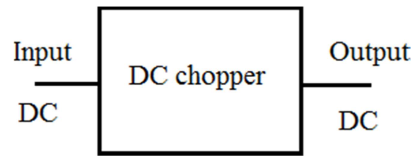
UNIT – III
Choppers and Inverters

Choppers

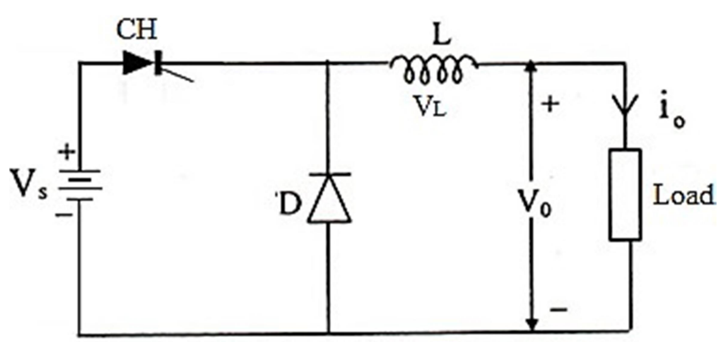
Chopper is a high speed on – off switch. A chopper is a static device that converts fixed dc input voltage to a variable dc output voltage. It is also known as dc to dc converter.



Step down chopper

The output voltage V_0 is less than the input voltage Vs can be obtained by a chopper called step down chopper. It is also known as Buck converter.

Circuit diagram:



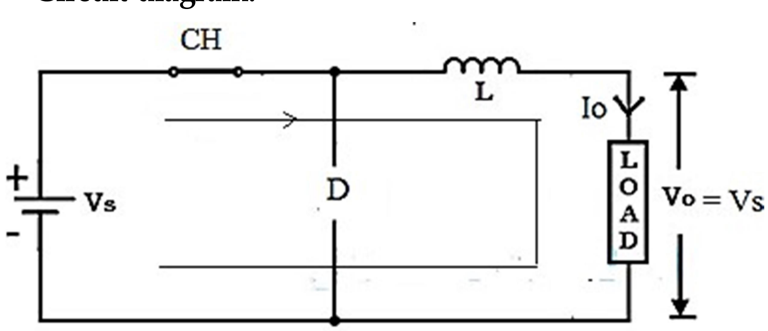
Description:

The used chopping device is SCR. It is a high speed static switch. It has pre-designed ON & OFF time period. SCR is triggered regularly by external trigger circuit and turned OFF by commutation process. Diode acts as feedback diode which provides discharge path for load current. The inductive load is connected in parallel with feedback diode. The output voltage V_0 is measured across load. The inductor is used to store energy.

Working:

<u>**Case (i): Chopper = ON condition**</u>

Circuit diagram:

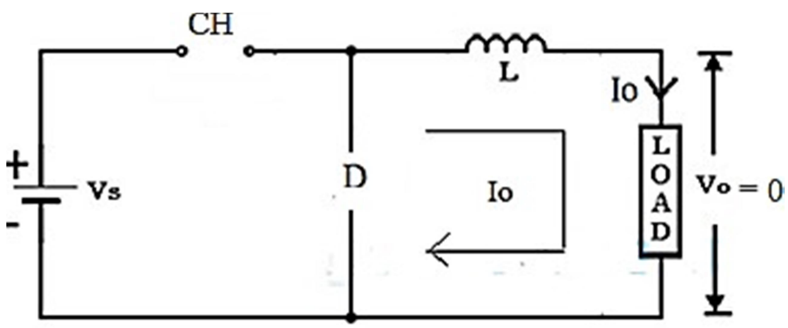


Description:

DC voltage is applied to the chopper circuit. Trigger signal is applied to SCR. Therefore SCR turns into ON state. During the period T_{ON}, chopper is ON and Load voltage is equal to Source voltage. ie) $V_0 = V_S$. The inductor is stores energy. The current path will be V_S -> chopper -> L ->Load -> V_S.

