Full Bridge Bi-Directional PMDC Drive Using Chopper Fed IGBT

Chaitali Shamkant Shukla
(Student-ME Electrical(Control)))
K.K.W.I.E.E.&R.Nashik COE

Prof. D. P. Kadam
(Assistance professor)

ABSTRACT

This paper present *the chopper circuit which employs "full bridge" configuration has advantage such as high operational frequency, smooth and linear control, high efficiency and fast response. IGBT' based power circuit and direction changing logic circuit is used for the D.C drive which does not involve any triggering circuit. Reversible DC drive system using IGBT, capable of switching at 20 KHZ frequency. The chopper circuit consists of full bridge configuration. The 4 quadrant chopper has certain advantage such as high operational frequency, smooth and linear control, high efficiency and fast response [2], [3]. Isolation card is also used as a precaution for the IGBT 'S. Pulse width modulation technique is used for controlling the speed of the motor. Soft start circuit is also provided to limit the inrush current to the motor in initial conditions when the motor is provided with the armature supply.*

1. Introduction

Power electronics is nowadays one of the most dynamic field of engineering. The applications of power electronics are more and more diversified and focused especially on electric power conversion (converters). The modern solution involve new power semiconductor devices with high performances, dedicated command circuits which achieve multiple specific functions and new control techniques. Prior to the development of Power Electronic devices and the chopper, it was very difficult to manage the variable speed in any application. However, nowadays, the long and cumbersome set up required to achieve the control has been transformed into few power devices and a chopper. Reliability and efficiency have also increased and such a process is aptly suited for the stringent demands of today's industries. DC Motors provide high starting torque and can be used over a wide range of applications. The speed control methods of DC Motors are much simpler than those of AC Motors, in addition to this; DC Motors are also less expensive. The conventional approach for speed control is the phase control method but this method has been discarded because it generates too many harmonics and has lower power factor at decreased speeds. Therefore, the chopper based IGBT switching technique is employed. Pulse Width Modulation technique is also employed to control the speed of the motor through duty cycle variations. Thus, the converters structure is much simplified, their volume and weight decrease, they become cheaper and more robust. Furthermore, the conversion quality increase and the disturbances against power supply networks and environment decrease. Figure The appearance of the power transistors with IGBT lead to the necessity of redesigning the power converters structure from the point of view of the gate command and protection circuits. The IGBT advantage are:- very high input impedance which is voltage controlled device , low level of loss in conduction state, low switching loss , high operating frequency(up to 50 KHz), simple protection circuits. They have wide area of applications like, used in Traction Drives for railways, buses & electrically driven vehicles, also in steelworks, hot strip mills, transformer winding machines, in position controls etc. The appearance of the power transistors with IGBT lead to the necessity of redesigning the power converters structure other than MOSFET because of low driving power and simple drive circuit due to the input MOS gate structure. IGBT can be easily controlled as compared to current controlled devices in high voltage and high current applications [5].Some typical IGBT applications include motor control where the operating frequency is <20 KHZ. Such D.C. supplies can be found in many industrial processes, e.g. transportation systems, chemical and steel plants etc. Except at very high power levels, the four-quadrant chopper has certain advantages such as high operational frequency, smooth and linear control, high efficiency and fast response.

1.1. Four quadrant chopper

Such D.C supplies can be found in many industrial processes, e.g. Transportation systems, chemical and steel plants etc. Expect at very high power levels, the four quadrant chopper has certain advantages such as high operational frequency, smooth and linear control, high efficiency and fast response. The converter is full bridge chopper with four quadrant operation. Because of the four quadrant there is rotation of the D.C motor in the both direction i.e. reverse and forward direction, this has been done with the help of direction changing logic circuit.

1.2. Insulated gate biopolar transistor

An IGBT is preferred over all other thyristors because it combines the attributes of MOSFET,BJT and Thyristors.

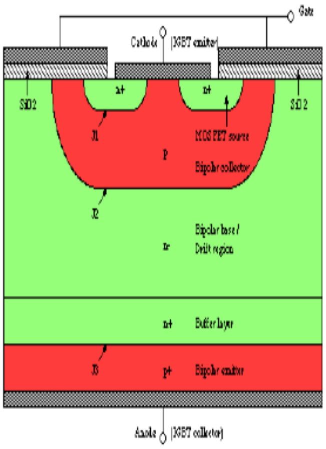

Figure 1:-IGBT structure

The structure is very similar to that of a vertically diffused MOSFET featuring a double diffusion of a p-type region and an n-type region. An inversion layer can be formed under the gate by applying the correct voltage to the gate contact as with a MOSFET. The main difference is the use of a p+ substrate layer for the drain. The effect is to change this into a bipolar device as this p-type region injects holes into the n-type drift region.

