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CONTROL SPEED OF DC MOTOR USING BJT (BIPOLAR JUNCTION TRANSISTOR) H-BRIDGE

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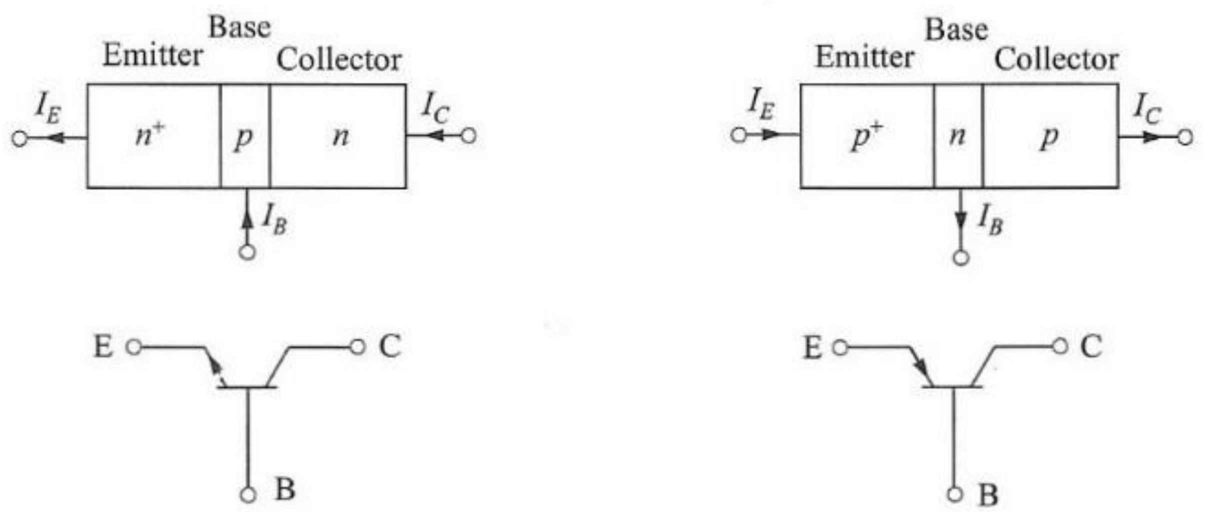
Abstract

The Bipolar Junction Transistor (BJT) when used for power switching applications operates as an IGBT. When it is conducting (BJT operating in the saturated region), a forward voltage Vf is developed between collector and emitter (in the range of 1 V). Therefore, the IGBT block can be used to model the BJT device.

The IGBT block does not simulate the gate current controlling the BJT or IGBT. The switch is controlled by a Simulink® signal (1/0). The DC motor uses the preset model (5 HP 24V 1750 rpm). It simulates a fan type load (where Load torque is proportional to square of speed). The armature mean voltage can be varied from 0 to 240 V when the duty cycle (specified in the Pulse Generator block) is varied from 0 to 100%.

The H-bridge consists of four BJT/Diode pairs (BJT simulated by IGBT models). Two transistors are switched simultaneously: Q1 and Q4 or Q2 and Q3. When Q1 and Q4 are fired, a positive voltage is applied to the motor and diodes D2-D3 operate as free-wheeling diodes when Q1 and Q4 are switched off. When Q2 and Q3 are fired, a negative voltage is applied to the motor and diodes D1-D4 operate as free-wheeling diodes when Q2 and Q3 are switched off.

BJT (Bipolar **J**unction **T**ransistor):



