EE 238

Power Engineering - II

Power Electronics

Lecture 14

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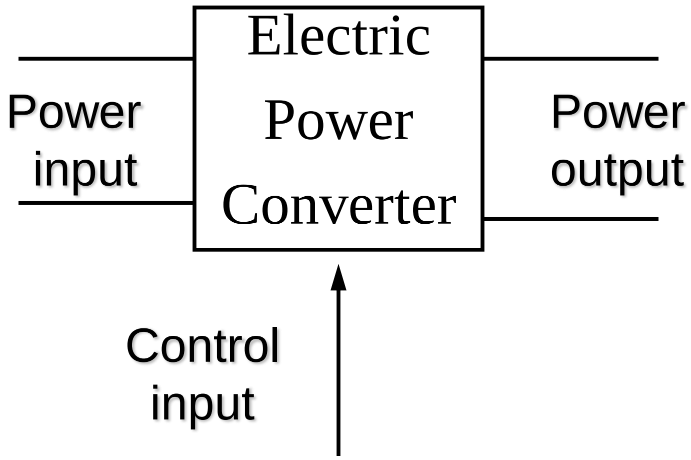
Conversion of electric power



Other names for electric power converter:

- Power converter
- Converter
- Switching converter
- Power electronic circuit
- Power electronic converter

Two types of electric power	Changeable properties in conversion
DC(Direct Current)	Magnitude
AC (Alternating Current)	Frequency, magnitude, number of phases

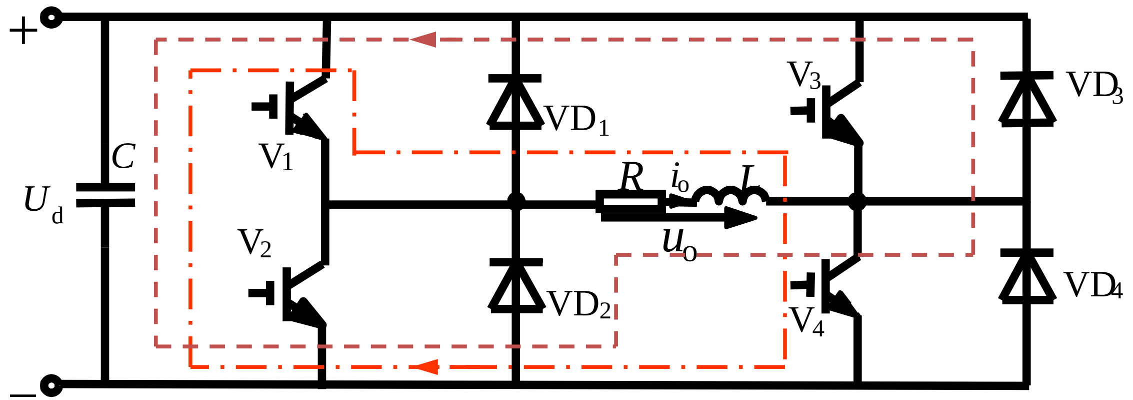
Inverters Classification

Voltage Source Inverter

The input is from a dc source and the ac output functions as a voltage source.

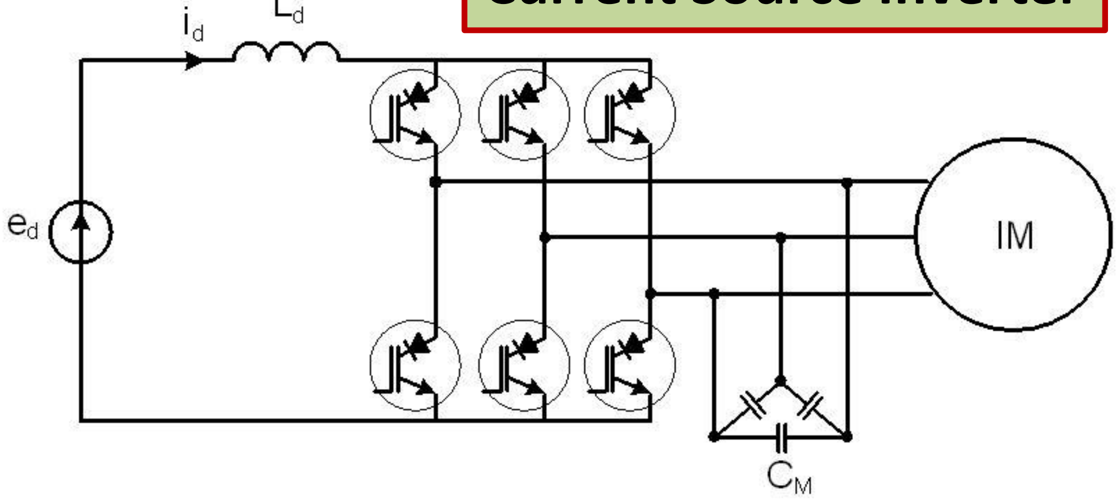
The input dc voltage may be from the rectified output of an ac power supply, in which case it is called a ‘dc link’ inverter.