Case (ii): Chopper = OFF condition

Circuit diagram:



Description:

During the period T_{OFF}, chopper is OFF and the load current flows through the feedback diode D. As a result Load terminals are short circuited by the feedback diode and the load voltage V_0 is equal to Zero. In this manner the chopped dc voltage is provided at load terminals.

Description:

The output voltage V_0 is given by

$$V_0 = \frac{T_{ON}}{T} Vs$$

Where T = chopping time

T_{ON} – ON time of the chopper

T_{OFF} – OFF time of the chopper

$T = T_{ON} + T_{OFF}$.

$$V_0 = \frac{T_{ON}}{T_{ON}+T_{OFF}} Vs$$

Where $T_{ON} = T_{OFF} = T$

$V_0 = [T/2T]\ Vs$

$= (½)\ Vs$

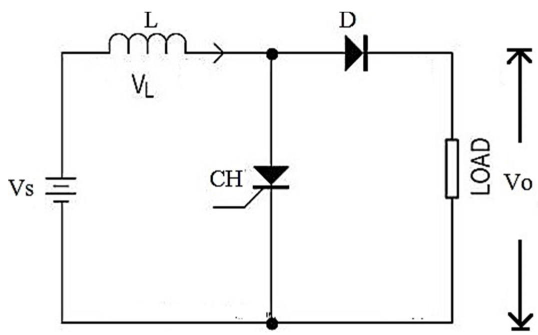
$V_0 = 0.5\ Vs$

The output voltage (V_0) is less then Source voltage (V_S) and hence the circuit is referred as step-down chopper.

Step up chopper:

Average output voltage V_0 is greater than input voltage V_S. ie) $V_0 > V_S$ can be obtained by a chopper called step up chopper it is also known as Boost converter.

Circuit diagram:



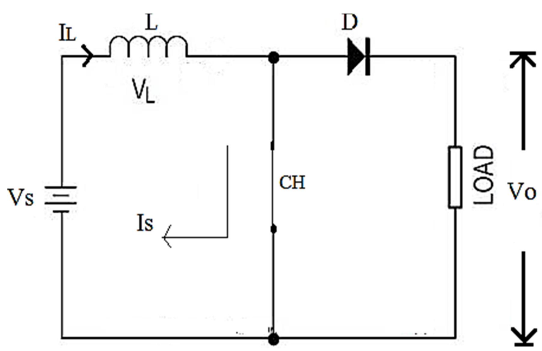
Description:

The used chopping device is SCR. It is a high speed static switch. It has pre-designed ON/OFF time period. SCR is triggered regularly by external trigger circuit and turned OFF by commutation process. Diode acts as feedback diode which provides discharge path for load current. The inductive load is connected in parallel with feedback diode (D). The output voltage V_0 is measured across load. The inductor L is connected in series with series voltage V_S and is used to store energy.

Working:

<u>Case (i): Chopper = ON condition</u>

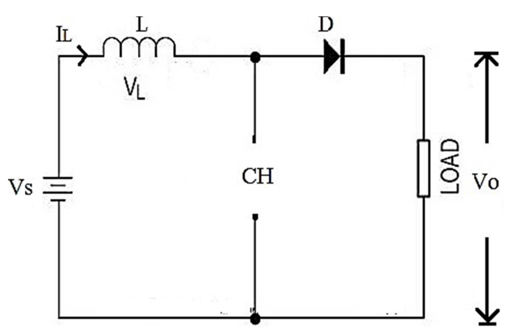
Circuit diagram:



DC voltage is applied to the chopper circuit. Trigger signal is applied to SCR. Therefore SCR turns into ON state. When chopper is ON, it forms closed current path and inductor stores energy.

<u>Case (ii): Chopper = OFF condition</u>

Circuit diagram:



When chopper is OFF, the closed current path is open. Inductor current doesn't reduces instantaneously and it flows through feedback diode and load for a time T_{OFF}. The current decreases the polarity of EMF induced in inductor is reversed.

The output voltage V_0 exceeds the source voltage V_S and hence the circuit is referred as step up chopper and the energy stored in inductor is released to the load.

Description:

Voltage across inductor

$V_0 = Vs + L\,(di/dt)$

$$V_0 = \frac{T}{T_{OFF}}\ Vs$$

Where T = chopping time

$T = T_{ON} + T_{OFF}$.

