

$$= \frac{1}{\sqrt{\pi}} \sqrt{\left[(\beta-\alpha) + \frac{1}{2}(\sin 2\alpha - \sin 2\beta)\right]}$$

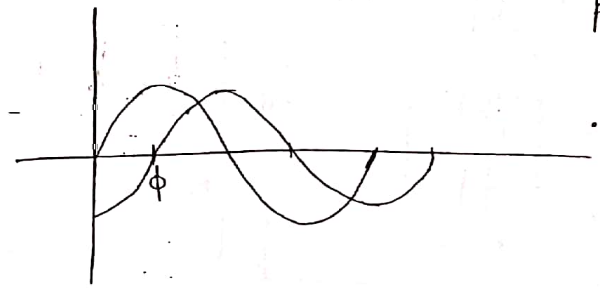
Case 2: $\alpha \le \phi$ (Continuous Conduction)

→ By increasing inductance, ϕ increases & β also increases.

when $\alpha \le \phi$, $\beta \longrightarrow \pi + \alpha$.

Hence, $V_o = V_s$

Thyristors conduct for π radians each & control of Voltage is lost (if the ~~gate pulse~~ high freq pulse gating is provided

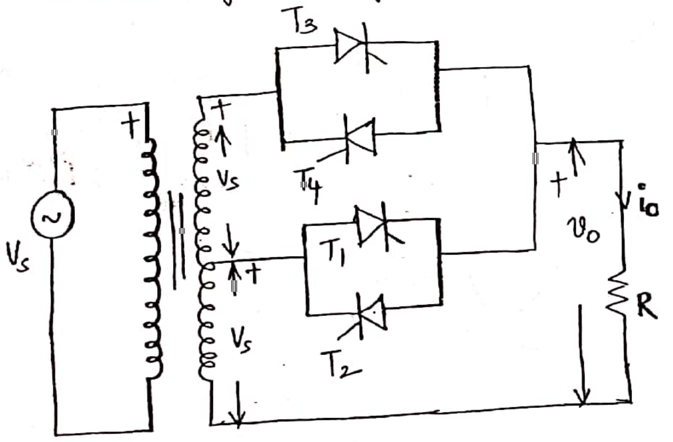


$$V_{or} = V_s \quad ; \quad I_{or} = \frac{V_{or}}{|Z|} = \frac{V_{or}}{\sqrt{R^2 + (\omega L)^2}}$$

★ α should be greater than ϕ for getting vg. control.

→ Here, in AC vg. regulators, we can replace the two antiparallel SCRs by a TRIAC for resistive loads. But, for inductive loads, it is not preferred.

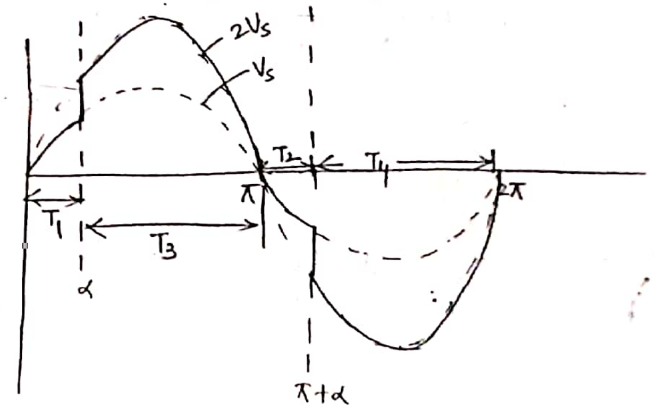
Two stage Regulators :



(8)

T_1, T_3 FB for +ve cycle

T_2, T_4 FB for −ve half cycle.