Alternatively, the input dc may be from an independent source such as a battery.



Full-bridge Inverter: Most commonly used topology.

Current Source Inverter



This is also a dc link inverter but in this case the dc link functions like a dc current source.

On the output side, CSI functions as an ac current source.

VSI: modulation methods

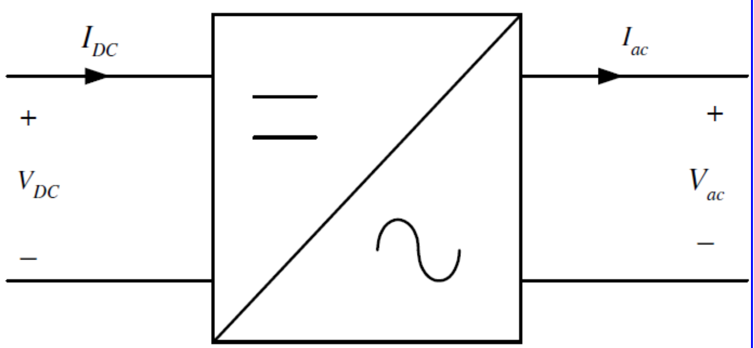
1. ***Pulse-width-modulated inverters***
   - Vdc is essentially constant in magnitude.
   - PWM is used to control the magnitude and frequency of the ac output voltages.
   - There are various PWM schemes to shape the output ac voltages to be as close to a sine wave as possible.

2. *Square-wave inverters.*

- Vdc is controlled in order to control the magnitude of the output ac voltage.
- The inverter has to control only the frequency of the output voltage.
- The output ac voltage has a waveform similar to a square wave.

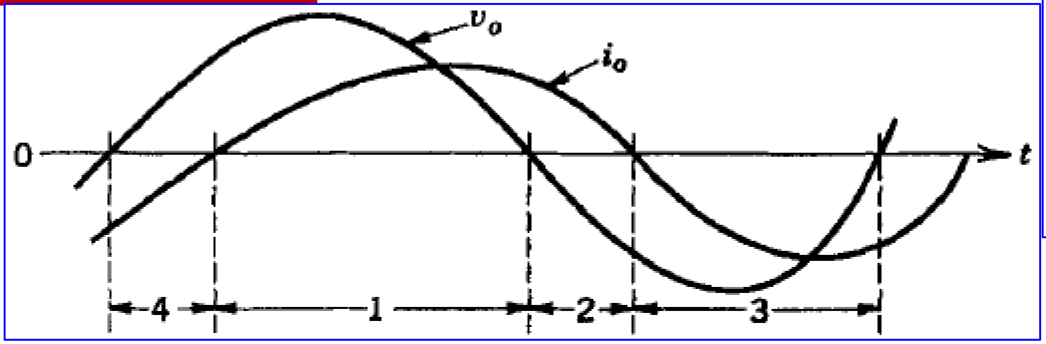
Inverters can be of single-phase or three-phase configurations.