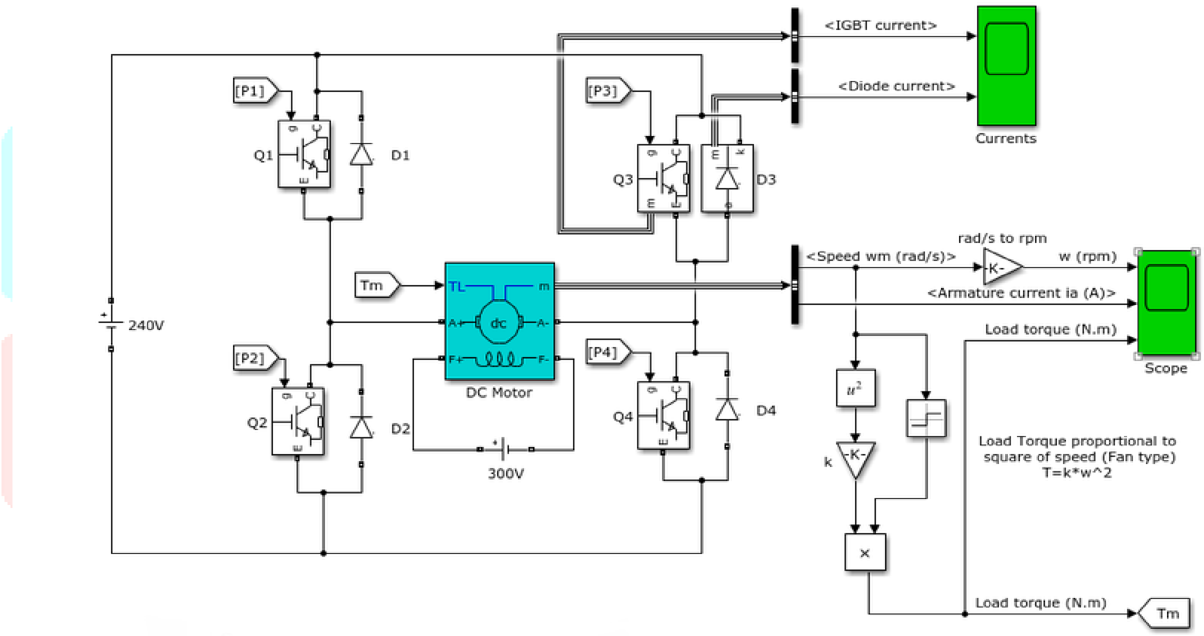
- A Bipolar Junction Transistor (BJT) is a type of transistor that uses both electrons and electron holes as charge carriers. In contrast, a unipolar transistor, such as a field-effect transistor, uses only one kind of charge carrier. A bipolar transistor allows a small current injected at one of its terminals to control a much larger current flowing between two other terminals, making the device capable of amplification or switching.

- BJTs use two junctions between two semiconductor types, n-type and p-type, which are regions in a single crystal of material. The junctions can be made in several different ways, such as changing the doping of the semiconductor material as it is grown, by depositing metal pellets to form alloy junctions, or by such methods as diffusion of n-type and p-type doping substances into the crystal.
- Bipolar transistor integrated circuits were the main active devices of a generation of mainframe and mini computers, but most computer systems now use integrated circuits relying on field effect transistors. Bipolar transistors are still used for amplification of signals, switching, and in digital circuits. Specialized types are used for high voltage switches, for radio-frequency amplifiers, or for switching heavy currents.

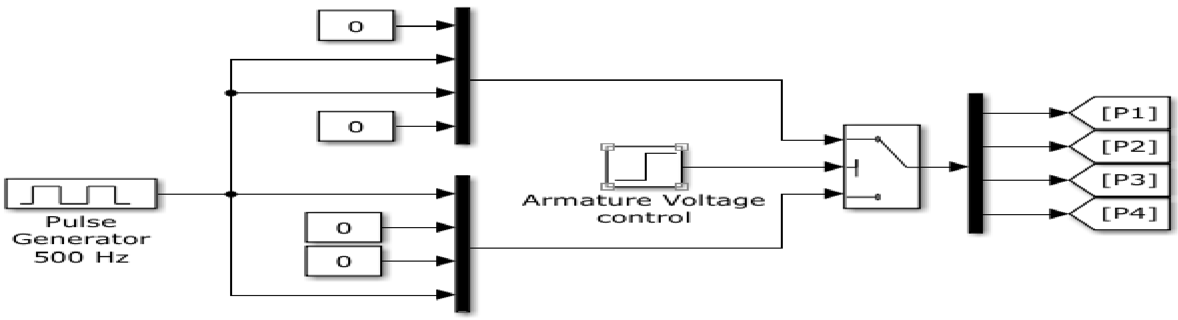
OBJECTIVES :

1. To Run MATLAB demo ‘Speed control of a DC motor using BJT H-bridge’. Modify the model such that armature current doesn’t shoot up when motor changes direction from forward to reverse.
2. Refer to help section of ‘The Four-Quadrant Chopper DC Drive (DC7) block’. Compare it with H-bridge model.
3. To Make a suitable EV model using DC7 block and make result report.
4. To Explain in a brief about operation of BLDC motor.