1.2.1 Blocking Operation

The on/off state of the device is controlled, as in a MOSFET, by the gate voltage VG. If the voltage applied to the gate contact, with respect to the emitter, is less than the threshold voltage Vth The forward breakdown voltage is therefore determined by the breakdown voltage of this junction. This is an important factor, particularly for power devices where large voltages and currents are being dealt with. The breakdown voltage of the one-sided junction is dependent on the doping of the lower-doped side of the junction, i.e. the n then no MOSFET inversion layer is created and the device is turned off. When this is the case, any applied forward voltage will fall across the reversed biased junction J2. The only current to flow will be a small leakage current. This is because the lower doping results in a wider depletion region and thus a lower maximum electric field in the depletion region. It is for this reason that the n- drift region is doped much lighter than the p-type body region. The device that is being modeled is designed to have a breakdown voltage of 600V.The n+ buffer layer is often present to prevent the depletion region of junction J2 from extending right to the p bipolar collector. The inclusion of this layer however drastically reduces the reverse blocking capability of the device as this is dependent on the breakdown voltage of junction J3, which is reverse, biased under reverse voltage conditions. The benefit of this buffer layer is that it allows the thickness of the drift region to be reduced, thus reducing on-state losses.

1.2.2 On-state Operation

The turning on of the device is achieved by increasing the gate voltage VG so that it is greater than the threshold voltage Vth. This results in an inversion layer forming under the gate which provides a channel linking the source to the drift region of the device. Electrons are then injected from the source into the drift region while at the same time junction J3, which is forward biased, injects holes into the n- doped drift region. In Fig 2 Internal hole and electron flow in the IGBT while in on state this injection causes conductivity modulation of the drift region where both the electron and hole densities are several orders of magnitude higher than the original n- doping. It is this conductivity modulation which gives the IGBT its low on-state voltage because of the reduced resistance of the drift region. Some of the injected holes will recombine in the drift region, while others will cross the region via drift and diffusion and will reach the junction with the p-type region where they will be collected. The operation of the IGBT can therefore be considered like a wide-base pnp transistor whose base drive current is supplied by the MOSFET current through the channel. If the current flowing through this resistance is high enough it will produce a voltage drop that will forward bias the junction with the n+ region turning on the parasitic transistor which forms part of a parasitic thyristors. Once this happens there is a high injection of electrons from the n+ region into the p region and all gate control is lost. This is known as latch up and usually leads to device destruction.

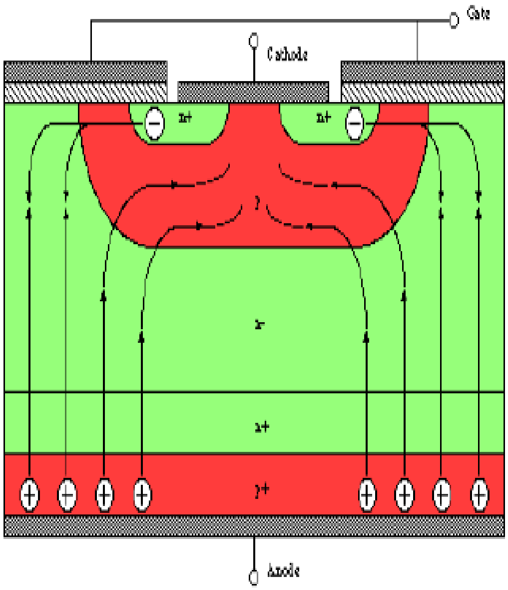

Figure 2:-IGBT operation

2. Block Diagram

The block diagram of the system is shown in fig 3. The converter is full bridge chopper with four quadrant operation. Because of the four quadrants there is rotation of the P.M.D.C motor in reverse and forward direction, this has been done with the help of direction changing logic circuit and direction changing switch.