T_{ON} – ON time of the chopper

T_{OFF} – OFF time of the chopper

$$V_0 = \frac{T_{ON}+T_{OFF}}{T_{OFF}}\ Vs$$

Where $T_{ON} = T_{OFF} = T$

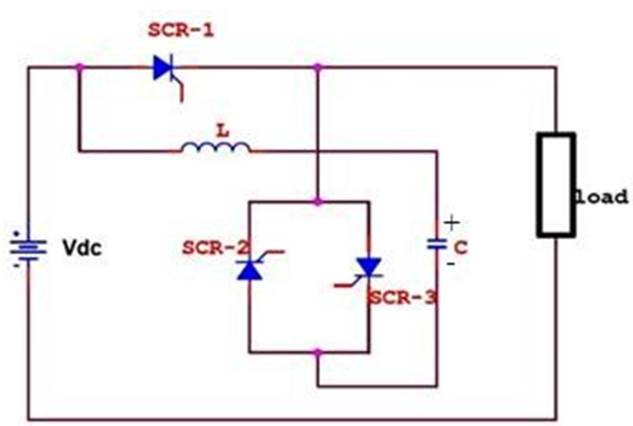
$V_0 = [2T/T]\ Vs = 2Vs$

Thus the output voltage (V_0) can be obtained as twice the input voltage (V_S). Hence it is called as step up chopper.

Morgan's chopper

The Morgan chopper circuit employs the forced communication technique. It has three SCRs 1, 2 and 3. SCR 1 is the main SCR, SCRs 2 and 3 are the two auxiliary SCRs. The auxiliary SCRs are used for communication of the main SCR. Inductor (L) and Capacitor (C) are the commutating elements which decide the time of commutation.

Circuit diagram:



Working:

First auxiliary SCR-2 is fired which allows capacitor C get charged with the polarities as shown in figure. As the capacitor charge increases the charging current decreases. When the capacitor achieves its full charge, the charging current stops flowing which automatically turns OFF SCR–2. Now, the capacitor C is fully charged. It retains its charge as SCRs 1 and 3 are in OFF position. When SCRs 1 & 3 are triggered simultaneously, capacitor C immediately starts discharging. Hence the polarities of capacitor C will reverse. Now, the upper plate will become negative and the lower plate will acquire positive charge. Hence SCRs 1 & 3 are turned OFF. Now, after a fixed period, SCR-2 is again fired and the process is repeated again.

Advantages:

- It assures better commutation
- It has better performance for lower values of chopper frequencies.

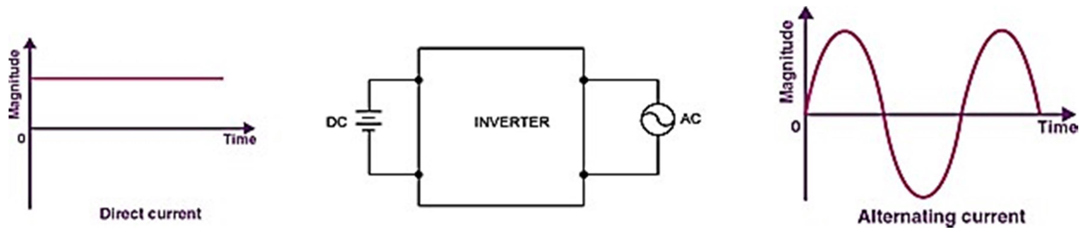
Disadvantages:

- It requires three SCRs and one extra SCR for the commutation purpose.
- The main SCR has to carry the commutation current.

