UNIT-7

INVERTERS

The converters which converts the power into ac power popularly known as the inverters.. The application areas for the inverters include the uninterrupted power supply (UPS), the ac motor speed controllers, etc.

The inverters can be classified based on a number of factors like, the nature of output waveform (sine, square, quasi square, PWM etc), the power devices being used (thyristor transistor, MOSFETs IGBTs), the configuration being used, (series. parallel, half bridge, Full bridge), the type of commutation circuit that is being employed and Voltage source and current source inverters.

The thyristorised inverters use SCRs as power switches. Because the input source of power is pure de in nature, forced commutation circuit is an essential part of thyristorised inverters. The commutation circuits must be carefully designed to ensure a successful commutation of SCRs. The addition of the commutation circuit makes the thyristorised inverters bulky and costly. The size and the cost of the circuit can be reduced to some extent if the operating frequency is increased but then the inverter grade thyristors which are special thyristors manufactured to operate at a higher frequency must be used, which are costly.

Typical applications
Un-interruptible power supply (UPS), Industrial (induction motor) drives, Traction, HVDC.

8.1 Classification of Inverters

There are different basis of classification of inverters. Inverters are broadly classified as current source inverter and voltage source inverters. Moreover it can be classified on the basis of devices used (SCR or gate commutation devices), circuit configuration (half bridge or full bridge), nature of output voltage (square, quasi square or sine wave), type of circuit (switched mode PWM or resonant converters) etc.

8.2 Principle of Operation:

1. The principle of single phase transistorised inverters can be explained with the help of Fig. 8.2. The configuration is known as the half bridge configuration.
2. The transistor Q1 is turned on for a time $T_o/2$, which makes the instantaneous voltage across the load $V_o = V/2$.
3. If transistor $Q_2$ is turned on at the instant $T_o/2$ by turning Q1 off then $-V/2$ appears across the load.
8.3 Half bridge inverter with Inductive load.

Operation with inductive load:

Let us divide the operation into four intervals. We start explanation from the second lime interval II to t2 because at the beginning of this interval transistor Q1 will start conducting.

Interval II (t1 - t2): Q1 is turned on at instant t1, the load voltage is equal to + V/2 and the positive load current increases gradually. At instant t2 the load current reaches the peak.
value. The transistor Q1 is turned off at this instant. Due to the same polarity of load voltage and load current the energy is stored by the load. Refer Fig. 8.3(a).

**Interval III (t2 - t3):** Due to inductive load, the load current direction will be maintained same even after Q1 is turned off. The self induced voltage across the load will be negative. The load current flows through lower half of the supply and D2 as shown in Fig. 8.3(b). In this interval the stored energy in load is fed back to the lower half of the source and the load voltage is clamped to -V/2.

**Interval IV (t3 - t4):**

At the instant t3, the load current goes to zero, indicating that all the stored energy has been returned back to the lower half of supply. At instant t3 ' Q2 ' is turned on. This will produce a negative load voltage v0 = -V/2 and a negative load current. Load current reaches a negative peak at the end of this interval. (See Fig. 8.4(a)).
Conduction period of the transistors depends upon the load power, factor. For purely inductive load, a transistor conducts only for T0/2 or 90°. Depending on the load power factor, that conduction period of the transistor will vary between 90 to 180° (180° for purely resistive load).

8.4 Fourier analysis of the Load Voltage Waveform of a Half Bridge Inverter

Assumptions:

• The load voltage waveform is a perfect square wave with a zero average value.
• The load voltage waveform does not depend on the type of load.
• $a_n$, $b_n$ and $c_n$ are the Fourier coefficients.
• $\theta_n$ is the displacement angle for the nth harmonic component of output voltage.
• Total dc input voltage to the inverter is $V$ volts.
Refer to Fig. 8.6. The instantaneous load voltage \( v_0 \) can be expressed in the Fourier series form as follows:

\[
v_0 = V_{0(\text{av})} + \sum_{n=1}^{\infty} C_n \sin(n \omega \text{t} - \theta_n)
\]

where \( C_n = \left(a_n^2 + b_n^2\right)^{1/2} \) and \( \theta_n = \tan^{-1}\left[\frac{a_n}{b_n}\right] \)

The values of \( a_n \) and \( b_n \) can be found as follows:

**Expression for \( a_n \):**

\[
a_n = \frac{1}{\pi} \int_{0}^{2\pi} v_0(t) \cos n \omega \text{t} \, dt
\]

but \( v_0(t) = +V/2 \), for \( 0 \leq \omega \text{t} \leq \pi \)

and \( v_0(t) = -V/2 \), for \( \pi \leq \omega \text{t} \leq 2\pi \)

\[
\therefore \quad a_n = \frac{1}{\pi} \left\{ \int_{0}^{\pi} \left( \frac{V}{2} \right) \cos n \omega \text{t} \, dt - \int_{\pi}^{2\pi} \left( \frac{V}{2} \right) \cos n \omega \text{t} \, dt \right\}
\]

\[
= \frac{V}{2\pi n} \left[ \sin n \pi - \sin 0 \right] - \frac{V}{2\pi n} \left[ \sin 2\pi n - \sin n \pi \right]
\]

\[
\therefore \quad a_n = 0 \text{ for all value of } n.
\]
Expression for $c_n$:

$$
c_n = b_n = \frac{2V}{n\pi}
$$

This is the peak amplitude of $n^{th}$ harmonic component of the output voltage and

$$
\theta_n = \tan^{-1} 0 = 0
$$

and

$$
V_o (av) = 0
$$

Therefore the instantaneous output voltage of a half bridge inverter can be expressed In Fourier series form as,

$$
v_o (t) = \sum_{n=1,3,5\ldots}^{\infty} \frac{2V}{n\pi} \sin n\omega t
$$

$$
= 0 \quad \text{for even values of } n.
$$
Equation indicates that the frequency spectrum of the output voltage waveform consists of only odd order harmonic components. i.e. 1,3,5,7 ....etc. The even order harmonics are automatically cancelled out.

**RMS output voltage**

\[ V_{0\text{rms}} = \sqrt{\frac{1}{\pi} \left( \frac{V}{2} \right)^2 \pi} \]

\[ = \sqrt{\frac{V^2}{4 \pi} \times \pi} \]

\[ V_{0\text{rms}} = \frac{V}{2} \text{ volts} \]

**RMS value of fundamental component of output voltage**

In order to find the value of fundamental component of output voltage substitute \( n = 1 \) in the above equation, we get \( V_{0\text{1}(\text{peak})} = \frac{2V}{\pi} \).

As the fundamental component is a sinewave, its rms value is given by,

\[ V_{0\text{1}\text{rms}} = \frac{2V}{\sqrt{2} \pi} = \frac{\sqrt{2}V}{\pi} = 0.45V \]

**8.5 Performance parameters of inverters**

The output of practical inverters contains harmonics and the quality of an inverter is normally evaluated in terms of following performance parameters:

- Harmonic factor of \( n^{\text{th}} \) harmonic.
- Total harmonic distortion.
- Distortion factor.
- Lowest order harmonic.

**Harmonic factor of \( n^{\text{th}} \) harmonics \( HF_n \):**

The harmonic factor is a measure of contribution of individual harmonics. It is defined as the ratio of the rms voltage of a particular harmonic component to the rms value of fundamental component.

\[ HF_n = \frac{V_{n\text{on rms}}}{V_{0\text{1 rms}}} \]

Where \( V_{n\text{on rms}} = \text{Rms value of the } n^{\text{th}} \text{ harmonic of output voltage.} \)

and \( V_{0\text{1 rms}} = \text{Rms value of the fundamental component.} \)
Total Harmonic Distortion

The total harmonic distortion is a measure of the total amplitude of the harmonics present in the output of an inverter except the fundamental component. In other words, it is the measure of closeness in shape between a waveform and its fundamental component.

The THD defined as,

\[
THD = \frac{1}{V_{o1\text{rms}}} \left( \sum_{n=2,3,...}^{\infty} \frac{V^2_{on\text{rms}}}{n^2} \right)^{1/2}
\]

\[
= \frac{1}{V_{o1\text{rms}}} \left[ V_2^2 + V_3^2 + V_4^2 + .... \right]^{1/2}
\]

where \( V_2, V_3, ... \) are the rms voltages at second, third harmonic frequencies. THD thus gives the total harmonic content.

Distortion Factor DF

THD gives the total harmonic content but does not indicate the level of each harmonic component.

If a filter is used at the output of the inverter, the higher order harmonics would be attenuated more effectively. Therefore, a knowledge of both the frequency and the magnitude of each harmonic is important.

The distortion factor indicates the amount of harmonic distortion that remains in a particular waveform after the harmonics of that waveform have been subjected to a second order attenuation (i.e., divided by \( n^2 \)).

