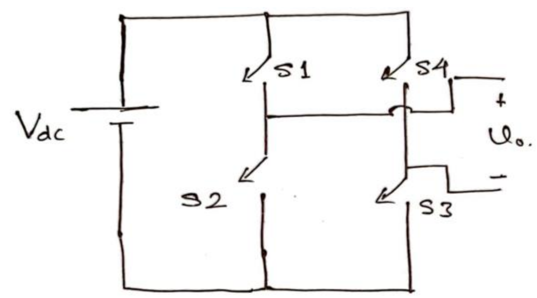
Assignment 4 (EE 238)

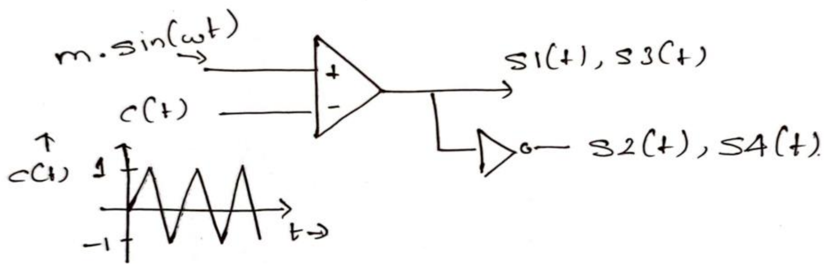
1. A single phase full bridge inverter has a switching sequence that produces a square wave voltage across a series RL load**.** The switching frequency is 60 Hz, V_{dc}=100 V, R=10 Ω and L=25 mH. Determine (a) an expression for load current at steady state, (b) the power absorbed by the load, and (c) the average current in the dc source. **(Ans: (b) 441 W (c) 4.41 A)**

2. Find the relation between modulation signal m(t) and the duty ratio d(t). Assume |m(t)|<1 and c(t) is a triangular wave swinging from -1 to +1. The frequency f_c of the c(t) is assumed to be very large such that m(t) is assumed to be constant over one period of c(t). d(t) is the ratio of on time period and $1/f_c$, corresponding to the switching function s(t). The switching function s(t) is defined as

   s(t)=1, when m(t)>c(t)
   0 otherwise . **(Ans: m(t)=2.d(t)-1)**

3. Consider the following single phase full bridge inverter. The switching is defined by the switching functions defined below. Prove that the average value of v_0 over one time period of c(t) is $m.V_{dc}.\sin(\omega t)$ where |m|<1.





4. A three-phase full bridge inverter delivers power to a resistive load from a 450 V dc source. For a star connected load of 10 Ω per phase, determine for 180° conduction mode, (a) rms value of load current, (b) rms value of switch current and (c) load power. **(Ans: (a) 21.213 A (b) 15 A (c) 13.5 kW)**

5. A 3-ph inverter is controlled in the 180 deg conduction mode for each switch, without PWM. The fundamental inverter output frequency is $\omega=100\pi$ radians per second. A balanced three phase star connected load is connected to the output. The load in each phase is made up of a series connection of resistor(R) and inductor(L), such that $\omega L \gg R$. If the amplitude of the 50 Hz component of the load current in each phase is 100 A, what is the amplitude of the 250 Hz current component?
(Ans: 4 A)

Date :

ASSIGNMENT-4 (EE 238).

Q 1:- a) $T = 1/f = 1/60 = 0.0167s.$

$\tau = L/R = 0.025/10 = 0.0025s.$

$T/2\tau = 3.33.$

$$I_{max} = -I_{min} = \frac{V_{dc}}{R}\left(\frac{1-e^{-T/2\tau}}{1+e^{-T/2\tau}}\right)$$

$$= \frac{100}{10}\left(\frac{1-e^{-3.33}}{1+e^{-3.33}}\right) = 9.31A.$$

$$\therefore i_o(t) = \frac{100}{10} + \left(-9.31 - \frac{100}{10}\right)e^{-t/0.0025}$$