SIMULINK MODEL FOR SPEED CONTROL OF A DC MOTOR USING BJT H-BRIDGE



SIMULINK INPUT BLOCK



SIMULATION

- The motor starts in the positive direction with a duty cycle of 75% (mean DC voltage of 180V). At t= 0.5 sec., the armature voltage is suddenly reversed and the motor runs in the negative direction.
- 'Scope' shows motor speed, armature current and load torque and 'Currents' shows currents flowing in BJT Q3 and diode D3.

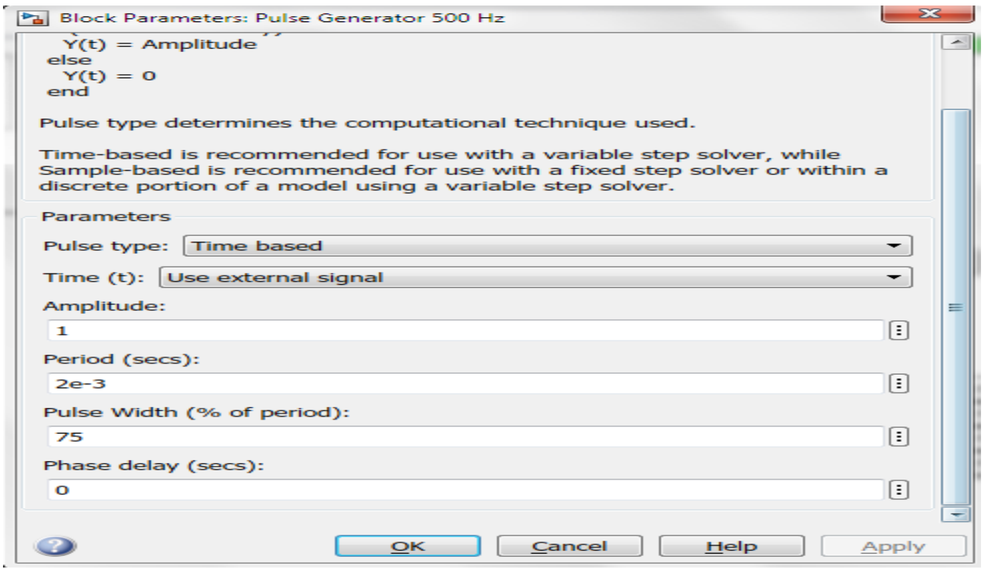
SIMULINK BLOCK EXPLANATION :

- Matlab has a inbuilt block to simulate the function of "Speed control of a DC motor using BJT H-bridge".
- When the Bipolar Junction Transistor (BJT) is used for power switching applications, then its operates as an IGBT. When it is conducting (BJT operating in the saturated region), a forward voltage Vf is developed between collector and emitter (in the range of 1 V). Therefore, the IGBT block can be used to model the BJT device.
- The IGBT block does not simulate the gate current controlling the BJT or IGBT. The switch is controlled by a Simulink® signal (1/0). DC motor uses the preset model (5 HP 24V 1750 rpm). It simulates a fan type load (where Load torque is proportional to square of speed).
- The armature mean voltage can be varied from 0 to 240 V when the duty cycle (specified in the Pulse Generator block) is varied from 0 to 100%. The H-bridge consists of four BJT/Diode pairs (BJT simulated by IGBT models).
- The armature voltage is controlled with the input of duty ratio at 500 Hz frequency and is stored as P1,P2,P3,P4 control block and it is sent as the control signal to all the IGBT switches respectively.
- The direction of the rotating motor changes with the change in the polarities of the current and it is achieved by the following, Two transistors are switched simultaneously: Q1 and Q4 or Q2 and Q3.
- When Q1 and Q4 switches are closed, a positive voltage is applied to the motor and diodes D2-D3 operate as free-wheeling diodes when Q1 and Q4 are switched off.
- When Q2 and Q3 switches are closed, a negative voltage is applied to the motor and diodes D1-D4 operate as free-wheeling diodes when Q2 and Q3 are switched off.
- When the direction of the rotating motor changes there will be a lot of stress developed in the IGBT Transistors.

