7/9/2011

Inverters

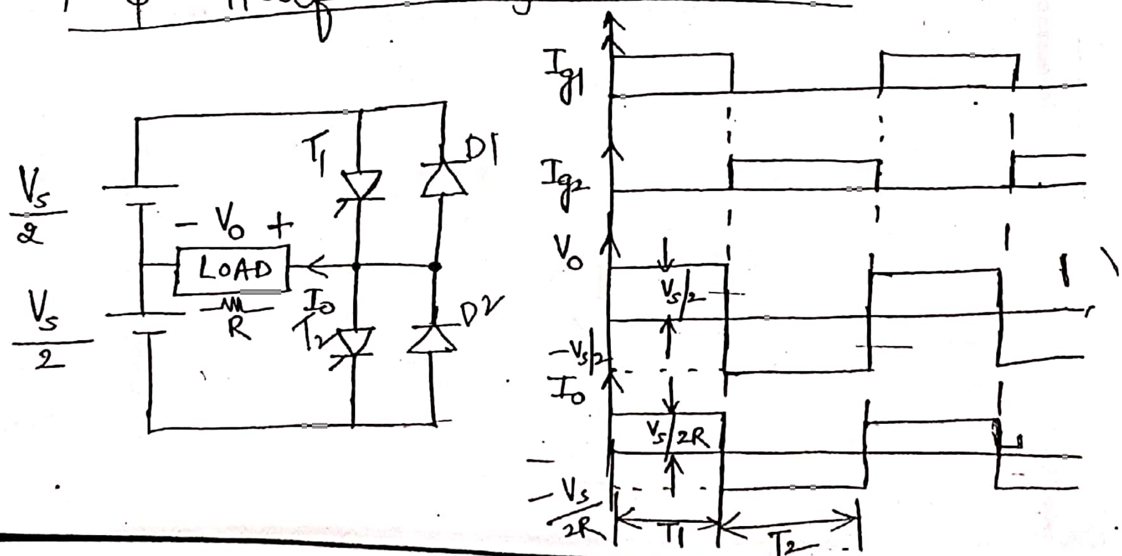
→ It converts Fixed DC to Variable AC. ~~(V, f)~~

Classification of Inverters

1. Voltage Source Inverters (VSI)
   - (a) 1-ϕ Half bridge Inverter
   - (b) 1-ϕ Full bridge Inverter
   - (c) 3-ϕ VSI
2. Current Source Inverter (CSI)
3. Series Inverter
4. Parallel Inverter

Voltage Source Inverters

1. 1-ϕ Half bridge Inverter



(2)

1. $T_1 \rightarrow ON$

$V_0 = \frac{V_s}{2}$

$I_0 = \frac{V_s}{2R}$

2. $T_2 \rightarrow ON$

$\therefore V_0 = \frac{-V_s}{2}$; $I_0 = \frac{-V_s}{2R}$

→ $V_{or} = \frac{V_s}{2}$

→ Forced commutation is required for Resistive load.

→ Feed back diodes won't conduct for resistive load.

(2)

Harmonic Analysis for o/p vg. waveform

Finding the Fourier series for the o/p waveform, we get,

$$V_0 = \sum_{n=1,3,5\ldots}^{\infty} \frac{4\left(\frac{V_s}{2}\right)}{n\pi} \sin n\omega t$$

$$\Rightarrow V_0 = \sum_{n=1,3,5}^{\infty} \frac{2V_s}{n\pi} \sin n\omega t$$

$$= \frac{2V_s}{\pi}\left[\sin \omega t + \frac{\sin 3\omega t}{3} + \frac{\sin 5\omega t}{5} + \cdots\right]$$

$$V_{on} = \frac{2V_s}{n\pi} \sin n\omega t$$

$$(V_{on})_{rms} = \frac{\frac{2V_s}{n\pi}}{\sqrt{2}} = \frac{\sqrt{2}V_s}{n\pi}$$

$$(V_{01})_{rms} = \frac{\sqrt{2}V_s}{\pi}$$

Distortion Factor, $g = \frac{(V_{01})_{rms}}{V_{or}} = \frac{\frac{\sqrt{2}V_s}{\pi}}{\frac{V_s}{2}} = \frac{2\sqrt{2}}{\pi}$

→ g value depends only on the shape of the waveform.