$$\therefore i_o(t) = \begin{cases} \frac{V_{dc}}{R} + \left(I_{min} - \frac{V_{dc}}{R}\right)e^{-t/\tau} & t < T/2 \\ -\frac{V_{dc}}{R} + \left(I_{max} + \frac{V_{dc}}{R}\right)e^{-(t-T/2)\tau} & T/2 < t < T \end{cases}$$

$$\boxed{\begin{aligned} i_o(t) &= 10 - 19.31e^{-t/0.0025} & 0 \le t \le 1/120 \\ &= -10 + 19.31\, e^{-(t-0.00835)6.0025} & 1/120 \le t \le 1/60 \end{aligned}}$$

b) $$I_{rms} = \sqrt{\frac{1}{120}\int_0^{1/120}\left[10 - 19.31\right]e^{-t/0.0025}\Big]^2 dt}$$

120

$= 6.64 A.$

$P = I_{rms}^2 R = (6.64)^2 \times 10 = 441W.$

c) Average source current can be computed by equating source and load power.

$$I_s = \frac{P_{dc}}{V_{dc}} = \frac{441}{100} = 4.41 A.$$

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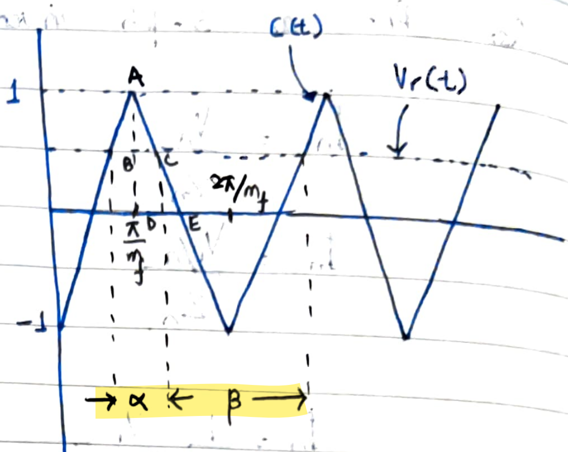
Q2:-

$$m_a(t) = \frac{V_r(t)}{c(t)}.$$



$$m_f = \frac{f_c}{f_r}$$

m_f is large.

$m_a \leq 1$.

~~Using~~ Using similarity property of triangles, in triangle ΔABC and ΔADE

$$\frac{\alpha/2}{\pi/(2m_f)} = \frac{C_t - V_r(t)}{C_t} = \frac{C_t - m_a(t) C_t}{C_t}.$$

$$\alpha = (1 - m_a(t)) \frac{\pi}{m_f}.$$

and $\beta = \frac{2\pi}{m_f} - \alpha = (1 + m_a(t)) \frac{\pi}{m_f}$

The duty ratio $d(t)$ is

$$d(t) = \frac{\beta}{2\pi/m_f} = (1 + m_a(t)) \frac{\pi}{m_f} \times \frac{m_f}{2\pi}.$$

$$d(t) = \frac{1}{2}(1 + m_a(t)).$$

$$\boxed{m_a(t) = 2\,d(t) - 1}$$

Q8:- $V_o = +V_{dc}$ $S_1 - S_2$ ON

$V_o = -V_{dc}$ $S_3 - S_4$ ON

The average value of V_o over one carrier cycle T_c is

$$\bar{V}_o = \frac{1}{T_c}\int_0^{T_c} V_o(t)\,dt$$

Since $V_o = +V_{dc}$ for DT_c

$= -V_{dc}$ for $(1-D)T_c$.

$$\therefore \bar{V}_o = \frac{1}{T_c}\left[\int_0^{DT_c} V_{dc}\,dt + \int_{DT_c}^{T_c} (-V_{dc})\,dt\right]$$

On simplifying,

$$\bar{V}_o = (2D-1)V_{dc}.$$

In Sinusoidal PWM, the duty cycle D is varied sinusoidally.

