



The Motor Control Warehouse

Basic Overview Of AC Inverter Power Stage

MCW Hints & Tips 0004

If a standard AC induction motor is connected directly to the mains supply has the following limitations:

- Uncontrolled speed
- Very high starting current
- Uncontrolled torque
- Uncontrolled acceleration
- No braking (stopping control)

The function of an AC inverter drive is to overcome these limitations.

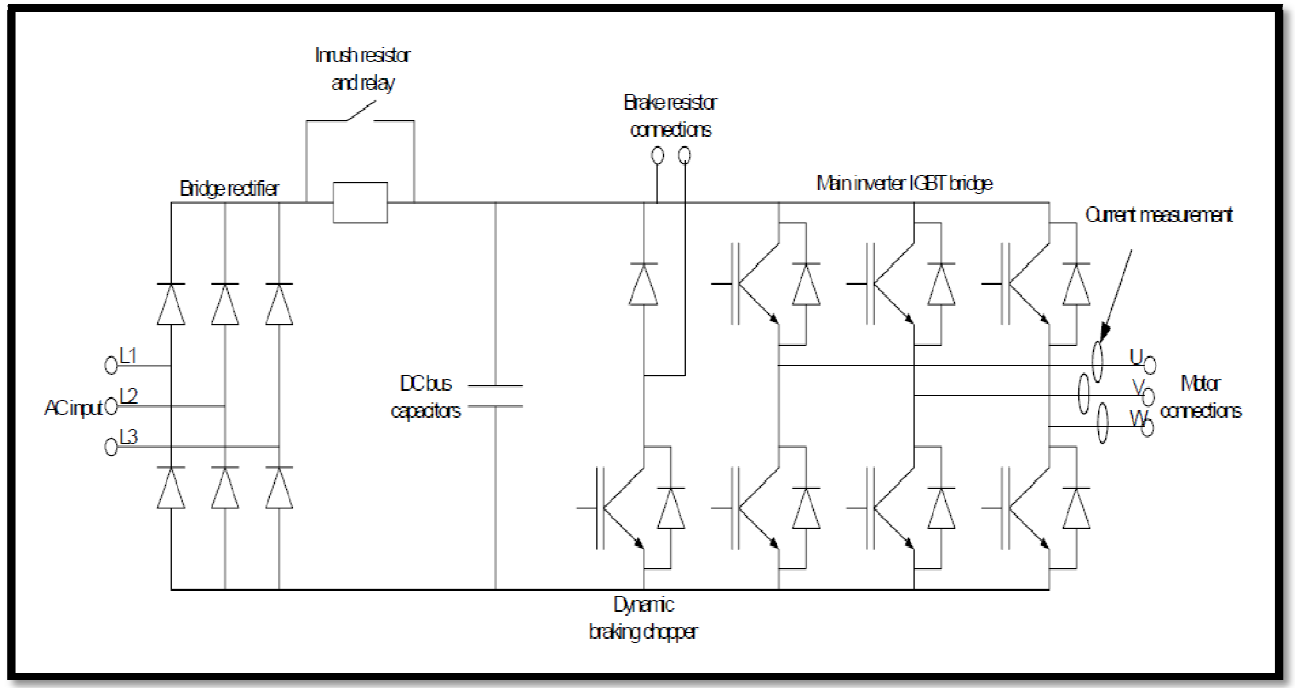
Speed control

You can't change the frequency of the incoming 3-phase power supply as this is fixed by the rotational speed of the generator that produces it, but by using an AC inverter, you can change the frequency of the supply to the motor.

The rated speed of an AC induction motor is the rotational speed of the stator field less the slip at rated load. A standard 4 pole motor run from a 50Hz supply with 2% slip will rotate at 1470rpm. AC inverters control the speed of the motor by varying the supply frequency to the motor. If you halve the supply frequency, you halve the speed of the motor, and so on.