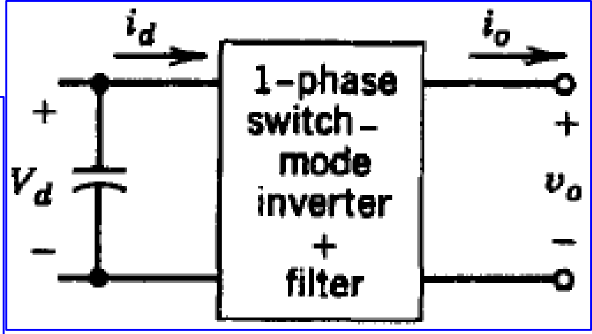
General block diagram



BASIC CONCEPTS OF SWITCH-MODE INVERTERS

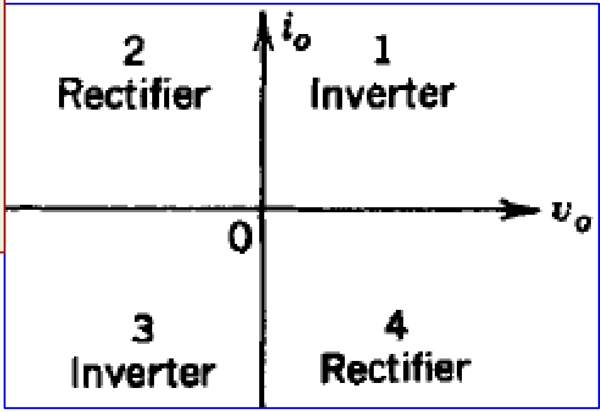
With filters and lagging load:



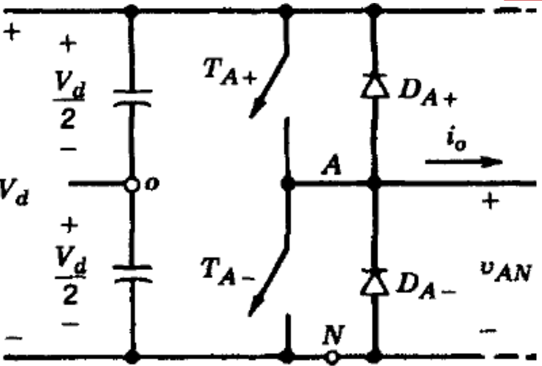


During intervals 1 & *3,* the instantaneous power flow *po (=v0i0)* is from the dc to ac side, corresponding to an inverter mode of operation.

In contrast, v0 and i0 are of opposite signs during intervals 2 and 4, and therefore *po* flows from the ac to dc side, corresponding to a rectifier mode of operation.



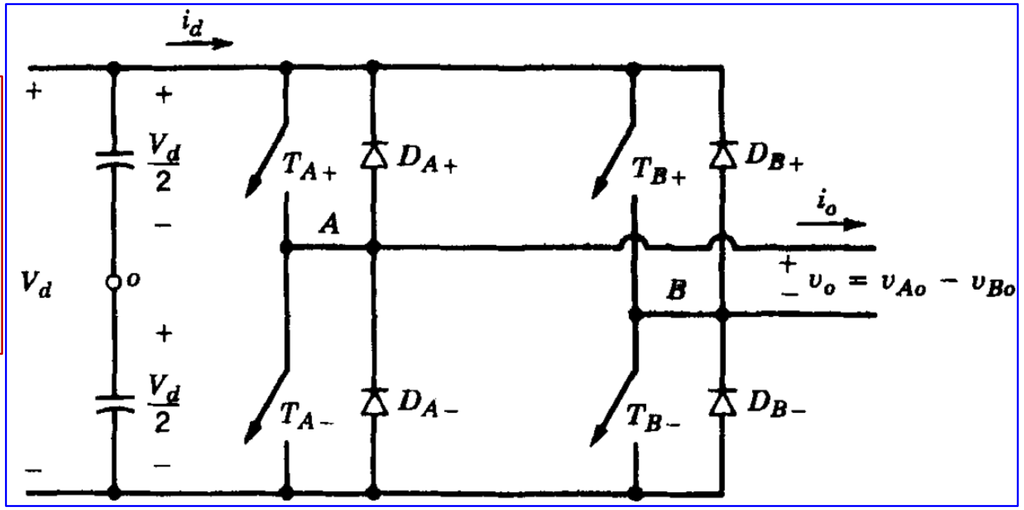
Therefore, the inverter must be capable of operating in all four quadrants of the *i0-v0* plane during each cycle of the ac output.