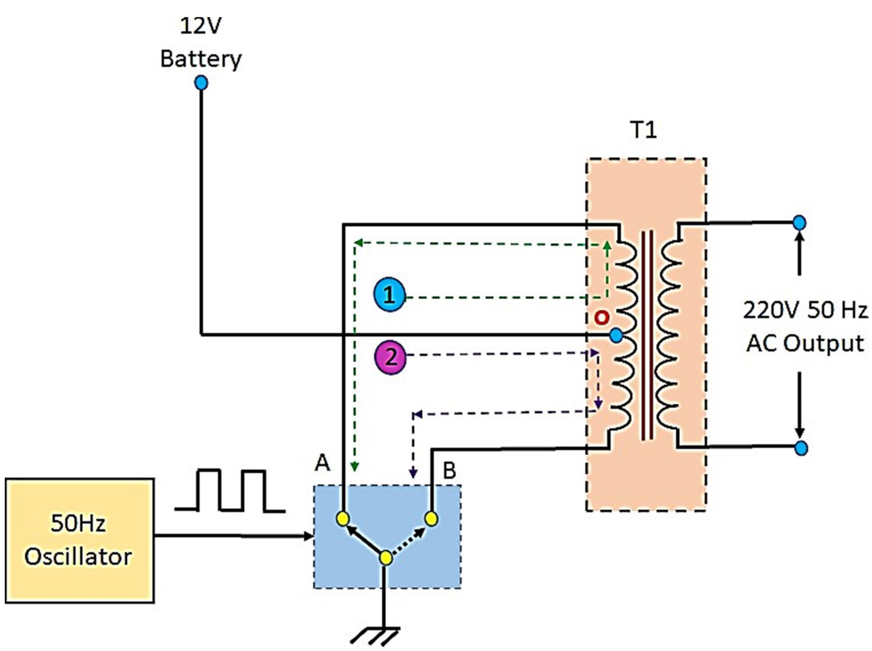
Inverters

Principle of working of Inverter

An inverter is a power electronics device which used to convert DC (Direct Current) into AC (Alternating Current).



Circuit diagram:



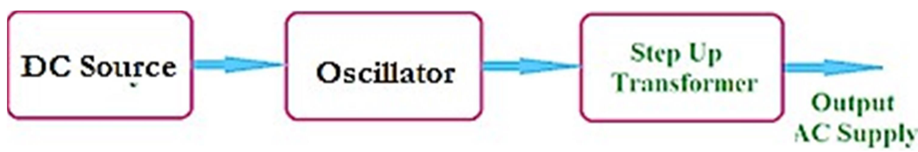
Description:

The 12V DC supply from the battery is applied to the primary winding of transformer which is center tapped. The two ends of the primary winding of transformer (A and B point) are connected to the two-ways switch to the ground. If the switch connects to A point of the primary winding. The current flows from the battery into upper half of primary winding (o) through A contact of the switch to the ground. If switch turn from A point into B point, the current number 1 stops flowing. Then the current 2 flows to the ground through o and contact B of the switch.

Here, 2 ways switch is controlled with the square wave oscillator it generates a frequency of 50 Hz. Also the current 1 and 2 flows to the transformer alternately at a rate of 50 times per second. So, the current flows into the transformer alternately look like AC voltage

The transformers work on the principle of Electromagnetic induction. When current flow in primary winding EMF induced and a current will be induced into the secondary winding of transformer which it causes AC voltage 220V 50Hz.

Block diagram:



Description:

DC Source

The dc is fed to the oscillator from a dc Source. In case a battery is used as a dc source, it should be charged by rectified dc obtained from ac mains.

Oscillator

Oscillator is also known as Resonance circuit. It is the heart of Inverter. It consists of Tank circuit and amplifier. Tank circuit has combination of inductor and /or capacitor with resistors of required value. The resistor, capacitor, inductor etc., used for building up the oscillations are called the resonant elements.

The oscillator builds up oscillations at the desired frequency at a low voltage. The frequency depends upon the values of combination of resonant elements. The low ac output from the oscillator is then fed to a step up transformer.

Step up transformer

The step up transformer is used to raise the output ac voltage of an oscillator at the required level.