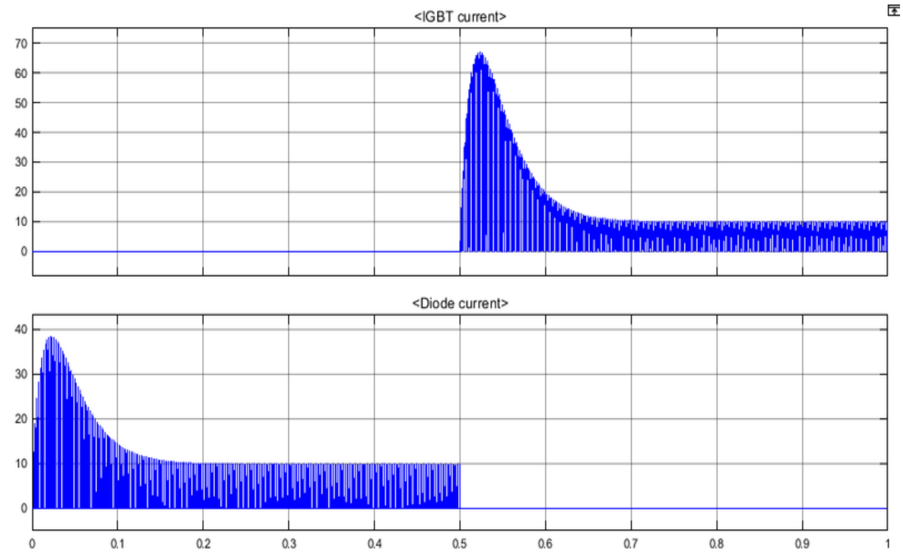
Simulation - 1 :
At Duty Cycle 75%

- One simple and easy way to control the speed of a motor is to regulate the amount of voltage across its terminals and this can be achieved using “Pulse Width Modulation”.
- For experimental section we will set the pulse width (that is refer as the duty cycle) of pulse generator block as 75% at the same time period.
- The input of the P1,P2,P3 and P4 are also changed according to the drive cycle.
- When Q1 and Q4 switch is ON the motor rotates in forward direction that state Q3 switch and Q2 switch is in OFF.
- When Q2 and Q3 switch is ON the motor rotates in reverse direction that state Q1 and Q4 switch is in OFF condition.

INPUT PULSE GENERATOR BLOCK :

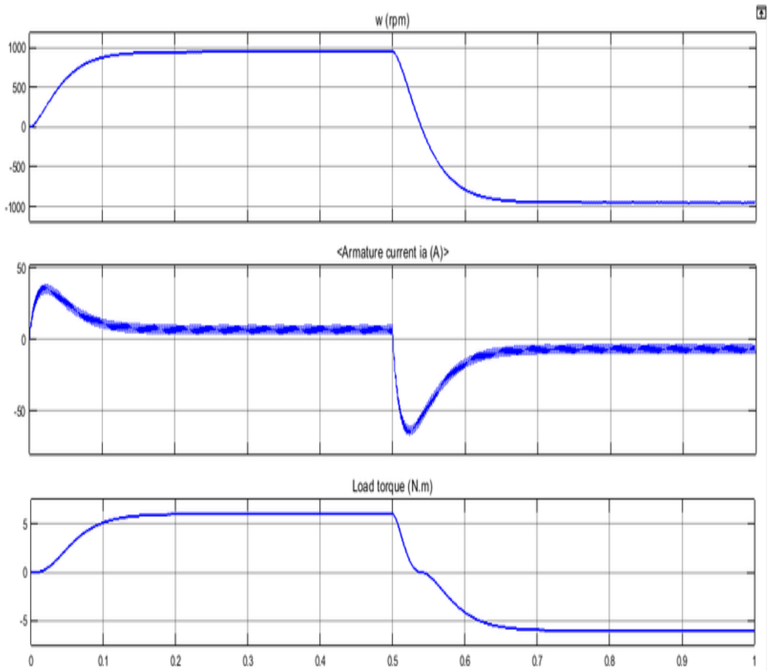


OUTPUT CURRENT PLOT



- In this current output the amount of current is acted is shown as the graphical representation during the period of duty cycle.
- This scope shows IGBT current and Diode current passed in the quadrant Q3 and D3. where Q3 is represented as IGBT current and D3 is represented as Diode current in scope.
- The switch Q3 is OFF on the starting stage of current flow and Diode current is ON on that stage.
- During the 0.5sec of time D3 switch is ON that are given according to pulse generator and after the time period of 0.5sec D3 switch is OFF. An IGBT current is acted after 0.5sec and Q3 switch remains ON