Thus DF is a measure of effectiveness in reducing the unwanted harmonics without having to specify the values of a second order load filter. DF is defined as

\[
DF = \frac{1}{V_{o1\text{rms}}} \left[ \sum_{n=2,3,...}^{\infty} \left( \frac{V_{on\text{rms}}}{n^2} \right)^2 \right]^{1/2}
\]

\[
: \quad DF = \frac{1}{V_{o1\text{rms}}} \left[ (V_2^2/2^2)^2 + (V_3^2/3^2)^2 + (V_4^2/4^2)^2 + ... \right]^{1/2}
\]

Lowest order Harmonic

The lowest order harmonic is that harmonic component whose frequency is the closest to the fundamental one and its amplitude is greater than or equal to 3% of the fundamental component.
8.6 Single Phase Bridge Inverter

A single phase bridge inverter is shown in Fig. 8.7. It consists of four transistors. These transistors are turned on and off in pairs of Q1, Q2 and Q3 Q4.

In order to develop a positive voltage + V across the load, the transistors Q1, and O2 are turned on simultaneously whereas to have a negative voltage - V across the load we need to turn on the devices Q3 and Q4.

Diodes D1, D2, D3, and D4 are known as the feedback diodes, because energy feedback takes place through these diodes when the load is inductive.

![Fig.8.7: single phase full bridge inverter](image)

**Operation with resistive load**

With the purely resistive load the bridge inverter operates in two different intervals in one cycle of the output.

**Mode I (0 - T0/2):**

The transistors Q1 and O2 conduct simultaneously in this mode. The load voltage is + V and load current flows from A to B. The equivalent circuit for mode 1 is as shown in Fig. 8.8 (A). At t = T0/2, Q1 and Q2 are turned off and Q3 and Q4 are turned on.

![Fig.8.8](image)

**Mode II (T0/2 - T0):**

- At t = T0/2, Q3 and Q4 are turned on and Q1 and Q2 are turned off. The load voltage is –V
and load current flows from B to A. The equivalent circuit for mode II is as shown in Fig. 9.5.1(b). At \( t = T_0 \), Q3 and Q4 are turned off and Q1 and Q2 are turned on again.

- As the load is resistive it does not store any energy. Therefore the feedback diodes are not effective here.
- The voltage and current waveforms with resistive load are as shown in Fig. 9.5.2.

![Waveform Diagram](image)

**Fig.8.10:** Voltage and current waveforms with resistive load.

The important observations from the waveforms of Fig. 8.10 are as follows:
(i) The load current is in phase with the load voltage
(ii) The conduction period for each transistor is \( 1t \) radians or 1800
(iii) Peak current through each transistor = \( V/R \).
(iv) Average current through each transistor = \( V/2R \)
(v) Peak forward voltage across each transistor = \( V \) volts.
8.7 Single Phase Bridge Inverter with RL Load

The operation of the circuit can be divided into four intervals or modes. The waveforms are as shown in Fig. 8.13.

Interval I (t₁ – t₂):
At instant t₁, the pair of transistors Q₁ and Q₂ is turned on. The transistors are assumed to be ideal switches. Therefore point A gets connected to positive point of dc source V through Q₁, and point B gets connected to negative point of input supply. The output voltage \( V₀ = +V \) as shown in Fig 8.11(a). The load current starts increasing exponentially due to the inductive nature of the load.

The instantaneous current through Q₁ and Q₂ is equal to the instantaneous load current. The energy is stored into the inductive load during this interval of operation.

![Diagram](a) Interval I (t₁ – t₂)

Interval II (t₂ - t₃):
- At instant t₂ both the transistors Q₁ and Q₂ are turned off. But the load current does not reduce to 0 instantaneously, due to its inductive nature.
- So in order to maintain the flow of current in the same direction there is a self induced voltage across the load. The polarity of this voltage is exactly opposite to that in the previous mode.
- Thus output voltage becomes negative equal to -V. But the load current continues to now in the same direction, through D₃ and D₄ as shown in Fig. 8.11(b).
- Thus the stored energy in the load inductance is returned back to the source in this mode. The diodes D₁ to D₄ are therefore known as the feedback diodes.
- The load current decreases exponentially and goes to 0 at instant t₃ when all the energy stored in the load is returned back to supply. D₃ and D₄ are turned off at t₃.