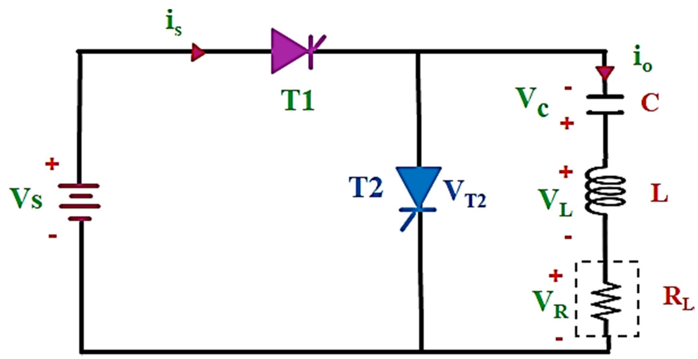
Series Inverter

Introduction:

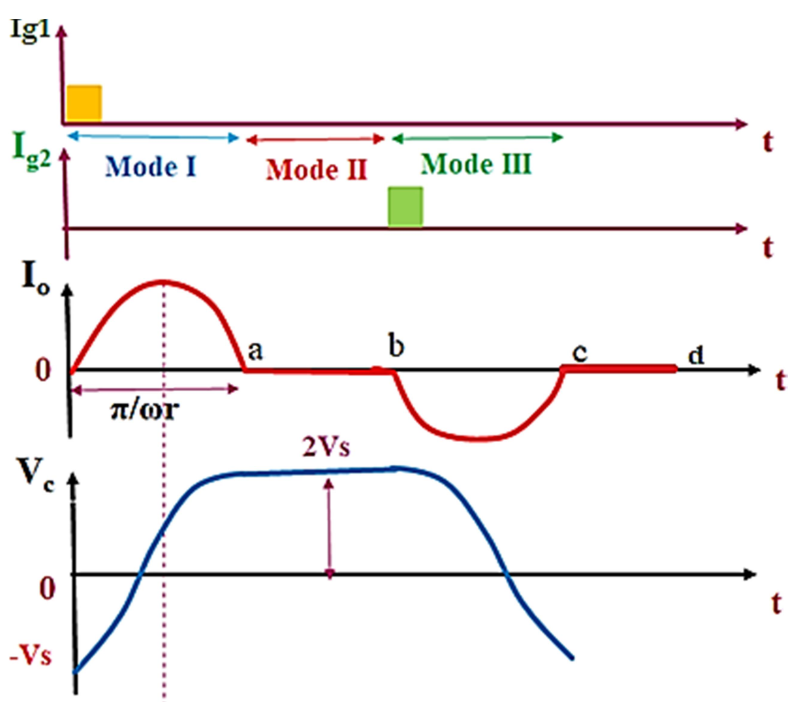
The inverter circuit in which the commutating elements L and C are connected in series with the load to form an under damped circuit is called a series inverter. The value of L and C is chosen in such a way that the R, L & C form an underdamped circuit.

Series inverter is also known as a "self-commutated inverter" or "Load commutated inverter" because thyristors of this inverter circuit are commutated by itself from the load.

Circuit diagram:



Waveform:



Working:

Mode-I (T_1 on and T_2 off):

Apply firing pulse to thyristor T_1 so, T_1 get turned on and T_2 thyristor is turned off initially. So, current flow from supply Vs…..T_1……load……back to Vs. Capacitor (C) starts charging from Vs to its max voltage. When the load current becomes maximum, the voltage across capacitor becomes +Vs. At point „a" the thyristor T_1 automatically turns off and the voltage across capacitor becomes +2Vs due to load current becomes zero.

Mode- II (T_1 and T_2 both off):

From point „a" to „b", the thyristors T_1 and T_2 are turned off and voltage across capacitor becomes equal to +2 V_s.

Mode III (T_1 off and T_2 on):