→ $$THD = \left(\frac{1}{g^2} - 1\right)^{1/2}$$

$$= \sqrt{\frac{\pi^2}{8} - 1}$$

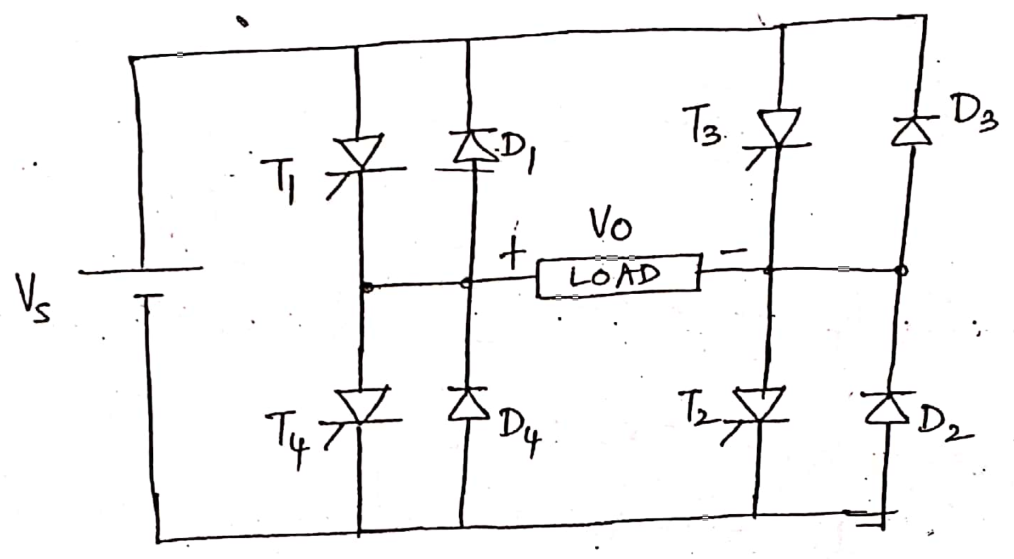
$$= 0.4834$$

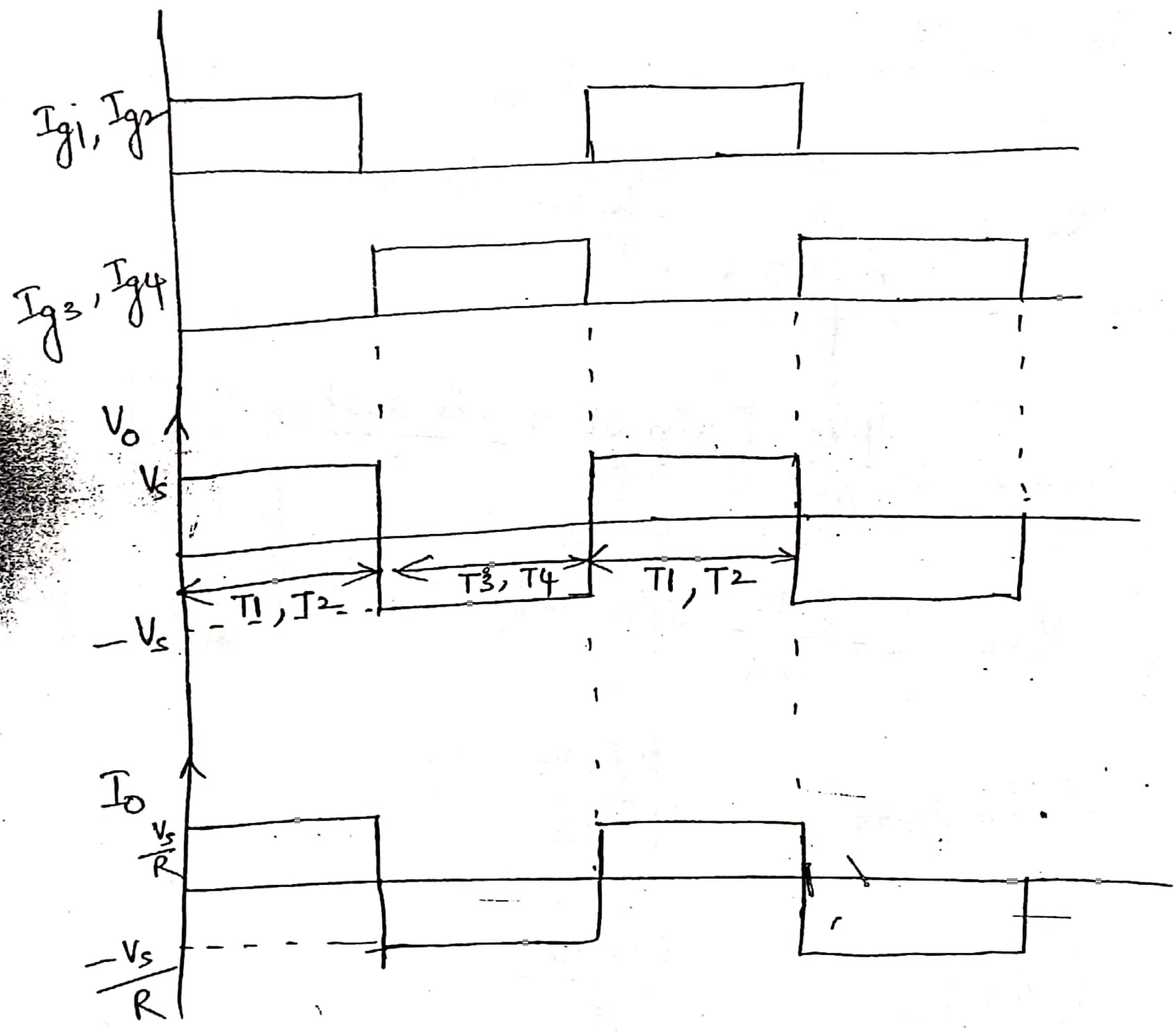
$$\boxed{T.H.D. = 48.34\ \%}$$

→ T.H.D. is a measure of harmonics in AC waveform.

* → In a VSI, o/p vg. waveform remains same irrespective of nature of the load. The load current magnitude & load ct. waveshape changes as the ~~Load~~ nature of the load changes.

1-ϕ Full bridge Inverter





1) $T_1, T_2 \longrightarrow$ ON

$$V_o = V_s$$

$$I_o = \frac{V_s}{R}$$

2) $T_3\, T_4 \longrightarrow$ ON

$$V_o = -V_s$$

$$I_o = \frac{-V_s}{R}$$

$\rightarrow V_{or} = V_s$

$$V_o = \sum_{n=1,3,5}^{\infty} \frac{4V_s}{n\pi} \sin n\omega t$$

$$= \frac{4V_s}{\pi}\left[\sin\omega t + \frac{\sin 3\omega t}{3} + \cdots\right]$$

$$V_{on} = \frac{4V_s}{n\pi} \sin n\omega t$$

$$(V_{on})_{rms} = \frac{2\sqrt{2}\,V_s}{n\pi}$$

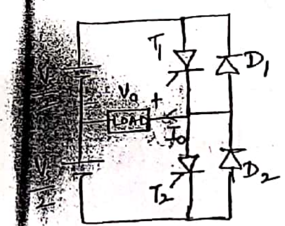
$$(V_{o1})_{rms} = \frac{2\sqrt{2}\,V_s}{\pi}$$

