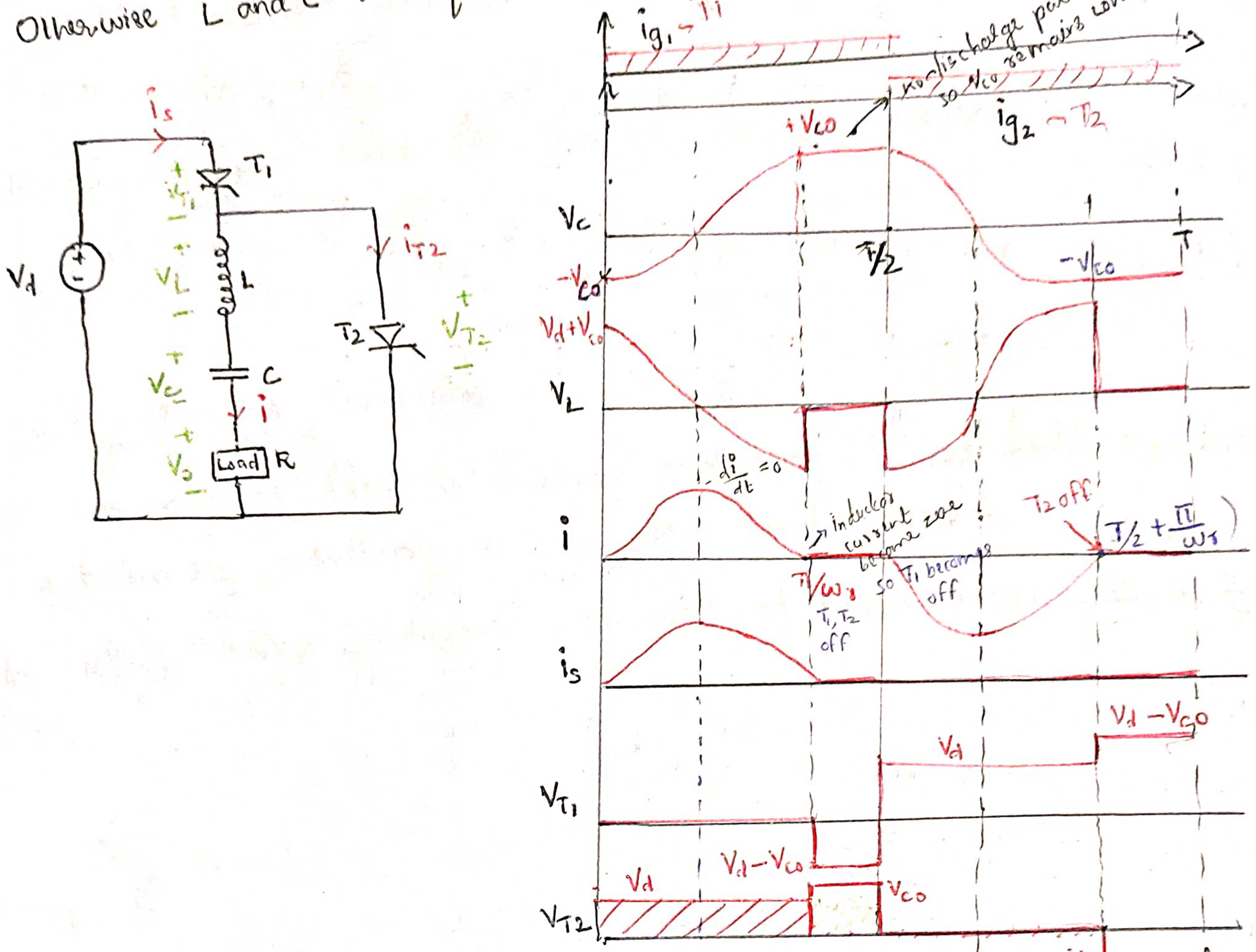
1/4/2020

Series Inverter

* Application in high power, high freq applications.

Otherwise L and C ~~wil~~ required will be high.

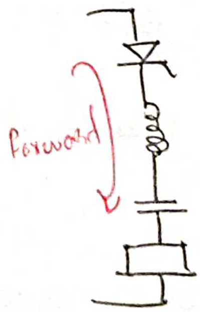


with load.

* The commutating elements L & C are connected in series with load.
* Load current flows continuously through L & C.
* Hence, this ckt is used in high freq applications.