OUTPUT RESULT :



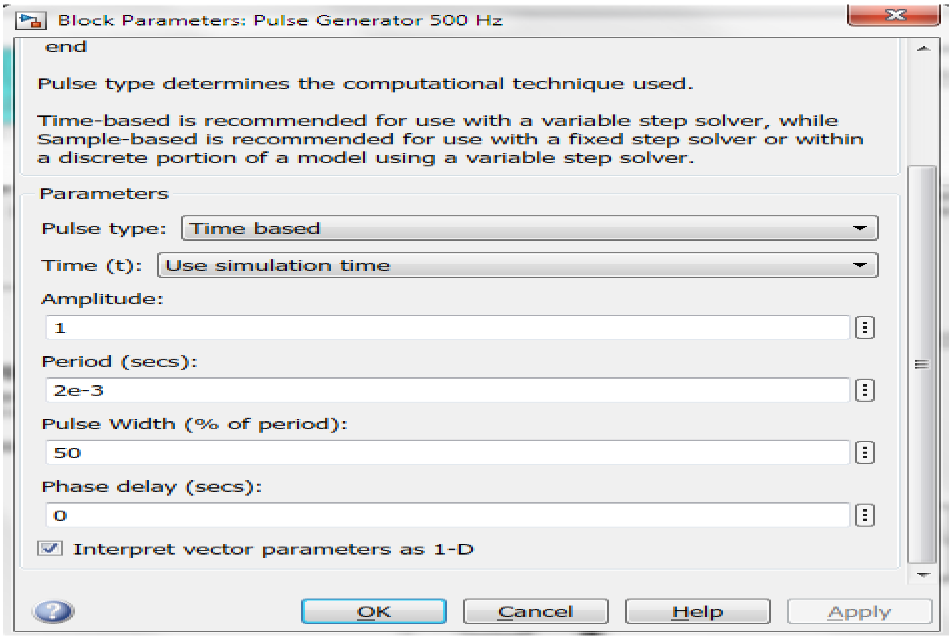
- The speed and armature current is obtained by the DC motor and load torque is calculated by Load Torque proportional to square of speed, T=k*w^2
- In starting point, there is a sudden shootup is acted.
- In this scope shows that speed is increased in certain period of time and that time armature current is in positive terminal whereas load torque also moves forward.
- After the time period of 0.5sec which is given by pulse generator sudden shoot-up is acted and speed gets decreased in that time armature current is in negative terminal whereas torque act as reverse action.
- Here the sudden shoot up is acted while the armature current is processed at a positive and negative terminal.

Simulation - 2 :

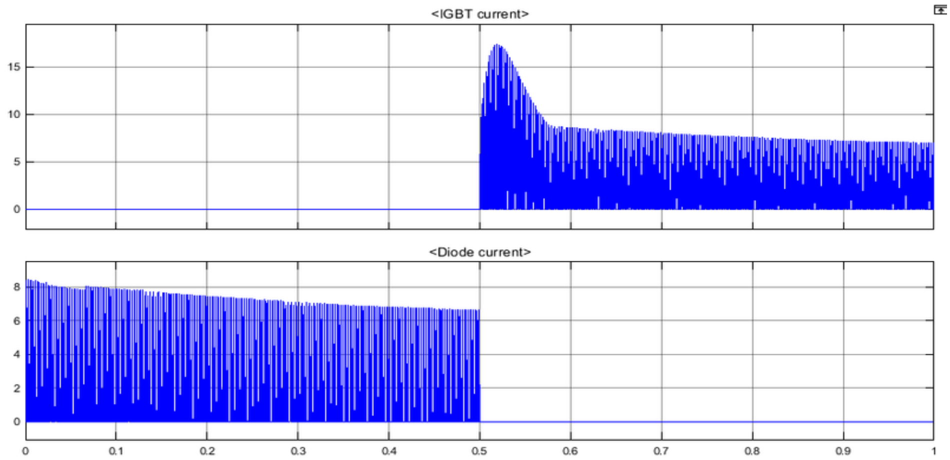
BY CHANGING THE PULSE GENERATOR INPUT VALUE (TO REDUCE THE SHOOT UP OF ARMATURE CURRENT) : At Duty Cycle 50%

- One simple and easy way to control the speed of a motor is to regulate the amount of voltage across its terminals and this can be achieved using "Pulse Width Modulation".
- For experimental section we will reduce the pulse width (that is refer as the duty cycle) of pulse generator block as 50% at the same time period.
- The input of the P1,P2,P3 and P4 are also changed according to the drive cycle.
- When Q1 and Q4 switch is ON the motor rotates in forward direction that state Q3 switch and Q2 switch is in OFF.
- When Q2 and Q3 switch is ON the motor rotates in reverse direction that state Q1 and Q4 switch is in OFF condition.

