3.1 Inverters

Inversion is the conversion of dc power to ac power at a desired output voltage or current and frequency.

The terms voltage-fed and current fed are used in connection with inverter circuits.

A voltage-fed inverter is one in which the dc input voltage is essentially constant and independent of the load current drawn. The inverter specifies the load voltage while the drawn current shape is dictated by the load.

A current-fed inverter is one in which the supply current cannot change quickly. This is achieved by series dc supply inductance which prevents sudden changes in current. The load current magnitude is controlled by varying the input dc voltage to the large inductance, hence inverter response to load changes is slow.

Inverters are used in many industrial applications. The following are some of their important applications:-

1- Variable-speed ac motor drives.
2- Induction heating.
3- Aircraft power supplies.
4- Uninterruptible power supplies (UPS) for computers.

3-2 Single-phase voltage-fed inverter bridge

Figure (3.1a) shows a bridge inverter for producing an ac voltage and employing switches which may be transistors or thyristors.

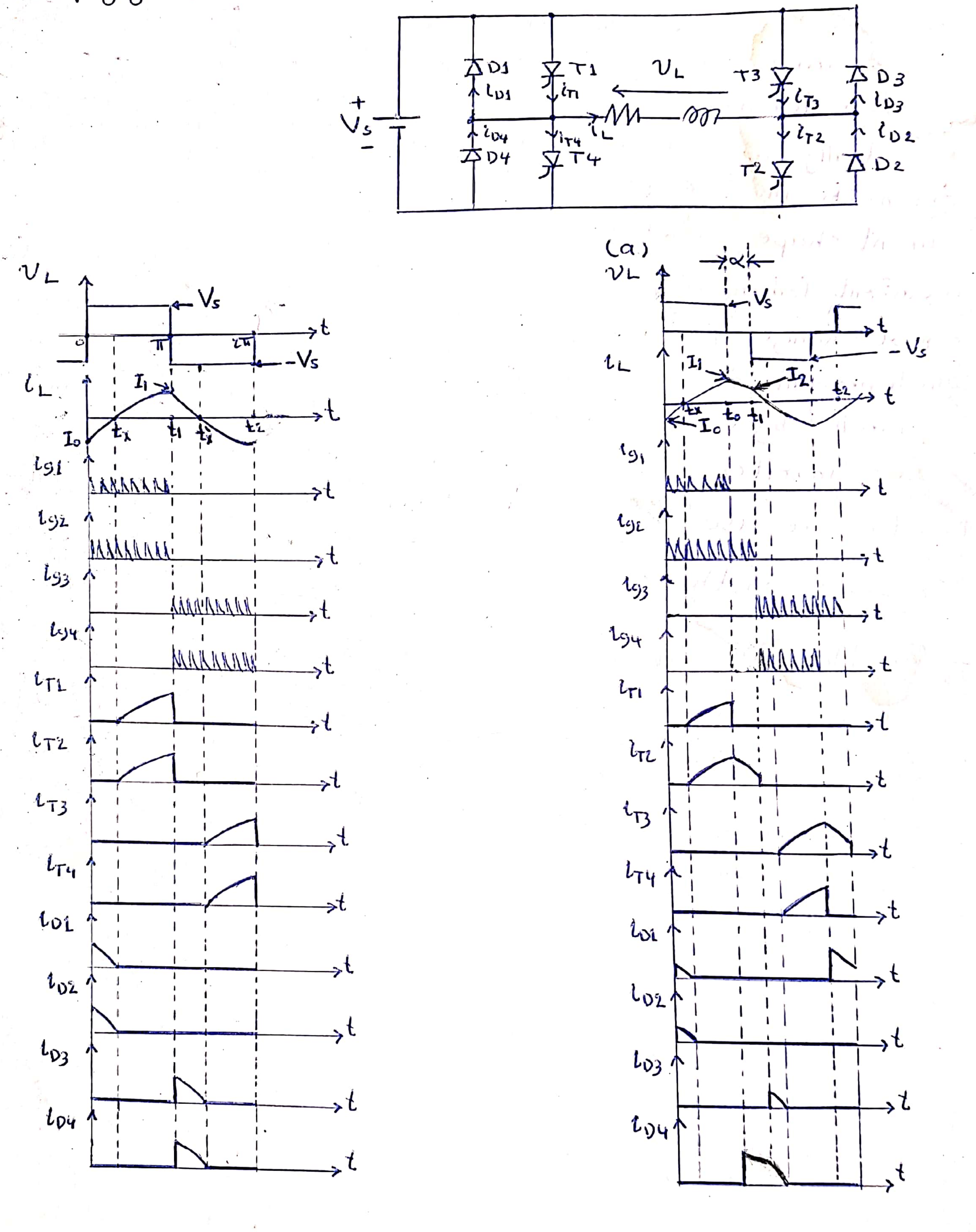

Figure (3.1)

(a) Square-wave output

Figure (3.1b) shows waveforms for a square-wave output where each device is turned on as appropriate for 180° of the output voltage cycle. The load current i_L grows exponentially through T1 and T2 according to

$$V_s = L\frac{di_L}{dt} + i_L R \quad (V) \qquad \text{---- (3.1)}$$

When T1 and T2 are turned off, T3 and T4 are turned on, thereby reversing the load voltage. Because of the inductive nature of the load, the load current cannot reverse and load reactive energy flows back into the supply via diodes D3 and D4 according to

$$-V_s = L\frac{di_L}{dt} + i_L R \quad (V) \qquad \text{---- (3.2)}$$

The load current falls exponentially and at zero, T3 and T4 become forward biased and conduct load current, thereby feeding power to the load.