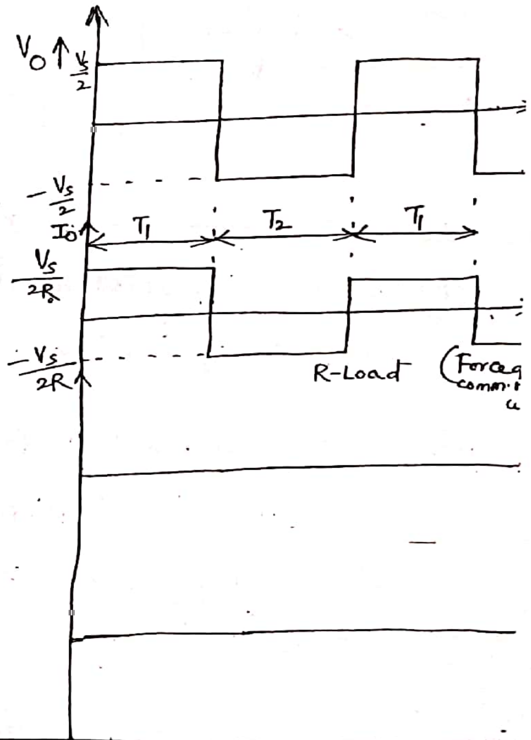
$$g = \frac{(V_{o1})_{rms}}{V_{or}}$$

$$= \frac{\left[\frac{2\sqrt{2}\,V_s}{\pi}\right]}{V_s} = \frac{2\sqrt{2}}{\pi}$$

$$T.H.D = \sqrt{\frac{1}{g^2} - 1} = 48.34\,\%$$

1 ⓐ $1-\phi$ half bridge Inverter

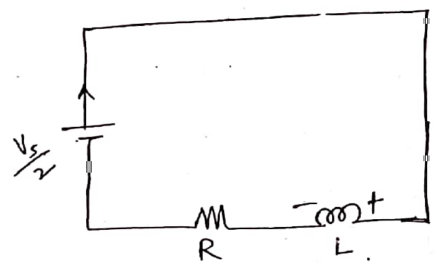




R-Load (Forced commutation)

→ For RL Load I_o lags V_o by

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



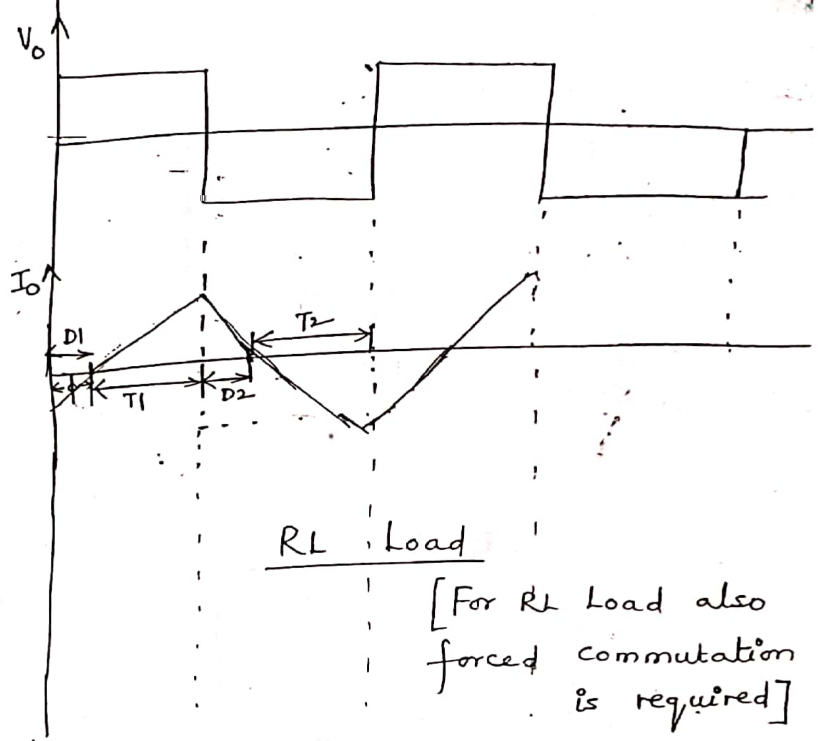
when T_1 is ON, L stores energy

⇒ Power flows from source to load.

$$\left(\frac{1}{2}Li^2 + i^2R\right)$$

(i) when thyristor is ON, Power is +ve ∵ L stores energy

(ii) The moment thyristor is force commutated, inductor starts releasing its energy to source through Diode.