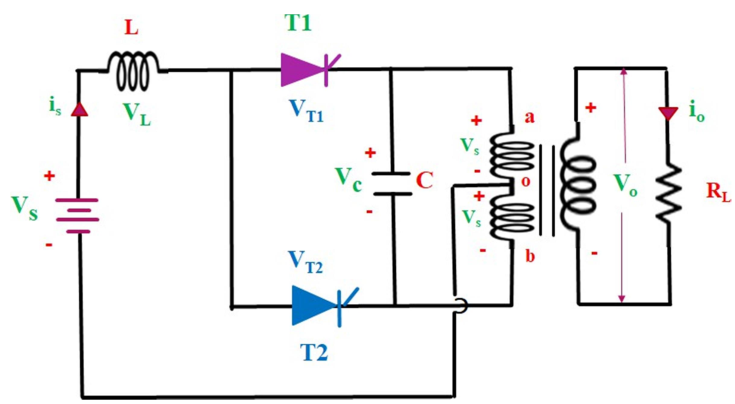
Apply firing pulse to thyristor T_2. So, T_2 get turned on. Now capacitor starts discharging from +2Vs to – Vs through thyristor T_2 and R – L circuit. Due to capacitor discharging reverse current flow across the load. Now at point C thyristor T_2 turns off automatically due to load current becomes zero. The thyristor T_2 turns off during point C to D and thyristor T_1 again turns on. The cycle repeated again and again.

Parallel Inverter

Introduction:

The inverter circuit in which the commutating component C (capacitor) is connected in parallel with the load via transformer called a parallel inverter. This circuit is also called Push-pull inverter.

Circuit diagram:



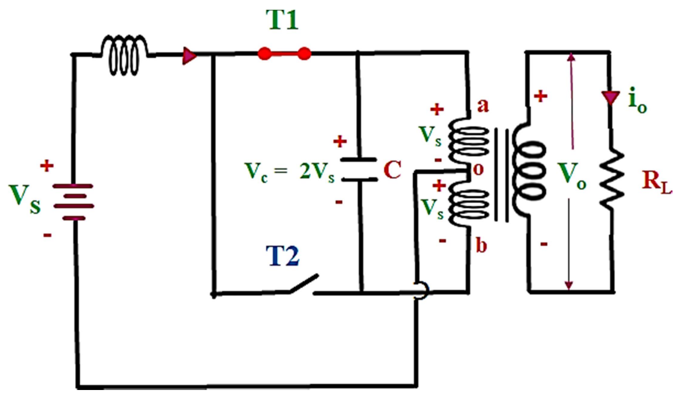
Description:

Parallel inverter uses a pair of named SCRs T_1 and T_2, a Center -tapped transformer, commutating components Capacitor C inductor L. Primary winding of center - tapped transformer is divided into two equal halves ao and ob.

Working:

Mode-I (T_1 on and T_2 off):

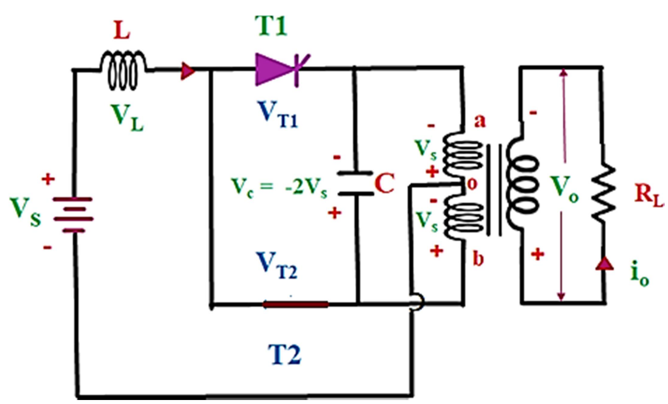
Circuit diagram:



Description:

Apply firing pulse to thyristor T_1 so, T_1 get turned on and T_2 thyristor is turned off initially. Current flow from supply Vs … L …. T_1…. ao …. Vs. As a result, Vs voltage is induced across upper as well as lower half of the primary winding of transformer. So, the total voltage across primary winding is 2Vs. Hence Capacitor is charged with 2Vs voltage with upper plate is positive and lower plate is negative.

Mode- II (T_1 off and T_2 on):



Description:

The capacitor is fully charged upto 2Vs the anode of SCR T_1 will receive a positive polarity from the upper plate of the capacitor. It will turn off SCR T_1. The capacitor remains at 2Vs voltage across it, SCR T_2 is triggered immediately. So, SCR T_2 get turned on. Load current flows from supply Vs …. L …. T_2… bo … Vs. Now capacitor starts discharging through SCR T_2.