The output voltage is a square wave and has an rms value of V_s.

For a simple R-L load, during the first cycle with no initial load current, solving equation (3-1) yields a load current :

$$i_L = \frac{V_s}{R}\left(1 - e^{-\frac{R}{L}t}\right) \quad A \qquad \text{------- (3-3)}$$

Under steady-state load conditions, the initial current is I_o and equation (3.1) yields

$$i_L = \frac{V_s}{R} - \left(\frac{V_s}{R} - I_o\right)e^{-\frac{R}{L}t} \quad A \qquad \text{---- (3-4)}$$

$$o \leq t \leq t_1$$

for $v_L = V_s$ V

$I_o \leq o$

During the second half-cycle ($t_1 \leq t \leq t_2$) when the supply is effectively reversed across the load, equation (3.2) yields

$$i_L = -\frac{V_s}{R} + \left(\frac{V_s}{R} + I_1\right) e^{-\frac{R}{L}t} \quad A \qquad \text{------ } (3\text{-}5)$$

$$0 \leq t \leq t_2 - t_1 \quad (s)$$

$$\text{for } v_L = -V_s \quad (V)$$

$$I_1 \geq 0 \quad (A)$$

A new time axis has been used in equation (3-5) starting at $t = t_1$

Since $I_1 = -I_0$, the initial steady-state current I_1 can be found from equation (3-4) when, at $t = t_1$, $i_L = I_1$ yielding

$$I_1 = \frac{V_s}{R} \, \frac{1 - e^{-\frac{R}{L}t_1}}{1 + e^{-\frac{R}{L}t_1}} \quad A \qquad \text{------ } (3\text{-}6)$$

The zero current cross-over point t_x, shown in figure (3-1b), can be found by solving equation (3.4) for t when $i_L = 0$, which yields

$$t_x = \frac{L}{R} \ln \left(1 - \frac{I_o R}{V_s}\right) \quad (s) \qquad \text{------ } (3\text{-}7)$$

The steady-state mean power to the load is given by

$$P_L = \frac{1}{t_1} \int_0^{t_1} V_s \, i_L(t) \, dt \quad (W) \qquad \text{---- } (3\text{-}8)$$

Where $i_L(t)$ is given by equation (3.4)

(b) Quasi-square-wave output

The rms output voltage can be varied by producing a quasi-square output voltage as shown in figure (3.1c). After T1 and T2 have been turned on, at the angle $\pi-\alpha$ one device is turned off. If T1 is turned off the load current slowly free-wheels through T2 and D4 in a zero voltage loop according to

$$0 = L\frac{di_L}{dt} + i_L R \quad (V) \qquad \text{---- (3-9)}$$

When T2 is turned off and T3 and T4 turned on, the remain load current rapidly reduces to zero through diodes D3 and D4. When the load current reaches zero, it reverses through T3 and T4. The variable rms output voltage is $V_s\sqrt{1-(\alpha/\pi)}$. The rms fundamental of the output voltage V_{L1} is given by

$$V_{L1} = \frac{2\sqrt{2}\,V_s}{\pi}\cos\left(\frac{\alpha}{2}\right) \quad (V) \qquad \text{---- (3-10)}$$

With reference to figure (3.1c), the load current i_L for an applied quasi-square-wave voltage is defined as follows:-

(i) $v_L > 0$

$$i_L = \frac{V_s}{R} - \left(\frac{V_s}{R} - I_o\right)e^{-\frac{R}{L}t} \quad (A) \qquad \text{---- (3-11)}$$

$0 \le t \le t_o$ (S)

for $I_o \le 0$

(ii) $v_L = 0$

$$i_L = I_1 e^{-\frac{R}{L}t} \quad (A) \quad ----(3.12)$$

$$0 \leq t \leq t_1 - t_0$$

for $I_1 \geq 0$

iii) $v_L < 0$

$$i_L = -\frac{V_s}{R} + \left(\frac{V_s}{R} + I_2\right) e^{-\frac{R}{L}t} \quad (A) \quad --(3.13)$$

$$0 \leq t \leq t_0 \ (s)$$

for $I_2 \geq 0$

The steady-state mean load power is given by

$$P_L = \frac{1}{t_1} \int_0^{t_0} V_s \, i_L(t) \, dt \quad (W) \quad ----(3.14)$$