Date ____________

Single Phase Semiconverter with RL load.

In Practice, a load has a finite inductance. Load current depends on load Resistance, load inductance L, and battery voltage E as shown in fig. 2(a). The converter operation can be devided into two modes:- mode-1 ad mode-2

Mode-1 $0 \leq \omega t \leq \alpha$ during which free wheeling diode will conduct. The load current i_{L_1} during mode 1 is described by

$$L \frac{di_{L_1}}{dt} + R i_{L_1} + E = 0 \quad -(8)$$

with initial condition $i_{L_1}(\omega t = 0) = i_{L_0}$ in the steady state, gives

$$i_{L_1} = I_{L_0} e^{-\frac{R}{L}t} - \frac{E}{R}\left(1 - e^{-R/L\, t}\right) \text{ for } i_{L_1} \geq 0 \quad -(9)$$

At the end of this mode i.e. at $\omega t = \alpha$ the load current becomes I_{L_1}.

$$I_{L_1} = i_{L_1}(\omega t = \alpha) = I_{L_0} e^{-\left(\frac{R}{L}\right)\left(\frac{\alpha}{\omega}\right)} - \frac{E}{R}\left(1 - e^{-\left(R/L\right)\left(\frac{\alpha}{\omega}\right)}\right)]$$

$$\text{for } i_{L_1} \geq 0 \quad -(10)$$

Mode-2: for $\alpha \leq \omega t \leq \pi$ while thyrister T_1 conduct. If $v_s = \sqrt{2} V_s \sin \omega t$, and load current in this mode is i_{L_2} found from

$$L\frac{di_{L_2}}{dt} + R\,i_{L_2} + E = \sqrt{2}V_s \sin\omega t \quad \text{for } i_{L_2} \geq 0$$

solution of this equation is in the form — (11)

$$i_{L_2} = \frac{\sqrt{2}V_s}{Z}\sin(\omega t - \theta) + A_1 e^{-(R/L)t} - \frac{E}{R} \quad \text{for } i_{L_2} \geq 0$$

Constant A_1 can be determined from — (12)
initial condition: at $\omega t = \alpha$, $i_{L_2} = I_{L_1}$ is found as

$$A_1 = \left[I_{L_1} + \frac{E}{R} - \frac{\sqrt{2}V_s}{Z}\sin(\alpha - \theta)\right] e^{(R/L)\left(\frac{\alpha}{\omega}\right)} \qquad (13)$$

After substituting A_1, found

$$i_{L_2} = \frac{\sqrt{2}V_s}{Z}\sin(\omega t - \theta) - \frac{E}{R} + \left[I_{L_1} + \frac{E}{R} - \frac{\sqrt{2}V_s}{Z}\sin(\alpha - \theta)\right] \times e^{(R/L)\left(\frac{\alpha}{\omega} - t\right)} \quad \text{for } i_{L_2} \geq 0 \qquad (14)$$

At the end of mode 2 in the steady-state condition

$$I_{L_0} = \frac{\sqrt{2}V_s}{Z} \cdot \frac{\sin(\pi - \theta) - \sin(\alpha - \theta)e^{(R/L)\left(\frac{\alpha - \pi}{\omega}\right)}}{1 - e^{-(R/L)\left(\frac{\pi}{\omega}\right)}} - \frac{E}{R}$$

$$\text{for } i_{L_0} \geq 0 \text{ and } \theta \leq \alpha \leq \pi \qquad (15)$$

rms current of a thyristor can be found from eqn. (14) as

$$I_R = \left[\frac{1}{2\pi}\int_{\alpha}^{\pi} i_{L_2}^2 \, d(\omega t)\right]^{1/2} \qquad (16)$$

Average current of thyristor can also be determined from eqn. (14)

Date

$$I_A = \frac{1}{2\pi}\int_{\alpha}^{\pi} i_{L_2}\, d(\omega t)$$

r.m.s. output current can be found from eqns. (9) and (14) as

$$I_{rms} = \left[\frac{2}{2\pi}\int_0^{\alpha} i_{L_1}^2\, d(\omega t) + \frac{2}{2\pi}\int_{\alpha}^{\pi} i_{L_2}^2\, d(\omega t)\right]^{1/2}$$