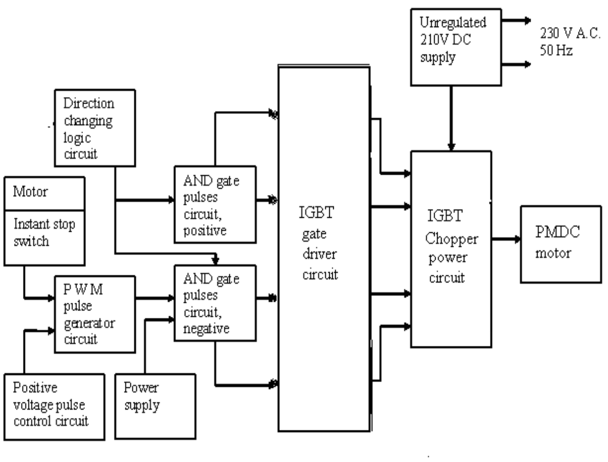

Figure 3:-block diagram

3. Direction change logic circuit

The function of direction change block is to rotate the motor in forward and reverse direction. Basically, it consist of two J-K filpflop, 555 timer, and 4 AND gate. The timer is used in monostable mode. When the power is turned on the power on reset components connected to reset pin of J-K flip-flops, reset the flip-flops. The 555 connected as Monostable multivibrator gets a trigger pulse on pin 2 on power on and its timing starts. At the end of monoshot timing the level change at the output pin of 555 which is inverted one. This set both the filpflop output to 1. The first flipflop output drives the relay driver circuit, which in turn operates the relay and PWM circuit generates PWM pulse which is desired DC level. At that time second flipflop output goes high so one direction is selected. For other direction, direction change switch is pressed which toggles the JK flipflop output. Now, the first filpflop output becomes zero and relay of soft start circuit is deactivated. The soft start capacitor gets shorted and PWM is not generated. Q output of first flip-flop gives trigger to pin 2 of 555 and Monoshot gets triggered. At the end of monoshot time the set pulse is given to flip-flop and again Q of first flip-flop becomes one and Q output of second flip-flop becomes equal to zero. Thus direction of rotation reverses.

4. Pulse Width Modulation Controller

Normal OP-AMP has high input impedance and low output impedance. While error amplifier of 3524 has low input impedance and high output impedance so that compensation voltage can over ride on error amplifier output. Initially when the circuit is on, output pulse width is low so proportional feedback voltage is less. As output voltage increases pulse width increases, feedback increases. Feedback is applied through R_f i.e. applied to error amplifier output (Compensation pin), inverter input because of this feedback; close loop action takes place comparator non-inverting input is triangular, which should be compared with D.C. level so as to get PWM at output, therefore output of error amplifier which is square wave integrated (compensated) to get D.C. level. Error amplifier output will be earned if its two inputs are same.Shut down input if exceeded the transistor becomes ON and output of error amplifier is brought down to low level. If a resistor across CL + and CL- is connected, which has drop across it of 200 mV. The duty cycle becomes 25%. The reference output 5V is generated and given to internal OP AMPS. PWM pulse generator is a main block which decided the speed of motor with the help of potentiometer. It provided the desired DC level with the help of positive voltage pulse circuit. This output along with the output of direction change logic is given to the ANDing circuit for the generation of 4 pulses. These pulses are used as gating pulses to drive the IGBT gate driver circuit.

5. Opto Isolator Circuit

When the light emitting diode driver transistor conducts then current flows through LED and LED emits light, which falls on base of optoisolator transistor. This causes base current to flow and thus collector current flows. The collector current produces drop across collector resistor. The emitter is connector to ground and voltage at collector is V_{CEsat} about 0.2 volts. This collector voltage is fed as input to base of next transistor connected in switch mode. This voltage (i.e. 0.2 V) is too small to turn on base emitter junction of next transistor, so collector is at high potential. This voltage is fed to input push pull driver circuit which drives the IGBT. When the collector voltages are high the upper transistor of diode conducts and applies high voltage to gate of IGBT and IGBT turns on.When the LED does not conduct, no light falls on base of optoisolator transistor, and then the collector of MCT 2E is at V_{CC} potential. This is fed as input to driver push pull transistor. Here the bottom transistor of push pull driver circuit conducts and this pulls the gate of IGBT low and thus the IGBT is made off.