Typical diagram of an AC inverter drive power stage



Input bridge rectifier & DC Link

An AC inverter is a variable frequency 3 phase supply generator. The incoming fixed frequency supply is connected to a 3 phase diode bridge which converts the AC supply into a DC voltage. This DC voltage on the output of the diode bridge is connected across a large high voltage capacitor. The capacitor is called a DC link and acts as a reservoir of charge. Charge accumulates in the capacitor until the voltage across it is equal to the peak of the voltage between any pair of 3 phases, nearly 600VDC for a 415VAC supply.

Inrush circuit

The inrush circuit is used to limit the current, at power up, which flows into the DC link capacitors. These capacitors look like a short circuit to DC at power up, so without the inrush circuit, a massive current would flow from the supply, through the bridge rectifier into the capacitors. This current could cause fuses to blow and could cause damage to the bridge rectifiers and capacitors. Once the DC link capacitors have charged, a relay across the resistors closes to short out them out. If the resistors were left in circuit, they would get extremely hot or even burn out when the drive is being loaded by the motor.



Dynamic Brake Chopper

When the rotor of a motor turns faster than the synchronous speed set by a drive output, the motor is transforming mechanical energy from the motor shaft into electrical energy. This condition is referred to as 'regeneration'.

Regeneration may be caused by a drive ramp to stop or a reduction in commanded speed on a high inertia load or an overhauling load that causes the shaft speed to be greater than the synchronous speed.

If the motor is regenerating, the DC bus voltage will increase. Unless a method of dealing with the regenerative energy is provided the drive will protect itself with a DC Bus overvoltage trip, thus stopping the regenerative condition. The braking chopper allows a braking resistor to be connected across the DC bus of the inverter thus dissipating the regenerated energy as heat rather than the drive tripping on a DC bus overvoltage.

Output transistor bridge

Connected across the DC supply is a circuit which turns the DC back into AC. This process is called inversion hence the name 'Inverter'. The inversion circuit consists of 6 high speed, high voltage transistors arranged as a 3 phase bridge. The arrangement is the same as for the input diode bridge but with transistors instead of diodes, except now the input is DC and the output is AC. The transistors are used to connect the + and - of the DC link to the 3 output phases. The transistors are switched on and off in a constantly repeating pattern to produce a synthesised AC waveform.

Current measurement

Either on the output phases of the drive or on the DC bus, or even a combination of both, current measurement devices are fitted to measure the current being taken by the load and feed this information back to the control hardware. This information can be used to make sure that the output current from the drive stays within the drives rating and also to protect the drive if a short circuit occurs either within the drives output stage or on the drives output terminals, motor cabling or motor itself.

PWM - pulse width modulation

The output voltage waveform looks nothing like a 3 phase supply. The pulses are in groups alternately positive and negative as the DC link is connected first one way round and then the other way round. Within each group, the pulses gradually vary in width making the connections for longer or shorter times. If a motor is connected to the inverter then the output voltage waveform of the inverter will be impressed across the motor stator windings. Because the motor is an inductive load, the current waveforms that result are approximately sinusoidal. This kind of inverter in which the output pulses are of constant amplitude (the DC link voltage), but vary in width, is called a Pulse Width Modulation Inverter (PWM).



Switching

The rate at which the pulse pattern alternates between positive and negative and then positive again is the frequency of the output. Within each cycle of positive and negative, the pulse widths average to a sine voltage waveform with narrow pulses for low output volts and wide pulses at the peak. The more pulses in a cycle for a given output frequency, the better the average voltage. During a pulse, the DC link is connected to the output so the motor current rises, between pulses the motor current falls. The closer the pulses are together, the smaller the current steps and therefore the current approximates better to a sine wave. Deviations from a perfect sine wave cause power losses in the motor so it gets hotter, make the motor noisy and generate interference.

Switching wastes power

Each time a transistor switches, it has to dissipate some power as heat. To get more pulses, you need to switch faster so switching is limited to the type of transistor used and the maximum power it can dissipate. Most drives now used IGBTs – Insulated Gate Bipolar Transistors which are fast switching, high frequency, low loss devices. The switching pattern is generated automatically by the electronics within the drive which controls which transistor is switched, when and for how long. All the user has to do is tell the drive what output frequency is required and the inverter electronics does the rest.