Average output current

$$I_{dc} = I_{ave} = \frac{1}{2\pi}\int_0^{\alpha} i_{L_1}\, d(\omega t) + \frac{1}{2\pi}\int_{\alpha}^{\pi} i_{L_2}\, d(\omega t)$$

Discontinuous load current:- By setting $I_{L_0} = 0$ in eqn. (15) deviding by $\sqrt{2}V_s/Z$ and substituting $R/Z = \cos\theta$ and $\frac{\omega L}{R} = \tan\theta$ we get the critical value of voltage ratio

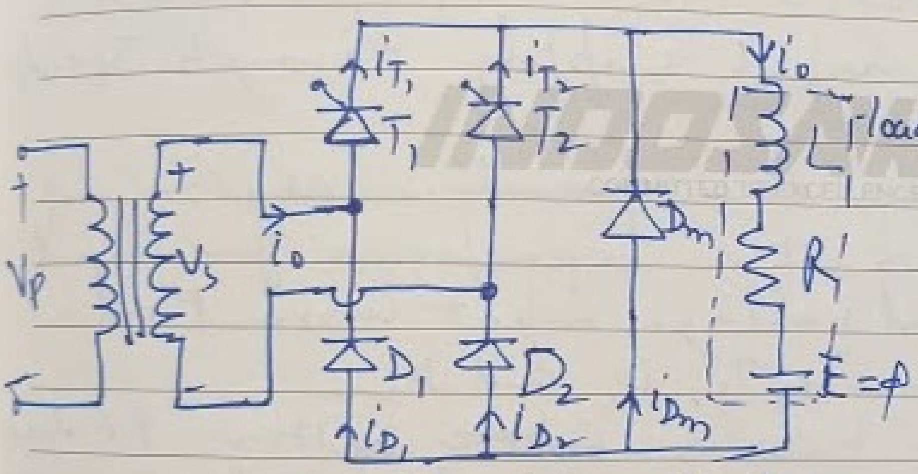
$x = \frac{E}{\sqrt{2}V_{ab}}$ as

$$x = \left[\frac{\sin(\pi-\theta) - \sin(\alpha-\theta)\, e^{\left(\frac{\alpha-\pi}{\tan\theta}\right)}}{1 - e^{-\pi/\tan\theta}}\right]\cos\theta$$

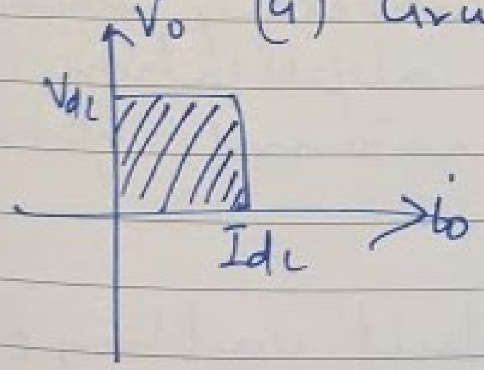
which can be solved for the corresponding critical value of $\alpha = \alpha_c$ for known values of x and θ. for $\alpha \geq \alpha_c$, $I_{L_1} = 0$. The load current that is described by eqn. (14) ~~for~~ flows only during the period $\alpha \leq \omega t \leq \beta$. At $\omega t = \beta$, the load currents falls to zero again.