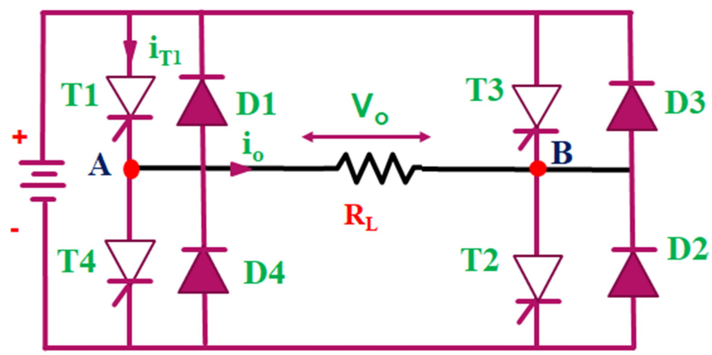
Capacitor is fully discharged and reverses its charge. (i.e) Its upper hand plate becomes negative and lower hand plate becomes positive. This gives positive polarity to SCR T_2 and turns it off immediately. Again SCR T_1 returns to conducting mode and triggered immediately. Capacitor C starts charging with opposite polarity. This process is repeated again and again.

Bridge Inverter

Introduction:

Bridge Inverter is basically a voltage source inverter and it is a topology of H-bridge inverter used for converting DC into AC.

Circuit diagram:



Description:

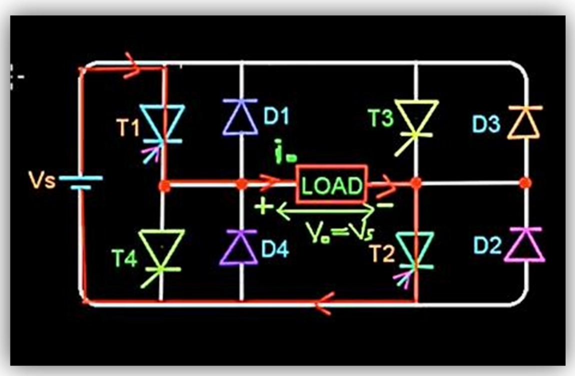
Bridge Inverter consists of four Thyristors ($T_1$to T_4) and four diodes (D_1 to D_4). The diodes are known as freewheeling diodes or feedback diodes because these diodes feedback the stored energy in the load back into the DC source. The feedback action happens only when load is other than pure resistive load. Each diode is connected in anti-parallel with each thyristor.

Working:

The operation of Bridge Inverter with Resistive load is based on the sequential triggering of SCRs placed diagonally opposite. This means that only two thyristors are turned ON in half of the time period like SCRs T_1 & T_2 will be triggered while for the remaining half of time period, SCRs T_3 & T4 will be triggered.

Mode-I (T_1, T_2 on and T_3, T_4 off):

Circuit diagram:



Description:

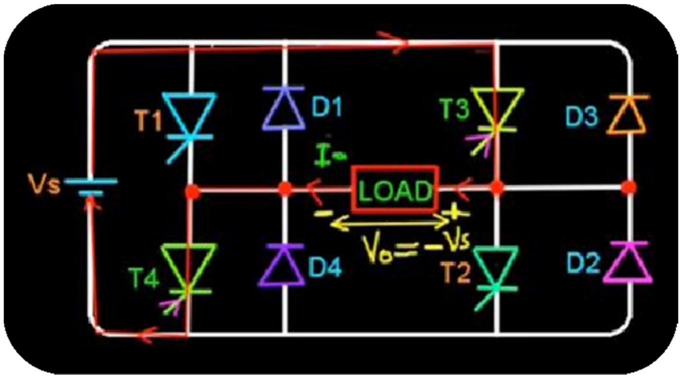
Apply gate triggering pulse to thyristors T_1 and T_2 so, thyristors T_1 and T_2 get turned on and T_3 and T_4 thyristors are turned off. Current flow from supply V_S…. T_1……load…. T_2…back to V_S. This time the direction of current flow across load is positive.

Output current Io = V_S/R_L Output voltage is also positive

Output voltage Vo = V_S.

