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Chopper Based Speed Control of DC Motor

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Abstract: **The DC motor is an attractive piece of equipment in many industrial applications requiring variable speed and load characteristics due to its ease of controllability. The "Chopper drive" based speed controlling method is superior in comparison to "Thyristor Controlled Bridge Rectifier" method as far as DC motor speed controlling is concerned. Microcontroller based controlling is adopted to retain simplicity & ease of implementation. This paper is written with the objective of illustrating how the speed of a DC motor can be controlled using a chopper drive. It further explains the methodology used in obtaining the required signal generation to drive the chopper. An Open-loop Control System adopted brings the motor to the speed set by the user irrespective of the load. This drive also providing functions like Start, Stop, Forward braking, reverses braking, increased and decreased speed of motor.**

Keyword: **Chopper, DC motor, Microcontroller 8051, MOSFET.**

I. INTRODUCTION

Standard motors are classified as either constant speed or adjustable speed motors. Adjustable speed motors may be operated over a wide speed range by controlling armature voltage and/or field excitation. The speed below the base speed can be controlled by armature voltage control method and field control method is used for speeds above the base speed.

For the last forty years, the development of various solid state switching devices in the thyristor families along with variety of different digital chips in control/firing circuits has made an impact in the area of DC drive. These power electronic (solid state) controllers are of two types:

1. Thyristor bridge rectifier (Converters) supply from ac supply.
2. Chopper Drives fed from DC supply.

The Chopper Driver method has the following advantages over Thyristor Bridge Rectifiers method:

1. Quick Response
2. Flexibility in control
3. High energy efficiency
4. Light weight & compact control unit.
5. Less ripples in the armature current.
6. Ability to control down to very low speeds.
7. Less amount of machine losses due to less ripple in armature current
8. Small discontinuous conduction region in the Speed-Torque plane.
9. Small discontinuous conduction region improves the speed regulation and transient response of the drive.

II. AIM AND OBJECTIVE

The aim of our project is to design and implementation of chopper based DC motor drive. The project is carried out by following objectives:

1. Simulation of all four quadrant operation of chopper using MATLAB Simulink.
2. Hardware implementation of chopper drive with protection of Commutation problem.
3. Hardware implementation of micro-controller card.(with IC P89V51RD2)
4. Complete hardware to control speed of brushed DC motor with working in all four quadrant operation.
5. Motor can be work with 1% duty cycle to 99% duty cycle accurately and smoothly by PWM technique.

III. COMPLETE BLOCK DIAGRAM

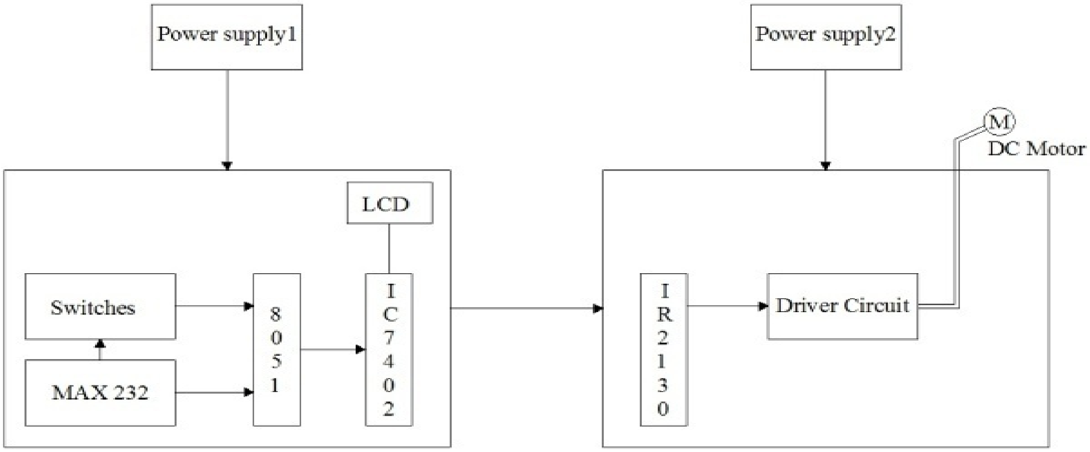

Fig.1 Schematic diagram of hardware set up

One is microcontroller card which include switches for Start, Stop, Forward braking, reverse braking, Increasing the speed and decreasing the speed. Also it includes MAX 232 IC to transfer controller data from Controller P89V51RD2 to the PC. IC 7402 contain four NOR gate by which we can make two OR gate for PWM comparison for upper MOSFETs used in driver card. For driver circuit, four MOSFETs are used with two legs, each leg has one upper and one lower MOSFET. LCD is of type 16×2 to display speed of the motor and also duty cycle. Special IC IR2130 provide certain protections for driver circuit.