INPUT PULSE GENERATOR BLOCK



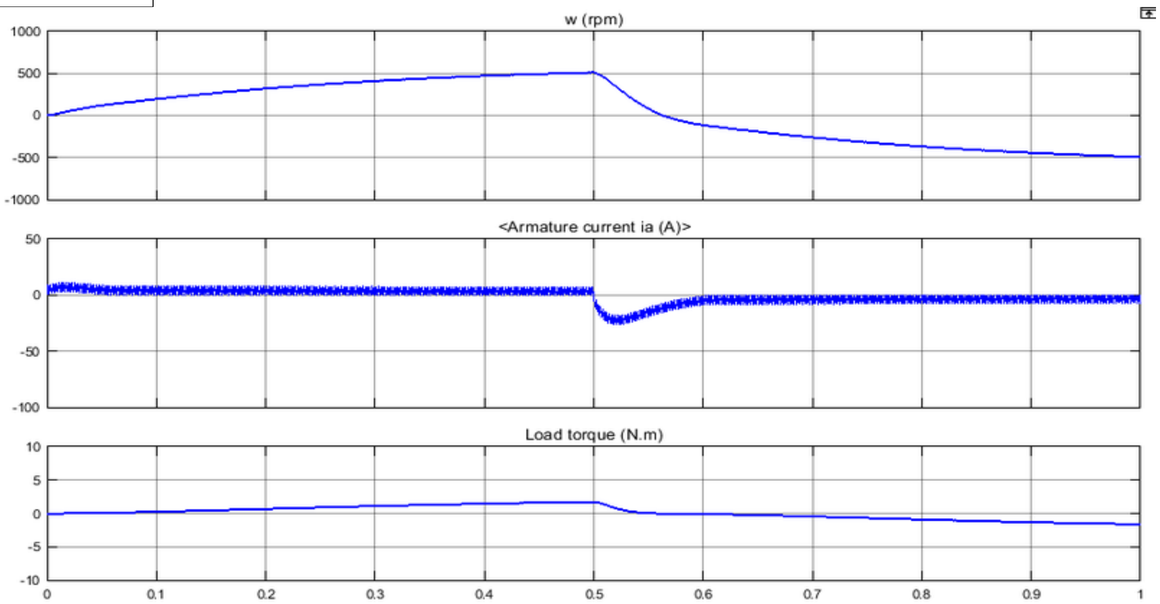
OUTPUT CURRENT PLOT :



- Here we see that the sudden shoot up is not acted by comparing with 75 of pulse width. Same cycle time is followed in this experiment also.
- In this observation a starting current is generated as diode current for time period of 0.5sec then IGBT current is acted while the diode current is being stoped.
- where Q3 is represented as IGBT current and D3 is represented as Diode current in scope. This graph shows when the switch Q3 is OFF on the starting stage of current flow and Diode current is ON on that stage.
- During the 0.5sec of time D3 switch is ON that is given according to the pulse generator and after the time period of 0.5sec D3 switch is OFF. An IGBT current is acted after 0.5sec and Q3 switch remains ON.

- There will be a little variation are shown in the graph at the starting point of current but the complete reduction of shoot up are not held here.

OUTPUT RESULT :