Mode- II (T_1, T_2 off and T_3, T_4 on):

Circuit diagram:



Description:

Apply gate triggering pulse to thyristors T_3 and T_4 so, thyristors T_1 and T_2 get turned on and T_1 and T_2 thyristors are turned off. So current flow from Supply Vs …. T_3……load…. T_4… Vs.

This time the direction of current flow across load is negative.

Output current $Io = - Vs/R_L$

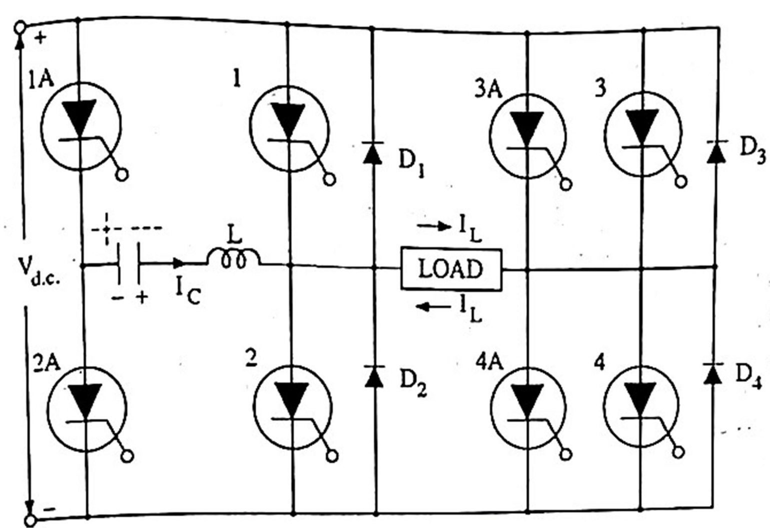
Output voltage is also negative

Output voltage **Vo = (-Vs).**

McMurray Inverter

McMurray Inverter was developed by McMurray and is an impulse commutated inverter. Impulse commutation is also called voltage commutation, auxiliary commutation.

Circuit diagram:



Description:

Forced commutation process is employed in this circuit. Forced commutation is an external circuitry to forcibly turn off SCR. Here, every SCR is commutated by means of an auxiliary SCR. The feedback diodes (D_1 to D_4) are used to feedback the stored energy in the load back into the DC source. 1, 2, 3 and 4 are the four main SCRs and 1A, 2A, 3A, 4A are the four auxiliary SCRs. SCRs 1 and 4 form the first pair of main SCRs and are fired simultaneously to produce the positive half of the a.c. output. SCRs 3 and 2 constitute the second pair and are fired simultaneously to give the negative half of the a.c. output.

Analyse the commutation of SCRs 1 and 2.

Assume that SCRs 1 and 4 are conducting. Load Current (I_L) flows from Supply V_{dc} …. SCR_1……load…. SCR_4… V_{dc}. At this instant, the right-hand plate of C becomes positive. Now, for commutating SCR_1, the auxiliary SCR 1A has to be gated. Now capacitor C will start discharging through L, feedback diode D_1, and SCR 1A. Thus the discharge current Ic will try to neutralize the current flowing through SCR_1. As soon as the SCR current is fully neutralised, SCR_1 will be turned OFF.

When the capacitor is fully discharged, it will start recharging with opposite polarities, i.e. now its left-hand plate will be positive and the right hand plate will become negative. When C is fully charged with the new polarities, SCR 1A will be automatically turned OFF and SCRs 2 and 3 can be gated. (i.e) SCRs 2 & 3 are starts to conduct. Load Current (I_L) flows from Supply V_{dc} …. SCR_3……load…. SCR_2… V_{dc}.

Now for turning OFF SCR_2, SCR 2A is gated. As soon as SCR 2A is gated capacitor C starts discharging through the path SCR 2A, D_2 and *L.* This discharge current will again neutralise the current flowing through SCR_2 and turn it OFF. When the capacitor is fully discharged it will start recharging with the opposite polarities i.e. with the right-hand plate attaining positive polarity and the left-hand plate negative.

When the capacitor is fully charged, SCR 2A will be automatically turned OFF, and C will retain its charge. SCR_1 can now again be gated for the next half cycle. The cycle is repeated continuously thus producing a.c. output across the load.