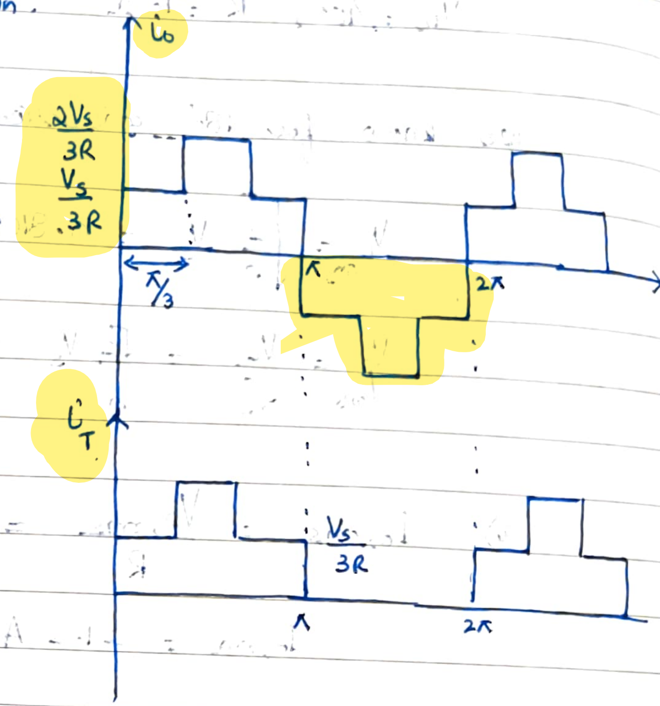
$$\therefore D = \tfrac{1}{2}(1 + m\sin(\omega t)).$$

Substituting this into V_o,

$$\therefore \bar{V}_o = \left(2 \times \tfrac{1}{2}(1+m\sin\omega t) - 1\right)V_{dc}.$$

$$\Rightarrow \boxed{\bar{V}_o = mV_{dc}\sin\omega t}$$

Q4:- For a resistive load, waveforms of phase-load current and thyristors current are shown.



$$I_{o,rms} = \left[\frac{1}{\pi} \left[\left(\frac{V_s}{3R}\right)^2 \frac{\pi}{3} + \left(\frac{2V_s}{3R}\right)^2 \times \frac{\pi}{3} + \left(\frac{V_s}{3R}\right)^2 \frac{\pi}{3} \right] \right]^{1/2}$$

$$= \left[\left(\frac{450}{3\times 10}\right)^2 \times \frac{2}{3} + \left(\frac{2\times 450}{3\times 10}\right)^2 \times \frac{1}{3} \right]$$

$$= \sqrt{450} = 21.213\ A.$$

$$I_{T,rms} = \left[\frac{1}{2\pi} \left\{ \left(\frac{450}{3\times 10}\right)^2 \times \frac{2\pi}{3} + \left(\frac{2\times 450}{3\times 10}\right)^2 \times \frac{\pi}{3} \right\} \right]^{1/2}.$$

$$= \sqrt{225} = 15\ A.$$

Power delivered to load

$$= 3 I_{o,rms}^2 R.$$

$$= 3 \times 21.213^2 \times 10.$$

$$= 13.5\,kW.$$

Date :

Qs: For a 3-ph inverter without PWM.

$$I_n = \frac{V_n}{Z_n}$$

$$I_n = \frac{V_1/n}{Z_n}$$

$$I_n = \frac{1}{n}\frac{V_1}{\sqrt{R^2+(n\omega L)^2}}$$

$\because \omega L >> R$

$\therefore (n\omega L)^2 + R^2 \simeq (n\omega L)^2$

$$I_n = \frac{1}{n}\frac{V_1}{\sqrt{(n\omega L)^2}}$$

$$= \frac{1}{n^2}\frac{V_1}{\omega L}$$

$$= \frac{1}{n^2} \times I_1$$

$$I_n = \frac{1}{n^2} \times 100$$

$$\therefore I_5 = \frac{1}{5^2} \times 100$$

$$\boxed{I_5 = 4A}$$