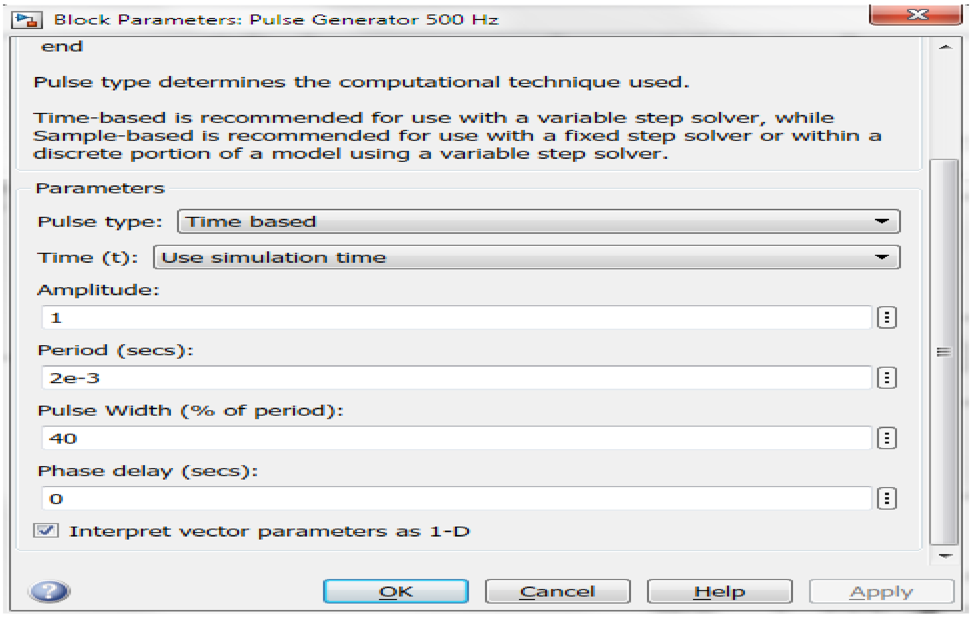
- In this above scope, a flow of armature current is displayed and speed, load torque is also displayed.
- The changes are made in pulse width as 50% from the pulse generator and results are shown that voltage fluctuation is held in starting point of forward state and reverse state.
- That sudden fluctuation is reduced in this experiment by reducing the pulse width (duty cycle of motor) of the input supply. An changes are also held in speed and load torque where the constant level of speed and torque is acted in above scope compare with 75% of pulse width.
- Time period of forward and reverse action is maintained as same as the previous duty cycle.
- In this observation the shoot up is reduced when motor changes direction from forward to reverse compared to 75 of pulse width.

Simulation - 3 :

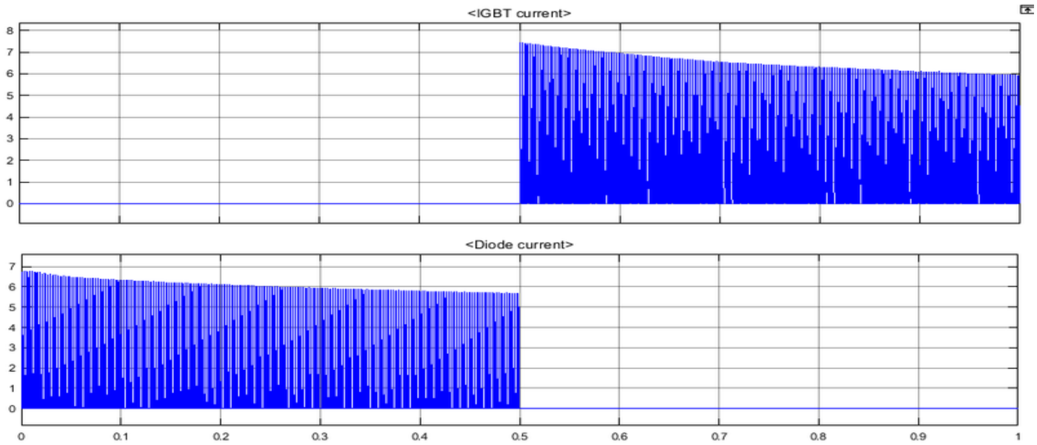
At Duty Cycle 40%

- In previous experiment there will be an reduction of shoot up(fluctuation) is observed, But we want to modify the model such that armature current doesn't shoot up when motor changes direction from forward to reverse.
- For the experimental section, we will reduce the pulse width (that is refer as the duty cycle) of pulse generator block as 40% at the same time period.
- The input of the P1,P2,P3 and P4 are also changed according to the drive cycle.
- When Q1 and Q4 switch is ON the motor rotates in forward direction that state Q3 switch and Q2 switch is in OFF.
- When Q2 and Q3 switch is ON the motor rotates in reverse direction that state Q1 and Q4 switch is in OFF condition.