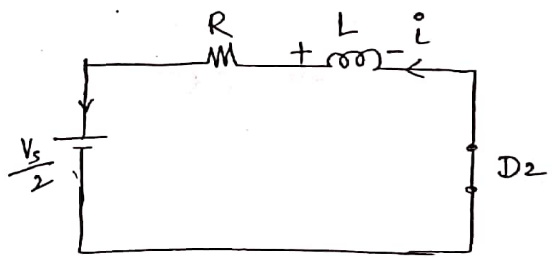


RL Load

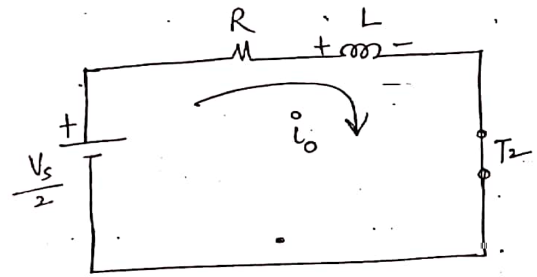
[For RL Load also forced commutation is required]

Mode 2 - D_2 is ON.

$$\frac{1}{2}Li^2 \longrightarrow P_{source} + i^2R$$

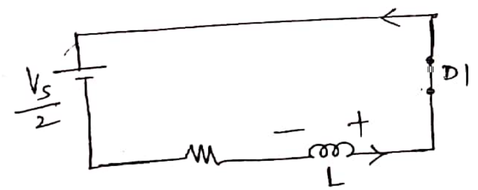


Mode 3 : T_2 is ON



$$P_{source} \longrightarrow \frac{1}{2}Li^2 + i^2R$$

Mode 4 : D1 is ON



$$\frac{1}{2}Li^2 \longrightarrow P_{source} + i^2R$$

$T_1 \rightarrow$ ON
(or) $D_1 \rightarrow$ ON
$\Big\}$ $V_o = \frac{V_s}{2}$ i.e., V_o is +ve

$T_2 \rightarrow$ ON
(or) $D_2 \rightarrow$ ON
$\Big\}$ $V_o = -\frac{V_s}{2}$ i.e., V_o is −ve

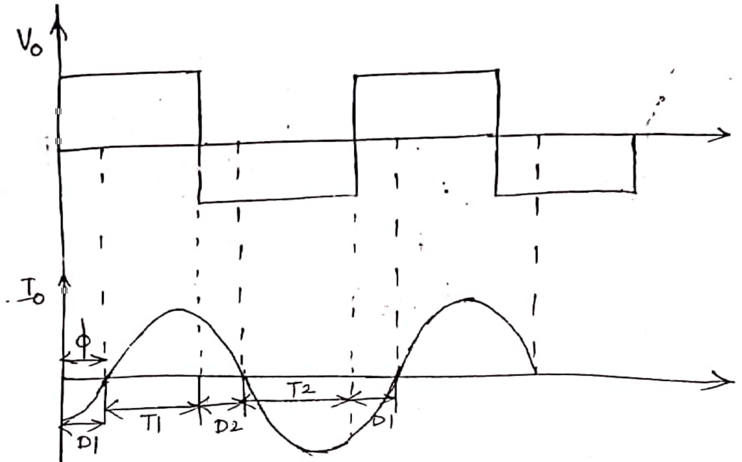
Logic Table

V_o	I_o	P	Device (ON) $\frac{1}{2}$ Bridge	Full bridge
+ (T_1, D_1)	+	+ (T_1, T_2)	T_1	T_1, T_2
+ (T_1, D_1)	−	− (D_1, D_2)	D_1	D_1, D_2
− (T_2, D_2)	−	+ (T_1, T_2)	T_2	T_3, T_4
− (T_2, D_2)	+	− (D_1, D_2)	D_2	D_3, D_4