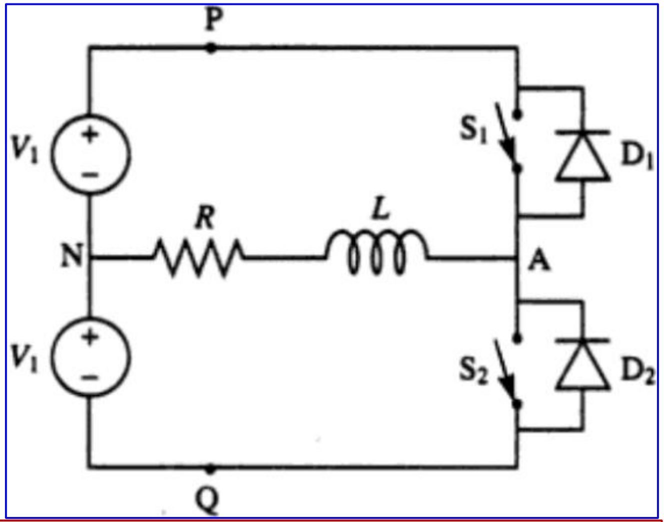
Basic Building Block

Most of the inverter topologies are derived from the one-leg converter.

The full-bridge converter meets the switch-mode inverter requirements.



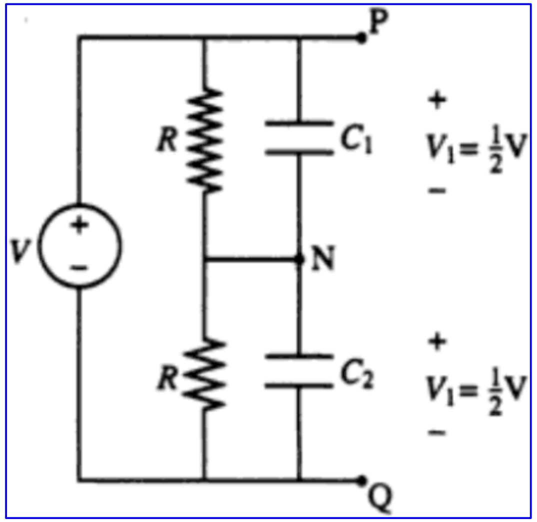
THE HALF-BRIDGE INVERTER



Common point of the DC capacitors should be made available.

The input dc to the half-bridge has to be a split power supply. If the midpoint is not available then two identical capacitors are connected in series across the dc source.

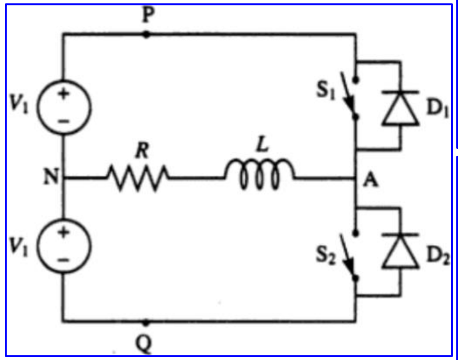
Two large and equal resistors may be connected to ensure correct voltage division. They also enable the capacitors to discharge when the DC supply is switched off.

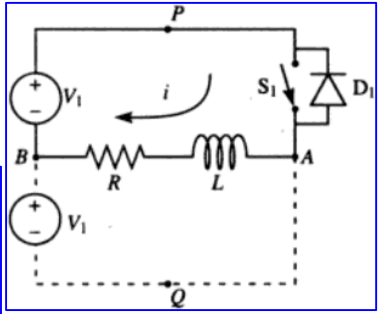


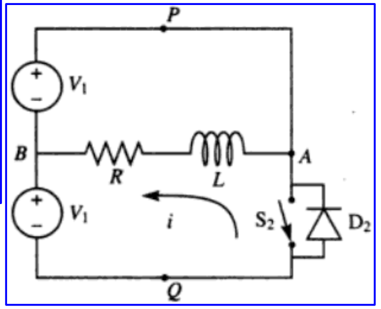
THE HALF-BRIDGE INVERTER WITH INDUCTIVE LOAD

Let us assume zero initial current in L and S_1 is turned ON at $t = 0$.

$$L\frac{di}{dt} + Ri = V_1 \qquad i = \frac{V_1}{R}(1 - e^{-t/\tau}) \qquad \tau = L/R \qquad T = 1/f$$







At t = T/2, the first half-period ends and the circuit configuration changes as S1 is turned OFF.

At this instant, $I_{01} = \frac{V_1}{R}(1 - e^{-T/2\tau})$

The second half-period commences at t = T/2 when S2 is turned ON.