INPUT PULSE GENERATOR BLOCK:

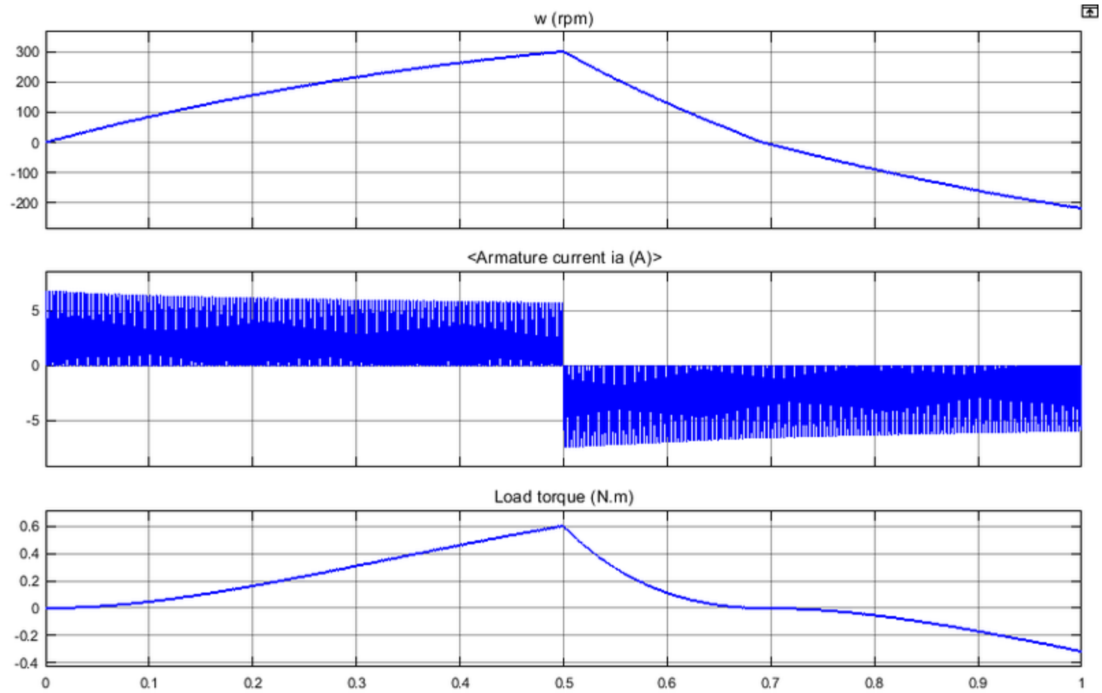


OUTPUT CURRENT PLOT :



- This graph shows that IGBT current and diode current flow from transistor Q3 and D3 after changing the pulse width(duty cycle) as 40. where Q3 is represented as IGBT current and D3 is represented as Diode current in scope.
- This graph shows when the switch Q3 is OFF on the starting stage of current flow and Diode current is ON on that stage.
- During the 0.5sec of time D3 switch is ON that are given according to pulse generator and after the time period of 0.5sec D3 switch is OFF. An IGBT current is acted after 0.5sec and Q3 switch remains ON.
- The flow of current is not much varied in IGBT current and Diode current when we compared it with 75 of pulse width. The shoot up(fluctuation) is less in this duty cycle when motor changes direction from forward to reverse

OUTPUT RESULT:



- In this above scope a flow of armature current is displayed and speed, load torque are also displayed.
- From the above experiments shows that shoot up (voltage fluctuation) doesn't appear while we reducing the pulse width (duty cycle) in pulse generator. But raise in fluctuation of armature current is not completely acted during motor changes direction from forward to reverse. Because starting point of current is raised during forward and reverse direction of motor. voltage fluctuation is acted on that point.
- Time period of forward and reverse action is maintained as same as the previous duty cycle.
- By the reduction of duty cycle(pulse width)as 40 we observed that armature current doesn't shoot up when motor changes direction from forward to reverse.
- The constant flow of armature current is observed in this experiment during motor changes direction forward to reverse.
- Therefore the shoot up is completely minimized by this Pulse Width Modulation method.

CONCLUSION :

MATLAB demo 'Speed control of a DC motor using BJT H-bridge' is simulated And the model is modified in such a way that armature current doesn't shoot up when motor changes direction from forward to reverse.

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[5].Bipolar Junction Transistor and Their Applications Sayed Tathir Abbas Naqvia * , Charanjeet Singha , Kamal Kumar Sharma *Research scholar, aSchool of Electronics and Electrical Engineering, Lovely Professional University, Jalandhar-Punjab, India.