IV. SPECIFICATION OF DRIVE

Rating of MOSFET STP80NF55 is 55 V, 80 A. With this drive it able to control the DC motor up to rating of 4.4 KW. For upper rating than 4.4 KW, MOSFET with higher ratings be employed with heat sink employed to each MOSFET individually. Transformer ratings are 230 V(prim)/12 V(sec). Two power supplies are provided for providing isolation between driver card and micro-controller card.

A. Driver Card Design Circuits

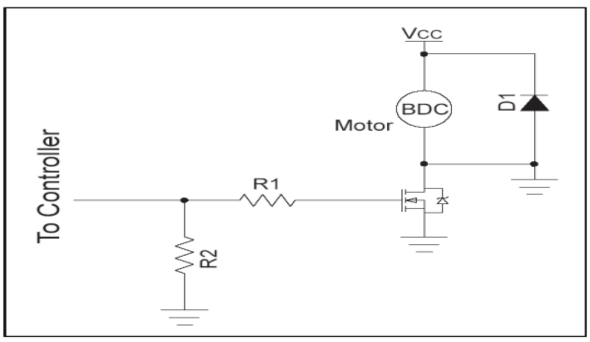

Fig.2 high side driver circuit

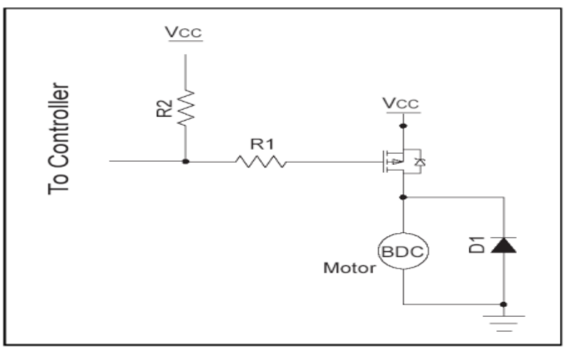

Fig.3 low side driver circuit

For fig. 2 and fig. 3, which see the position of resistors and how controller is connected while individual MOSFET will be

ON. As in fig. 1 the IC IR2130 gives special functions for this drive. These are:

1. When MOSFETs of same leg is in ON mode, It stops to given supply voltage to MOSFETs and Fault LED will glow.
2. If boot strap capacitor is not charged to 10 V or in operation goes below 10 V, Stop working and Fault LED will glow.
3. It provides 20ms delay between each operation to avoid commutation.
4. As in inner construction it consists npn- and pnp- transistors, upper MOSFET can be turn off easily even without ground terminal connect with it.