Interval III (t₃ – t₄)
- At instant t₃ Q₃ and Q₄ are turned on simultaneously. The load voltage remains negative equal to -V but the direction of load current will reverse and become negative.
- The current increases exponentially in the negative direction. And the load again stores energy) in this mode of operation. This is as shown in Fig. 8.12(a) .
Fig. 8.12

Interval IV (t₄ to t₅) or (t₀ to t₁)

- At instant t₄ or to the transistors Q3 and Q4 are turned off. The load inductance tries to maintain the load current in the same direction, by inducing a positive load voltage.
- This will forward bias the diodes D₁ and D₂. The load stored energy is returned back to the input dc supply. The load voltage Vₒ = + V but the load current remains negative and decrease exponentially towards 0. This is as shown in Fig. 8.12(b).
- At t₅ or t₁ the load current goes to zero and transistors Q1 and Q2 can be turned on again.

Conduction period of devices:
- The conduction period with a very highly inductive load, will be T₀/4 or 90° for all the transistors as well as the diodes.
- The conduction period of transistors will increase towards T₀/2 or 180° with increase in the load power factor. (i.e., as the load becomes more and more resistive).
Fig. 8.13. Voltage and current waveforms for single phase bridge inverter with RL load.
Analysis of Bridge Inverter:

The output voltage waveform is as shown in Fig. 8.13.

RMS output voltage:

The rms output voltage can be found from the output voltage waveform of Fig. 8.13 as

\[ V_{o\text{rms}} = \left( \frac{1}{T_o/2} \int_0^{T_o/2} V^2 \, dt \right)^{1/2} \]

\[ V_{o\text{rms}} = \left( \frac{2 V^2}{T_o \left( \frac{T_o}{2} - 0 \right)} \right)^{1/2} = V \text{ volts} \]

Fourier series representation:

1. Fourier series for output voltage of full bridge inverter is found on the same lines as that of a half bridge inverter discussed in the previous section.
2. The shape of the load voltage waveform of a bridge inverter is same as that of a half bridge circuit, except for the value of peak output voltage.
3. The peak output voltage is "V" volts here therefore the expression for the output voltage in terms of Fourier series is expressed on the same lines, i.e. substitute the value of instantaneous output voltage as + V instead of + V/2.
4. The instantaneous output voltage can be expressed in Fourier series as follows:

\[ v_o(\omega t) = \sum_{n=1,3,5,...} \frac{4V}{n\pi} \sin n \omega t \]

That means

\[ v_o(\omega t) = \left( \frac{4V}{\pi} \sin \omega t + \frac{4V}{3\pi} \sin 3 \omega t + \frac{4V}{5\pi} \sin 5 \omega t + \ldots \right) \]

Conclusion:

This equation indicates following things:

(1) The output voltage waveform contains only the odd order harmonic components i.e. 3,5,7....
(2) The even order harmonics (i.e. n = 2,4,6...) are automatically cancelled.
In this equation $Z_n = \sqrt{R^2 + \left( \frac{n \omega L}{R} \right)^2}$ is the impedance offered by the load to the $n^{th}$ harmonic component and $\frac{4V}{n \pi}$ is the peak amplitude of $n^{th}$ harmonic voltage.

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

**Prob 1**

A single phase half bridge inverter has a resistive load of $R = 3 \ \Omega$ and the dc input voltage $V = 24$ volts. Determine

(a) The rms output voltage at the fundamental frequency, $V_1$

(b) The output power $P_o$

(c) The average and peak currents of each transistor.

(d) The peak reverse blocking voltage $V_{BR}$ for each transistor.

(e) Total harmonic distortion THD

(f) The distortion factor DF

(g) The harmonic factor and the distortion factor of the lowest order harmonic.

**Solu. :**

**Data**

$V = 24$ volts, $R = 3 \ \Omega$

(i) The rms output voltage at fundamental frequency $V_{1 \text{rms}}$

$$V_{1 \text{rms}} = \frac{2V}{\sqrt{2}} = 10.8 \ \text{volts}.$$

(ii) The output power:

$$P_o = \frac{V_o^2}{R} \text{ and } V_o = V/2$$

where $V_o = \text{rms output voltage}.$

$$\therefore P_o = \frac{(24)^2}{3} = 48 \ \text{watt}.$$

$$P_o = 48 \ \text{watt}.$$

(iii) The average and peak current of each transistor.