$T_1 \to 0°$
$T_3 \to \alpha$
$T_2 \to \pi$
$T_4 \to \pi+\alpha$

$$V_{or}^2 = \frac{1}{\pi}\left[\int_0^{\alpha} V_m^2 \sin^2\omega t \, d(\omega t) + \int_{\alpha}^{\pi} 4V_m^2 \sin^2\omega t \, d(\omega t)\right]$$

$$= \frac{1}{\pi}\left[V_m^2 \int_0^{\alpha} \frac{1-\cos 2\omega t}{2} \, d(\omega t) + 4V_m^2 \int_{\alpha}^{\pi} \frac{1-\cos 2\omega t}{2} \, d(\omega t)\right]$$

$$= \frac{V_m^2}{2\pi}\left[(\alpha - 0) - \frac{1}{2}\sin 2\alpha + 4\left[(\pi-\alpha) + \frac{1}{2}\sin 2\alpha\right]\right]$$

$$\Rightarrow V_{or} = \frac{V_m}{\sqrt{2\pi}}\left\{\left[\left(\alpha - \frac{1}{2}\sin 2\alpha\right) + 4\left[(\pi-\alpha)+\frac{1}{2}\sin 2\alpha\right]\right]\right\}^{1/2}$$

$$(I_{T1})_{rms} = \sqrt{\frac{1}{2\pi}\left[\int_0^{\alpha}\frac{V_m^2 \sin^2\omega t}{R^2}\, d(\omega t)\right]}$$

$$= \sqrt{\frac{V_m^2}{4\pi R^2}}\sqrt{\left[(\alpha-0)-\frac{1}{2}\sin 2\alpha\right]}$$

$$= \frac{V_m}{2\sqrt{\pi}\,\cancel{\sqrt{2\pi}}\cdot R}\left[\sqrt{\alpha - \frac{1}{2}\sin 2\alpha}\right]$$

$$= (I_{T2})_{rms}$$

Illy –

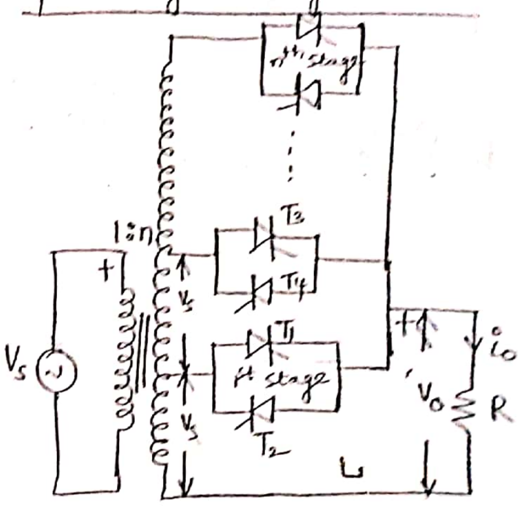
$$(I_{T3})_{rms} = \frac{(2V_m)}{\cancel{\sqrt{2}}\cdot 2\sqrt{\pi}\cdot R}\sqrt{(\pi-\alpha)-\frac{1}{2}(\sin 2\pi - \sin 2\alpha)}$$

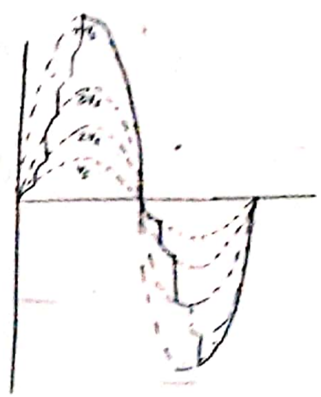
$$= \frac{2V_m}{2\sqrt{\pi}\cdot R}\sqrt{\pi-\alpha+\frac{1}{2}\sin 2\alpha}$$

$$= \frac{V_m}{\sqrt{\pi}\cdot R}\sqrt{\pi-\alpha+\frac{1}{2}\sin 2\alpha}$$

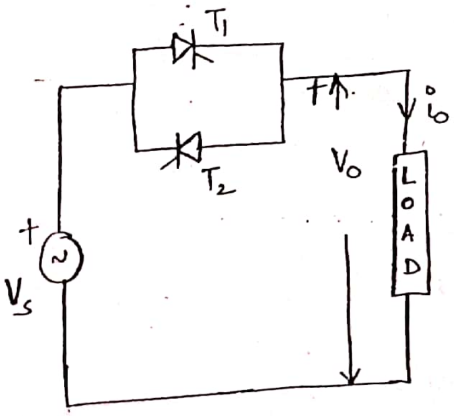
$$= (I_{T4})_{rms}$$

Multistage regulators :