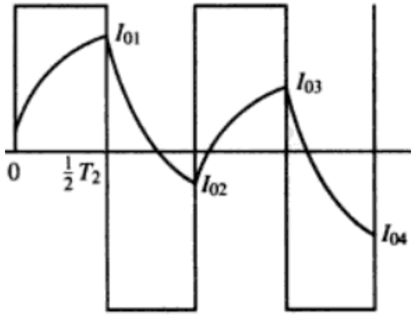
What will happen if, after turning OFF S1, we do not instantly turn ON S2, but delay this by a short 'dead time'?

The induced e.m.f. due to L will cause D2 to become forward-biased and turn ON. Therefore, it'll not make any difference to the voltage across the load, or the current through it, if we delay the turn-ON of S2, as long as this delay does not exceed the time it takes for the current to fall to zero.

Take a new reference zero for t, at the commencement of the second half-period,

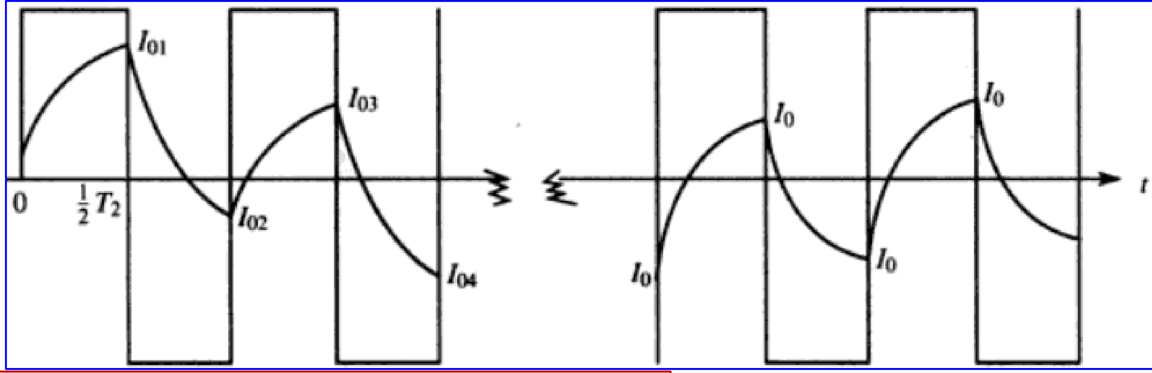
$$L\frac{di}{dt} + Ri = -V_1 \qquad i = I_{01} \quad \text{at} \quad t = 0$$

$$i = -\frac{V_1}{R}(1 - e^{-t/\tau}) + I_{01}e^{-t/\tau}$$



THE HALF-BRIDGE INVERTER WITH INDUCTIVE LOAD

After several cycles of switching, the difference in the current waveform between successive cycles become negligible.



The voltage waveform is repetitive from the very beginning, whereas the current waveform needs several cycles of operation to attain repetitive conditions.

Taking $t = 0$ at the instant of turn ON of switching block 1

$$\left.\begin{aligned} L\frac{di}{dt} + Ri &= V_1 \\ i = -I_0 \quad &\text{at } t = 0 \end{aligned}\right\}$$

The solution of this is

$$i = -I_0 e^{-t/\tau} + \frac{V_1}{R}(1 - e^{-t/\tau})$$

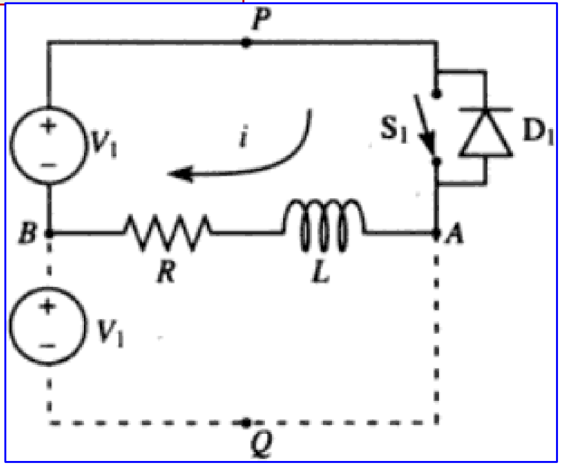
At $t = \frac{1}{2}T$, from symmetry considerations, $i = I_0$. Therefore