6. IGBT Gate Driver Circuit

IGBT is a voltage controlled device and has high input capacitance of 3000 to 7000 pf between its gate and source terminal. The on state voltage across IGBT depends on gate to source voltages Vgs therefore to keep the on state voltage low relatively high positive gate to source voltage must be applied .However the voltage should not exceed breakdown voltage of the gate. Vgs should around 15V.During the off state a negative Vgs should be applied. It is about 2 to 5V.The Vgs must be applied continuously or else IGBT will be turn off. The output current of the driver circuit should be sufficient to charge and discharge the gate to source capacitance as quickly as possible. This will help in reducing Ton and Toff for IGBT. It will also reduce switching losses. The IGBT and control circuit must be electrically isolated. The wiring to the drive circuit to IGBT must be short as possible to avoid oscillations at the gate. The wires must be twisted to eliminate the effect of EMI. The drain current of IGBT must be sensed by sensing circuit. As soon as the drain current exceeds the saturation value the gate drive to the IGBT must be turned off. The gate driver circuit consist of opto-isolator along with Darlington pair which is used for the driving of the IGBT. The function of opto-isolator is to provide the isolation between the control circuitry and to control the short circuit. The Darlington connected transistors provide higher output current and lower output resistance. The advantage of using the Darlington pair is that it has very high DC current gain (β) and high collector breakdown voltage**.**

7. Soft Start Circuit

The soft start circuit here consists of a simple capacitor connected to the supply through a resistance. On power on, ‘c’ is in discharged condition and hence the level input to the comparator of LM 3524 is low and hence pulse width is zero or minimum. Gradually the capacitor goes on charging towards the level set by the speed control potentiometer and pulses of proper width are applied to the IGBT. Soft start time is about 7 to 8 seconds to the IGBT.

8. D.C. Motor

Electric motors are frequently used as the final control element in positional or speed control system. The control of the D.C motor is done with the help of IGBT based chopper circuit. The most important application of chopper is in the speed control of the d.c motor such as traction drives, steel works, used in hot strip mills. Here Permanent Magnet D.C.(PMDC) motor is used. A permanent-magnet motor does not have a field winding on the stator frame, instead relying on permanent magnets to provide the magnetic field against which the rotor field interacts to produce torque. These PMDC motor are more compact, efficient and high higher starting torque compared to wound field motors. High coercively. PATENTED magnets are used to prevent demagnetization even in conditions, which involve frequent start-stops. The specification is H.P-0.25, current =1.3A, Vdc= 180V, RPM=1500, Torque=12. [7]

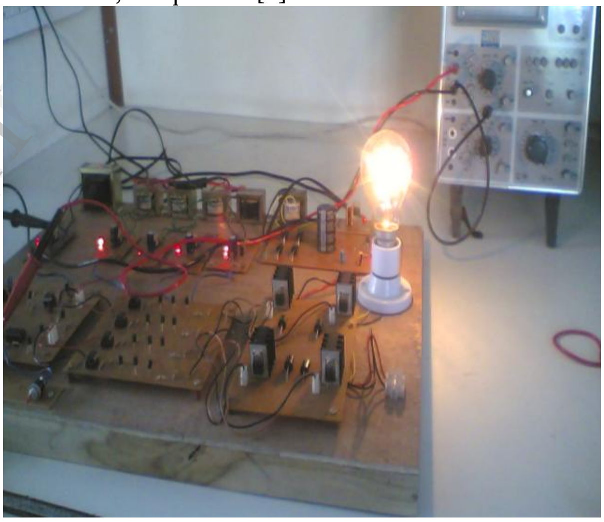

Figure 4:-DC drive with chopper fed IGBT

9. Conclusion

Thus, Power electronics becomes nowadays most dynamic field of engineering. The application of power electronics are more and more diversified and focus especially on electric power conversion i.e converters. By using modern semiconductors devices having high performance, multiple functions and with new control techniques, the structure becomes simple, size get reduced. They become cheaper & more robust. Furthermore, the conversion quality increase and disturbances against power supply networks and environment decrease.

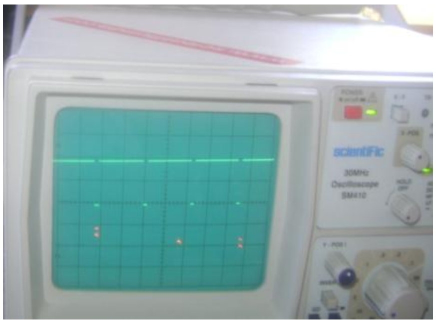

Figure 5: waveform of pulse width modulation circuits at maximum potentiometer position

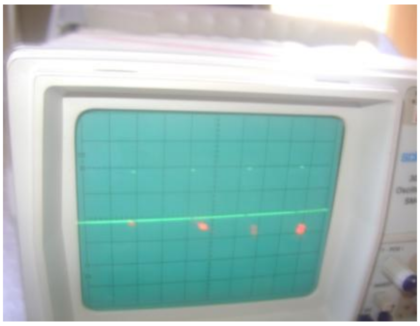

Figure 6: waveform of pulse width modulation circuits at minimum potentiometer position

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