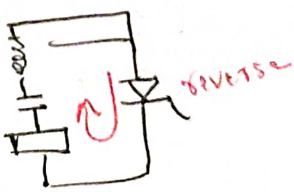
* Initially T_1 is made to conduct for 1^{st} half cycle.

current path



Then T_2 is made to conduct for 2^{nd} half cycle

current path



* L & C are selected such that combination R-L-C is underdamped

* At $t=0$, T_1 is turned on
  T_2 is off state

$$V_d = Ri(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)dt + V_c(0), \quad 0<t<T/2$$

Initial conditions, At $t=0$ → (1) $i(0)=0$ | (2) $V_c(0) = -V_{co}$

(3) $\left.\frac{d(i)}{dt}\right|_{t=0} = (V_d + V_{co})$

$$\frac{V_d}{s} = RI(s) + L(sI(s) + \overset{0}{I_o}) + \frac{1}{Cs}I(s) + \frac{V_c(0)}{s}$$

$$\frac{V_d}{s} = RI(s) + LsI(s) + L\overset{0}{I_o} + \frac{I(s)}{Cs} + \frac{V_c(0)}{s}$$

$$\frac{V_d - V_c(0)}{s} = I(s)\left[R + Ls + \frac{1}{Cs}\right] + L\overset{0}{I_o}$$

$$I(s) = \frac{V_d - V_c(0) - L\overset{0}{I_o}}{s\left(R + Ls + \frac{1}{Cs}\right)} = \frac{(V_d - V_c(0) - L\overset{0}{I_o})C}{RCs + LCs^2 + 1}$$

$$I(s) = \frac{(V_d - V_c(0))\cancel{C}}{L\cancel{C}\left(s^2 + \frac{R}{L}s + \frac{1}{LC}\right)} = \frac{\frac{V_d + V_{co}}{L}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$C \times \sqrt{LC} = \frac{}{L\sqrt{C}}$

complete the derivation

$$= \frac{\sqrt{C}\,(V_d - V_c)}{\sqrt{L}} \cdot \frac{\omega_o}{s^2 + 2\xi\omega_n s + \omega_o^2} = \sqrt{\frac{C}{L}}(V_d - V_c) * \frac{\omega_o}{s^2 + 2\xi\omega_o s + \omega_o^2}$$

Finding roots $s_1, s_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-2\xi\omega_o \pm \sqrt{(2\xi\omega_o)^2 - 4\omega_o^2}}{2}$

$$= \frac{-\cancel{2}\xi\omega_o \pm \cancel{2}\omega_o\sqrt{\xi^2 - 1}}{\cancel{2}}$$

$$= \frac{V_d + V_{co}}{L} \times \frac{1}{\left(s^2 + \frac{sR}{L} + \frac{1}{LC} + \left(\frac{R}{2L}\right)^2 - \left(\frac{R}{2L}\right)^2\right)}$$

$$i(t) = \frac{1}{\left(s + \frac{R}{2L}\right)^2 + \left(\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2}\right)^2} \times \frac{\omega_r}{\omega_r} \times (V_d + V_{co})$$

$$\boxed{i(t) = \frac{V_d + V_{co}}{\omega_r L} e^{-\delta t} \sin(\omega_r t)}$$ Laplace inverse

$$\delta = \frac{R}{2L}, \quad \omega_r = \sqrt{\left(\frac{1}{\sqrt{LC}}\right)^2 - \left(\frac{R}{2L}\right)^2}, \quad \omega_0 = \frac{1}{\sqrt{LC}}$$

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* $$\boxed{V_L(t) = \frac{L\,di(t)}{dt} = \frac{\omega_0}{\omega_r}\left[V_d + V_{co}\right] e^{-\delta t} \cos(\omega_r t + \phi)}$$

$$= \left[\phi_t = \tan^{-1}\frac{\delta}{\omega_r}\right]$$

* $$\boxed{V_c(t) = V_d - V_L - iR}$$

* when $t < \frac{\pi}{\omega_r}$, $V_{T_1} = 0$,

$V_{T_2} = V_d$ & $V_o = i(t)R$

* At $t = \frac{\pi}{\omega_r}$, $i(t) = 0$, T_1 is turned off

$\frac{\pi}{\omega_r} < t < \frac{T}{2}$: Both switches are off

Load current — source current

$i(t) = 0 \Rightarrow i_s(t) = 0$

$V_L(t) = 0$. $V_c = V_{cmax}$

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$T/2 < t < (T/2 + \frac{\pi}{\omega_r})$

$t' = t - T/2$

* At $t' = 0$, T_2 is turned on.