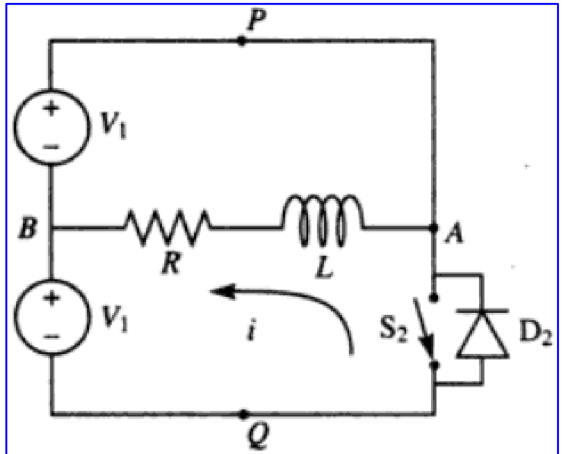
$$I_0 = -I_0 e^{-T/2\tau} + \frac{V_1}{R}(1 - e^{-T/2\tau})$$

This gives I_0 and the expression for i as

$$I_0 = \frac{V_1}{R}\frac{1 - e^{-T/2\tau}}{1 + e^{-T/2\tau}}$$

$$i = -\frac{V_1}{R}\frac{1 - e^{-T/2\tau}}{1 + e^{-T/2\tau}}e^{-t/\tau} + \frac{V_1}{R}(1 - e^{-t/\tau}) \quad \text{for } 0 \leqslant t \leqslant \tfrac{1}{2}T$$

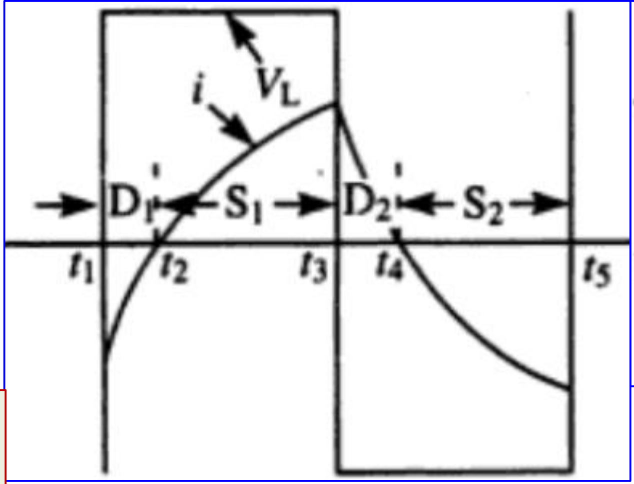


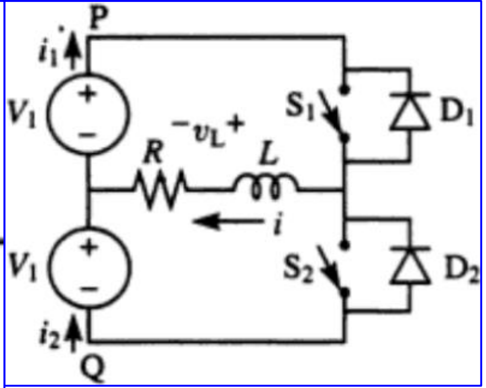


Commutation Sequence of Switching Elements

The turn OFF switching of one element and the turn ON switching of another element, by which a transfer of current takes place from one element to another, is called commutation.

The instants at which four commutations take place in a half-bridge inverter are the instants of zero-crossings of the voltage waveform and current waveforms.





The commutations at the zero-crossings of the voltage waveform, namely t1 and t3, are implemented directly by the action of the switching control circuit. For example, the commutation at t1 takes place when the switching control circuit turns OFF S2.

The instant at which the current goes through zero depends on the load circuit time constant, which can be different for different loads. For example, at t2, the switching control circuit should be so designed that the control signal to turn ON S1 must be present at this instant, although t2 itself is variable and dependent on the load circuit time constant. The practical way in which this can be done is to commence the turn ON switching signal of S1 after a short 'dead time' after t1, even though the switch itself is not ready to turn ON. The signal should continue to be present when the switch is able to turn ON at the current zero-crossing.