The average current

$$I_{T(\text{av})} = \frac{1}{T} \int_0^{T/2} \frac{V}{2R} \, dt = \frac{V}{2RT} \left( \frac{T}{2} \right) = \frac{V}{4R}$$

$$\therefore \text{average transistor current}$$

$$I_{T(\text{av})} = 24/3 \times 4$$

$$I_{T(\text{av})} = 2 \ \text{Amp}$$

The transistor peak current

$$I_{T(\text{peak})} = \frac{V/2}{R} = 4 \ \text{Amp}$$
(iv) Peak reverse blocking voltage $V_{BR}$ for each transistor.

\[ V_{BR} = 2 \times \frac{V}{2} = 24 \text{ volts.} \]

(v) Total harmonic distortion (THD)

\[
\text{THD} = \frac{1}{V_{1 \text{ rms}}} \left( \sum_{n=2,3}^{\infty} V_{n \text{ rms}}^2 \right)^{1/2}
\]

\[ V_{01 \text{ rms}} = 10.8 \text{ volts as already calculated in (i)} \]

The rms harmonic voltage

\[
\left[ \sum_{n=3,5,7,...}^{\infty} V_{n \text{ rms}}^2 \right]^{1/2}
\]

\[ = (V_0^2 - V_{01 \text{ rms}})^{1/2} = \left[ 12^2 - (10.8)^2 \right]^{1/2} = 5.23 \text{ volts.} \]

\[ \text{THD} = \frac{5.23}{10.8} = 0.484 = 48.4 \% \]

(vi) The distortion factor DF

\[
\frac{1}{V_{01 \text{ rms}}} \left[ \sum_{n=3,5,7}^{\infty} \left( \frac{V_{n \text{ rms}}}{n^2} \right)^2 \right]^{1/2}
\]

to find $\frac{V_{on \text{ rms}}}{n^2}$ we have to find $V_{n \text{ rms}}$ first

\[ v_o = \sum_{n=1,3,5}^{\infty} \frac{2V}{n \pi} \sin n \omega t = 0, \text{ for } n = 2,4,6; \]

\[ v_o = \frac{2V}{\pi} \sin \omega t + \frac{2V}{3 \pi} \sin 3 \omega t + \frac{2V}{5 \pi} \sin 5 \omega t + \frac{2V}{7 \pi} \sin 7 \omega t + \ldots \]

\[ V_{3 \text{ rms}} = \frac{2V}{3 \pi \sqrt{2}} = 3.6 \text{ volts.} \]

\[ V_{5 \text{ rms}} = \frac{2V}{5 \pi \sqrt{2}} = 2.16 \text{ volts.} \]

\[ V_{7 \text{ rms}} = 1.54 \text{ volts.} \]

\[ V_{11 \text{ rms}} = 0.982 \text{ volts.} \]

\[ V_{13 \text{ rms}} = 0.83 \text{ volts.} \]

\[
\left[ \sum_{n=3,5,7}^{\infty} \left( \frac{V_{n \text{ rms}}}{n^2} \right)^2 \right]^{1/2} = \left[ \left( \frac{V_3^2}{3^2} \right)^2 + \left( \frac{V_5^2}{5^2} \right)^2 + \left( \frac{V_7^2}{7^2} \right)^2 + \ldots \right]^{1/2}
\]

\[ = \left[ 0.16 + 0.0348 + 2.3 \times 10^{-3} + \ldots \right]^{1/2} = 0.44 \text{ volts.} \]
8.8 Comparison of half bridge and full bridge inverters

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameter</th>
<th>Half bridge</th>
<th>Full bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Need of an output transformer</td>
<td>Not needed</td>
<td>Not needed</td>
</tr>
<tr>
<td>2</td>
<td>Number of transistors required to be used.</td>
<td>Two</td>
<td>Four</td>
</tr>
<tr>
<td>3</td>
<td>Efficiency</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Voltage across the nonconducting transistor</td>
<td>V Volts</td>
<td>V Volts</td>
</tr>
<tr>
<td>5</td>
<td>Output voltage waveform</td>
<td>Square, Quasi square or PWM</td>
<td>Square, Quasi square or PWM</td>
</tr>
<tr>
<td>6</td>
<td>Current rating of power device</td>
<td>Equal to the load current</td>
<td>Equal to the load current</td>
</tr>
<tr>
<td>7</td>
<td>Number of devices conducting simultaneously</td>
<td>One</td>
<td>Two</td>
</tr>
<tr>
<td>8</td>
<td>Necessity of dead band to avoid cross conduction</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

8.9 Principle of Operation of CSI:

The circuit diagram of current source inverter is shown in Fig. 8.14. The variable dc voltage source is converted into variable current source by using inductance L.