* $0 < t' < T/2$

$$0 = Ri(t') + \frac{L\,di(t')}{dt} + \frac{1}{C}\int i(t')\,dt + V_{cmax}$$

Initial conditions at $t' = 0 \Rightarrow i(0) = 0, \; V_c(0) = V_{cmax}$.

solving

$$0 = RI(s) + L(sI(s) + \overset{\nearrow 0}{I_0}) + \frac{1}{Cs}(I(s)) + \frac{V_c(0)}{s}$$

$$\left.\frac{di(t')}{dt}\right|_{t'=0} = \frac{-V_{cmax}}{L}$$

$$I(s) = \frac{\frac{-V_{cmax}}{L}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$$\boxed{i(t) = \frac{-V_{cmax}}{\omega_r L} e^{-\delta t} \sin(\omega_r t')}$$

$$\delta = \frac{R}{2L} \qquad \omega_r = \sqrt{\left(\frac{1}{\sqrt{LC}}\right)^2 - \left(\frac{R}{2L}\right)^2} \qquad \omega_0 = \frac{1}{\sqrt{LC}}$$

* $$V_L(t) = \frac{L\,di(t)}{dt} = -\frac{\omega_0}{\omega_r} V_{cmax} e^{-\delta t'} \cos(\omega_r t' + \phi)$$

* $$V_c(t) = -V_L - iR$$

$$= -\frac{\omega_0}{\omega_r} V_{cmax} e^{-\delta t'} \cos(\omega_r t' + \phi) + \frac{R V_{cmax}}{\omega_r L} e^{-\delta t} \sin(\omega_r t')$$

* $V_{T1} = -V_d$

* $V_{T2} = 0$

Draw back of Series Inverter

① Maximum Inverter frequency is limited to a value less than circuit ringing frequency (ω_r).

② For very low values of inverter frequencies, load voltage is highly distorted.

Design of L

* L is choosen on basis of attenuation factor.

$$i(t) = \frac{V_d + V_{co}}{W_r L} e^{-R/2Lt} \sin(w_r t)$$

$\Rightarrow$ Peak Value of $i(t)$ is $\frac{V_d + V_{co}}{W_r L} e^{\frac{-R\pi}{2L \cdot 2W_r}}$

* If there is no attenuation, then $i(t)$ would be

$\frac{V_d + V_{co}}{W_r L} \sin W_r t$ and peak value is $\frac{V_d + V_{co}}{W_r L}$

* Attenuation factor $AF = \dfrac{\frac{V_d + V_{co}}{W_r L} e^{\frac{-R}{2L} \cdot \frac{\pi}{2W_r}}}{\frac{V_d + V_{co}}{W_r L}} = e^{\frac{-R}{2L} \cdot \frac{\pi}{W_r}}$

~~Log~~ $\ln(AF) = \frac{-R}{8 f_r L}$

$$\boxed{L = \frac{-R}{8 f_r \ln(AF)}}$$

* L is selected such that $AF = 0.5$

Design of C

* C is selected from value of W_r.

$$W_r = \sqrt{\left(\frac{1}{LC} - \left(\frac{R}{2L}\right)^2\right)} \Rightarrow \boxed{C = \frac{1}{L}\left[\frac{1}{W_r^2 + \left(\frac{R}{2L}\right)^2}\right]}$$

W_r selected such that $\frac{W_r t}{\pi} < \frac{T}{2}$

* If Load is variable, then C is selected for maximum possible value of R so that circuit is under damped.

* Voltage rating of ~~C~~ Thyristo is $V_d + V_{comax}$

Selection of Thyristor

* Forward blocking voltage rating must be greater than V_{comax}. ($V_d + V_{comax}$)

* Peak current rating must be greater than peak load current for minimum load resistance.

$$\frac{V_d + V_{co}}{\omega_r L} e^{-\frac{R_{min}}{2L} \cdot \frac{\pi}{2\omega_r}}$$