(iii) RLC (overdamped case) –

i.e., $(X_L > X_C)$

I_o lags V_o by $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$



Overdamped case

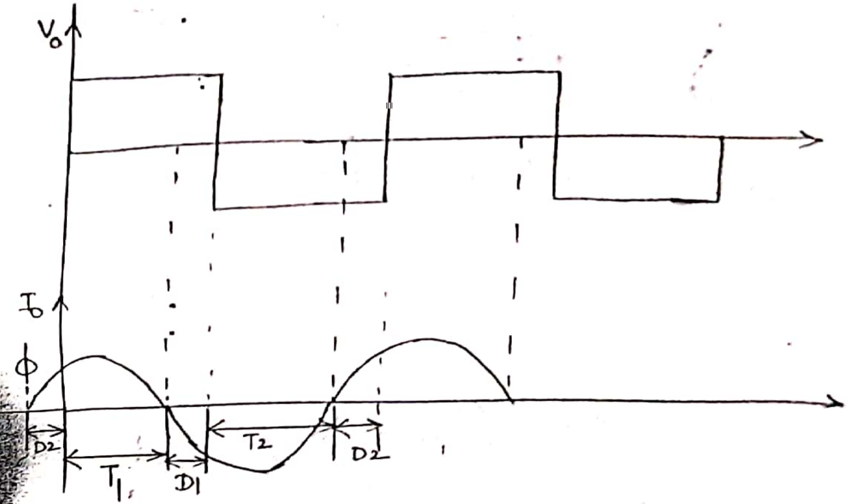
[Forced commutation is required]

RLC (Underdamped case)

i.e., $X_C > X_L$ (or $R^2 < \frac{4L}{C}$)

I_o leads V_o by $\tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

(or I_o lags V_o by $\tan^{-1}\left(\frac{X_L - X_C}{R}\right)$)



Underdamped Case

[Load Commutation takes place]

→ In this case t_c of T1 is same as Conduction time of D1 i.e., $\frac{\phi}{\omega}$

i.e., $t_c = \frac{\tan^{-1}\left(\frac{X_C - X_L}{R}\right)}{\omega}$

→ If $t_c > t_q$, forced commutation is not required because load commutation takes place.

→ If $t_c < t_q$, forced commutation is required.

Harmonic analysis for o/p current for a generalised load : (Half-bridge)

→ Let RLC be the generalised load

$$V_{on} = \frac{2V_s}{n\pi} \sin n\omega t$$

$$Z_n = R + j(X_{Ln} - X_{cn})$$

$$X_{Ln} = n\omega L$$

$$X_{cn} = \frac{1}{n\omega C}$$

$$|Z_n| = \sqrt{R^2 + (X_{Ln} - X_{cn})^2}$$

$$I_{on} = \frac{V_{on}}{|Z_n|} \angle -\phi_n$$

$$\phi_n = \tan^{-1}\left(\frac{X_{Ln} - X_{cn}}{R}\right)$$

Here ϕ_n is n^{th} harmonic displacement angle.

$$I_{on} = \frac{2V_s}{n\pi |Z_n|} \sin(n\omega t - \phi_n)$$

⇒ For pure inductive load,

$$|Z_n| = n\omega L$$

$$\phi_n = 90^\circ$$

$$I_{on} = \frac{V_{on}}{n\omega L} \angle -90^\circ$$

$$= \frac{2V_s}{n\pi(n\omega L)} \sin(n\omega t - 90^\circ)$$

$$= \frac{2V_s}{n^2(\pi\omega L)} \sin(n\omega t - 90^\circ)$$

[For Square waveform, n^{th} harmonics $\propto \frac{1}{n}$
Triangular " , n^{th} harmonic $\propto \frac{1}{n^2}$]