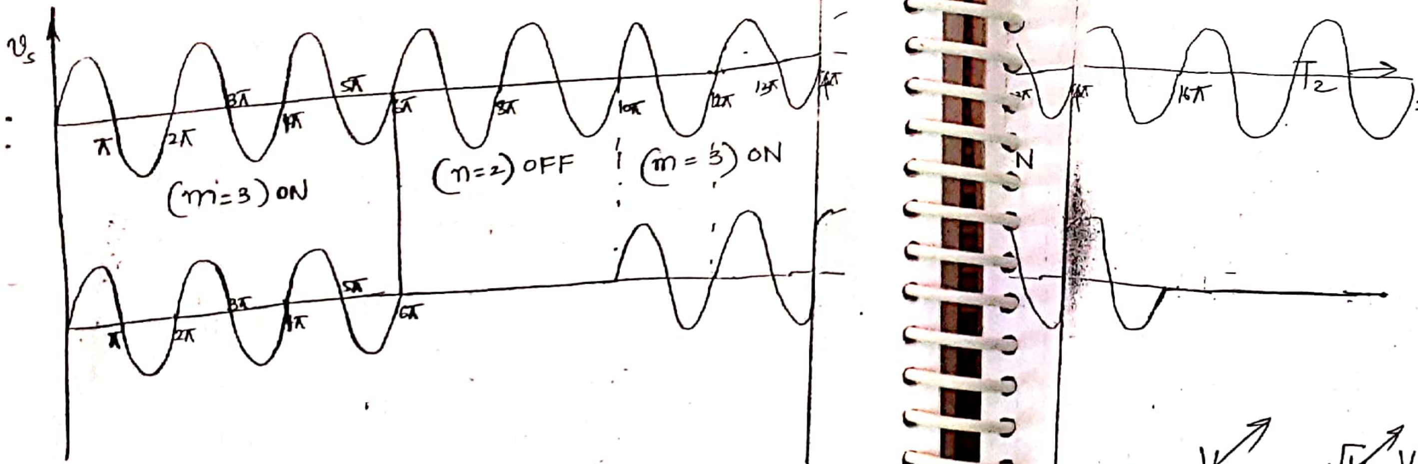


Integral cycle control : (ON/OFF control)



m cycles → ON
n cycles → OFF

T_1 FB (+ve cycles)
T_2 FB (−ve cycles)



→ F.B (−ve cycle)

m = 3 $T_1 \rightarrow$ FB (+ve cycle)

$\Rightarrow I_g$ (0, 2π, 4π, (m=3)
$\cancel{6\pi}$, $\cancel{8\pi}$ (n=2))

10π, 12π, 14π (m=3),
16π, 18π
× ×
(n=2)

$\Rightarrow I_g$ (π, 3π, 5π (m=3) ;
$\cancel{7\pi}$, $\cancel{9\pi}$ (n=2) ;
11π, 13π, 15π (m=3) ;
17π, 19π
× ×
(n=2)

$$V_{or} = \sqrt{K} \cdot V_{sr}$$

$$K = \frac{m}{m+n}$$

$$pf = \frac{V_{or}}{V_{sr}}$$

$$\boxed{pf = \sqrt{K}}$$

Applications:

It can be used in all applications where mech. time constant is high. For example, for rotating AC machines, it can be used for machines having very large size mechanical time const associated with high moment of inertia.

Limitation of Integral cycle control:

The range of control is limited ∵ we can't increase the value of n to a very high value.

In integral cycle control, the harmonic problem in the o/p vg. & current waveform are very much reduced.

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