* t_q must be less than $t_c = \frac{T}{2} - \frac{\pi}{\omega_r}$

Modified Series Inverter

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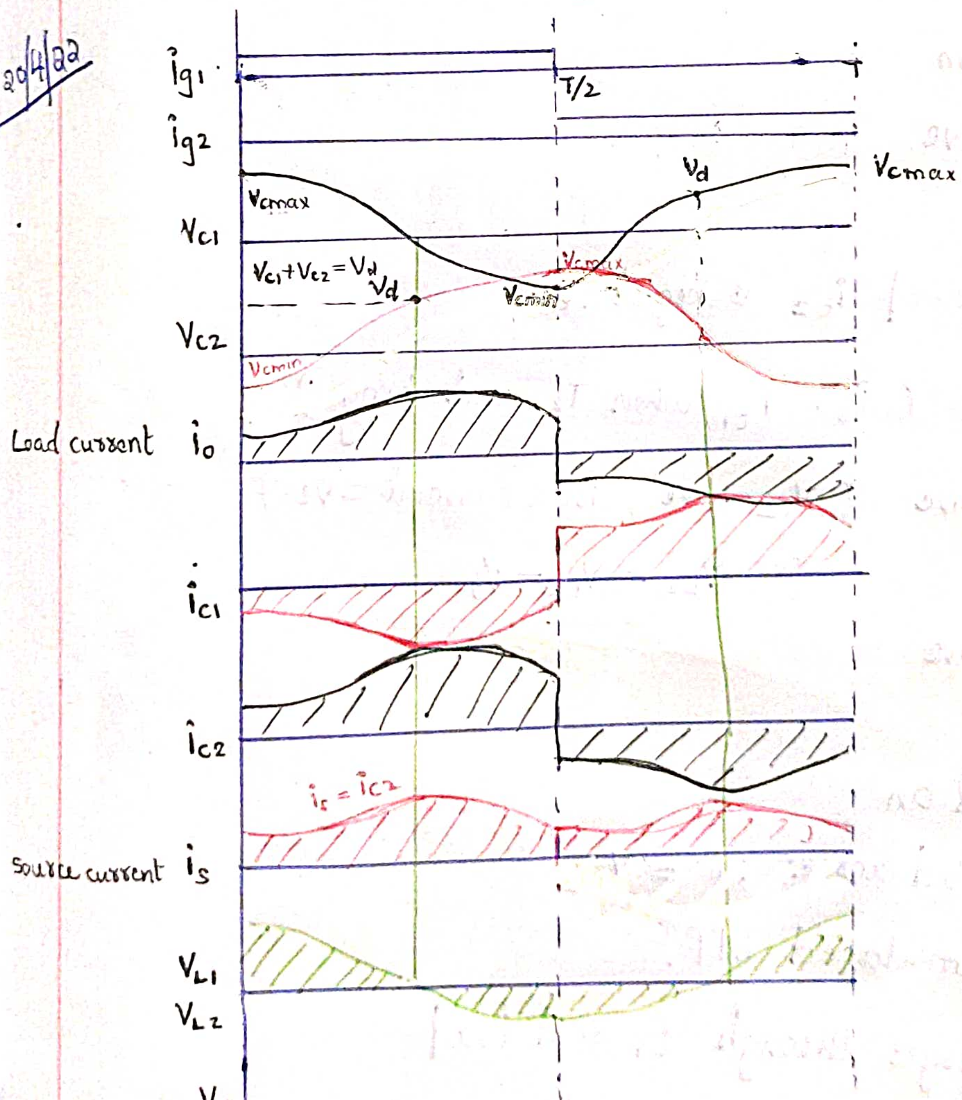

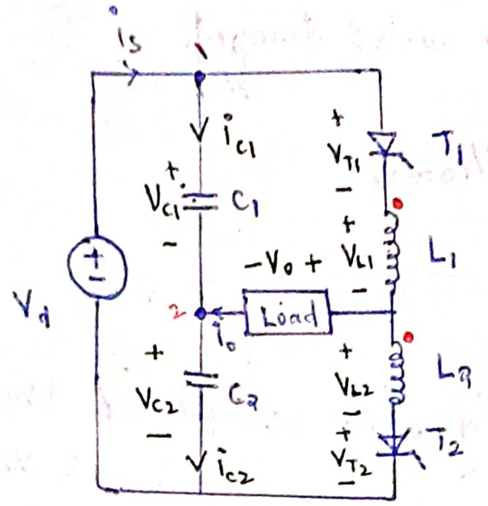

$L_1 = L_2$

$C_1 = C_2$

L_1 & L_2 are tightly coupled - high coef of coupling (mutual inductance)

* For $t \leq 0$ T_2 is on

$V_{C1} = V_{Cmax}$

$V_{C2} = -V_{Cmin}$

i_o is negative

$V_o = i_o \times R$

i_{C1} is +ve | i_{C2} is negative

i_s is +ve ($i_s = i_{C1}$ when T_2 conducting)

V_{L2} negative ($V_{C2} = -ve$, load current -ve)

so $V_{L2} = V_{C2} - V_o$

V_{L1} negative

* At $t = 0$ T_1 is turned on

V_{C1} is coupled across $L_1 = V_{L2}$

T_2 is commutated off.

C_1 discharges through L_1 and load

* V_{c1} changes from V_{c1max} to V_{c1min}

  C_2 gets charged through T_1, L_1 and Load

  $i_o = i_s - i_{c1}$ KCl at node 1

  $i_{c2} = i_{c1} + i_o$ KCl at node 2

  $i_s = i_{c2}$

* At $t = \frac{T}{2}$, T_2 is turned on

  V_{c2} is coupled across $L_2 = V_{L1}$

  T_1 is commutated off

  C_2 discharges through L_2 and load

  V_{c2} changes from V_{c2max} to V_{c2min}

  C_1 gets charged through load, T_2, & L_2

  $i_o =$

$$V_{T1} = V_d - V_{L1} - V_{L2} = V_d - 2V_{L2}$$

Advantages over series inverter.

Inverter freq can be less than ringing freq

During -ve half cycle also source supplies power → Less distortion in source current.