![Fig.8.14. CSI using Thyristor](www.getmyuni.com)
The current $I_L$ supplied to the single phase transistorised inverter is adjusted by the combination of variable dc voltage and inductance $L$.

The waveforms of base currents and output current $i_o$ are as shown in Fig. 8.15. When transistors $Q1$ and $Q2$ conduct simultaneously, the output current is positive and equal to $+ I_L$. When transistors $Q3$ and $Q4$ conduct simultaneously the output current $i_o = - I_L$. But $i_o = 0$ when the transistors from same arm i.e. $Q( Q4$ or $Q2$ $Q3$ conduct simultaneously.

Fig.8.15: Waveforms for single phase current source

The output current waveform of Fig. 8.15 is a quasi-square waveform. But it is possible to obtain a square wave load current by changing the pattern of base driving signals. Such waveforms are shown in Fig. 8.16.
Load Voltage:
- The load current waveform in CSI has a defined shape, as it is a square waveform in this case. But the load voltage waveform will be dependent entirely on the nature of the load.
- The load voltage with the resistive load will be a square wave, whereas with a highly inductive load it will be a triangular waveform. The load voltage will contain frequency components at the inverter frequency $f$, equal to $1/T$ and other components at multiples of inverter frequency.
- The load voltage waveforms for different types of loads are shown in Fig. 8.17.
8.10 Variable DC link Inverter

The circuit diagram of a variable DC-link inverter is shown in Fig.8.18. This circuit can be divided into two parts namely a block giving a variable DC voltage and the second part being the bridge inverter itself.

The components Q, Dm, Land C give out a variable DC output. L and C are the filter components. This variable DC voltage acts as the supply voltage for the bridge inverter.
The pulse width (conduction period) of the transistors is maintained constant and the variation in output voltage is obtained by varying the DC voltage.

The output voltage waveforms with a resistive load for different dc input voltages are shown in Fig. 8.19.

We know that for a square wave inverter, the rms value of output voltage is given by,

\[ V_{0 \text{ (rms)}} = V_{\text{dc}} \text{ volts} \]

Hence by varying \( V_{\text{dc}} \), we can vary \( V_0 \text{ (rms)} \)

One important advantage of variable DC link inverters is that it is possible to eliminate or reduce certain harmonic components from the output voltage waveform.

The disadvantage is that an extra converter stage is required to obtain a variable DC voltage from a fixed DC. This converter can be a chopper.

**Prob 2**

The 1 \( \phi \) half bridge inverter using transistors has a resistive load of 2Ω. The DC supply is 24V. Calculate:

(i) RMS output voltage at fundamental frequency
(ii) Output power
(iii) Average and peak current
(iv) Peak reverse blocking voltage of each transistor.

**Soln. :**

(i) Refer to Equation (9.3.12)

\[ V_{0 \text{ rms}} = 0.45 \times V = 0.45 \times 24 \]

\[ = 10.8 \text{ volts} \]

(ii) Output power = \( V_{0 \text{ rms}} \div R \)

But \( V_{0 \text{ rms}} = V/2 = 12 \text{ volts} \)

\[ \text{Output power} = \left( \frac{12}{2} \right)^2 / 2 = 72 \text{ watt} \]

(iii) Peak load current = \( \frac{V}{2R} = \frac{24}{4} \)

\[ = 6 \text{ Amp} \]

(iv) Average load current = 0

(v) Peak reverse blocking voltage of each transistor = \( V = 24 \text{ volts} \).
Recommended questions:
1. What are the differences between half and full bridge inverters?
2. What are the purposes of feedback diodes in inverters?
3. What are the arrangements for obtaining three phase output voltages?
4. What are the methods for voltage control within the inverters?
5. What are the methods of voltage control of I-phase inverters? Explain them briefly.
6. What are the main differences between VSI and CSI?
7. With a neat circuit diagram, explain single phase CSI?
8. The single phase half bridge inverter has a resistive load of $R = 2.4 \, \Omega$ and the dc input voltage is $V_s = 48\, \text{V}$ Determine a) the rms output voltage at the fundamental frequency $V_{o1}$ b) The output power $P_o$ c) the average and peak currents of each transistor d) the peak reverse blocking voltage $V_{br}$ of each transistor e) the THD f) the DF g) the HF and DF of the LOH.