Single-phase Semiconverters (~~Single-phase~~

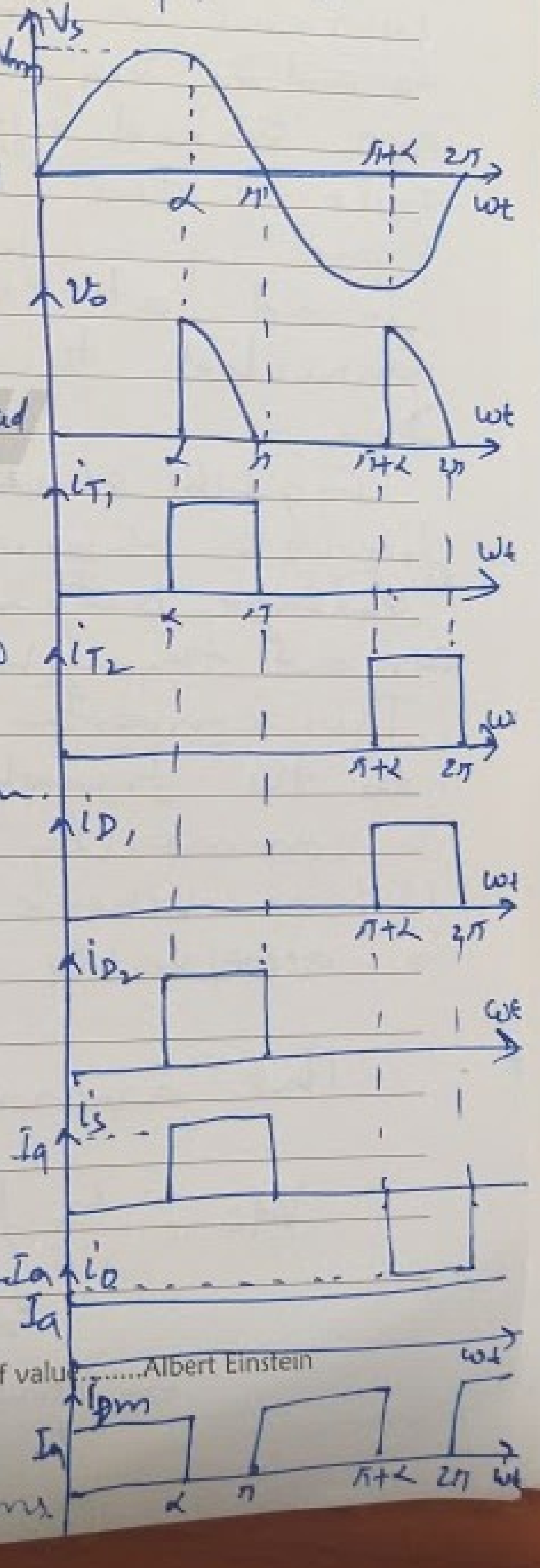
The circuit arrangement of single-phase semiconverter is shown in fig. 2(a) with a highly inductive load. The load current is assumed continuous and ripple free. During positive half cycle, thyristor T_1 is forward biased. When thyristor T_1 is fired at $\omega t = \alpha$, the load is connected to the input supply through



(a) Circuit diagram.



(b) Quadrant



(c) Waveforms

Fig. 2

Date

T_1 and D_2 during the period $\alpha \le \omega t \le \pi$. During the period from $\pi \le \omega t \le (\pi+\alpha)$, the input voltage is ~~dc~~ negative, and the freewheeling diode D_m is forward biased. D_m conduct to provide the continuity of current in the inductive load. The load current is transferred from T_1 and D_2 to ~~T_1 and D_2~~, D_m; and thyristor T_1 and diode D_2 are turned off. During the negative half cycle of the input voltage, thyristor T_2 and D_1 is forward biased and T_1 is fired at $\omega t = \pi+\alpha$ and the load is connected to input supply through T_2 and D_1.

Fig 2(b) shows the operative region and fig. (2c) shows the waveforms for input voltage, output voltage, input current and current through T_1, T_2, D_1 and D_2.

This converter has a ~~better~~ better P.f. due to the ~~freewheel~~ freewheeling diode and is commonly used in application up to 15 kW where one quadrant operation is acceptable.

The average output voltage

$$V_{dc} = \frac{2}{2\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \, d(\omega t) = \frac{2V_m}{2\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$

$$= \frac{V_m}{\pi}(1+\cos\alpha).$$

5

Date

and V_{dc} can be varried from $2V_m/\pi$ to 0 by varying α from 0 to π.
The max. output voltage

$$V_{dm} = \frac{2V_m}{\pi}$$ and normalized average output voltage is

$$V_n = \frac{V_{dc}}{V_{dm}} = 0.5(1+\cos\alpha).$$

The rms output voltage is found from

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

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

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