V. SIMULATION CIRCUITS AND WAVEFORMS FOR DIFFERENT QUADRANTS

A. Simulation for First and Second Quadrant

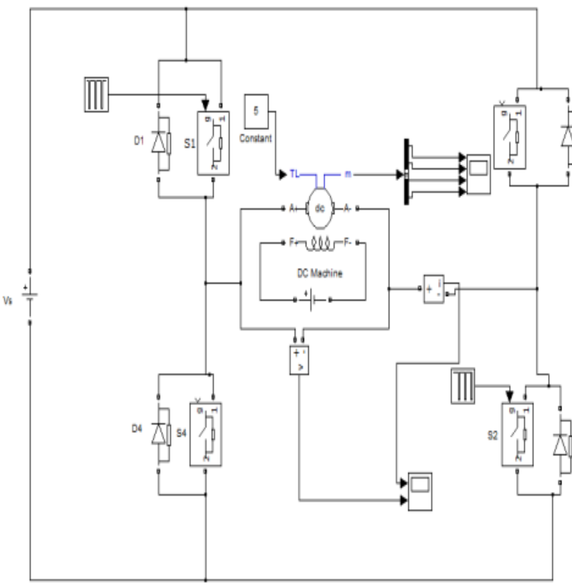

Fig. 4 Simulation for First and Second quadrants

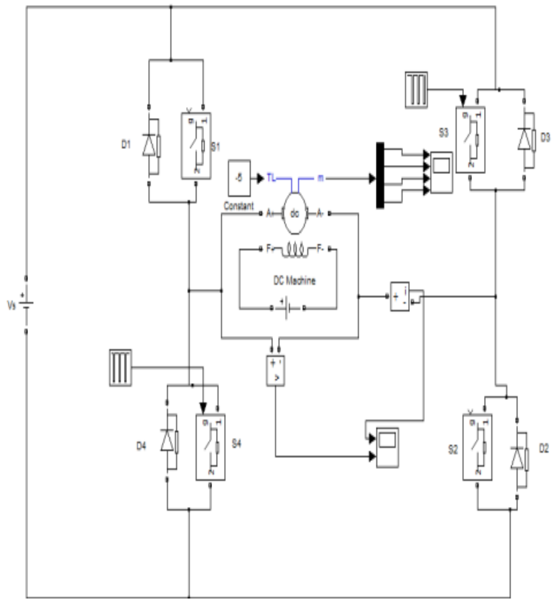

Fig. 5 Simulation for Third and Four quadrants

B. Simulation Results for all Four Quadrants

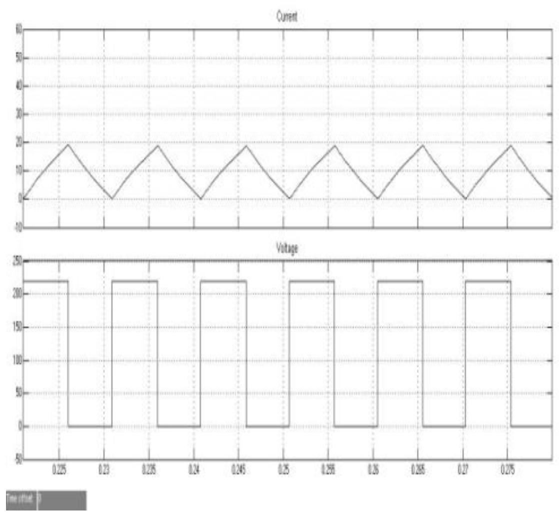

Fig. 6 Current and Voltage waveform for First Quadrant

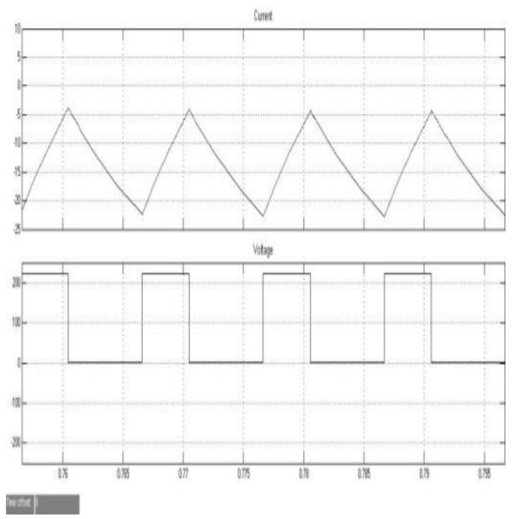

Fig. 7 Current and Voltage waveform for Second Quadrant

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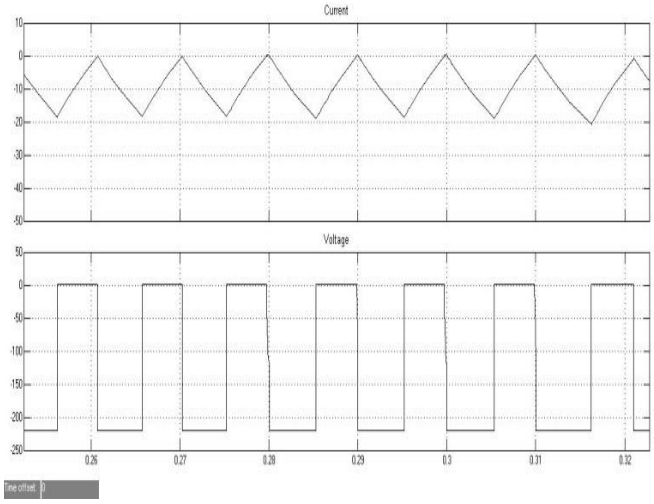

Fig. 8 Current and Voltage waveform for Third Quadrant

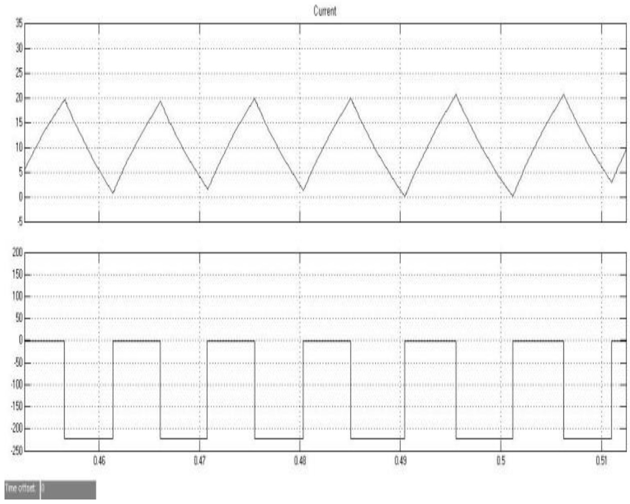

Fig. 9 Current and Voltage waveform for fourth Quadrant

From fig. 6, current and voltage both waveforms are laid in positive value as in theoretical fundamentals of Chopper. From fig. 7, current is negative and voltage is positive which is also as need as in theoretical. From fig. 8, current and voltage both are negative which represent third quadrant operation and fig. 9. Current is positive and voltage is negative which represents fourth quadrant operation. All four results for simulation are as identical as theoretical.

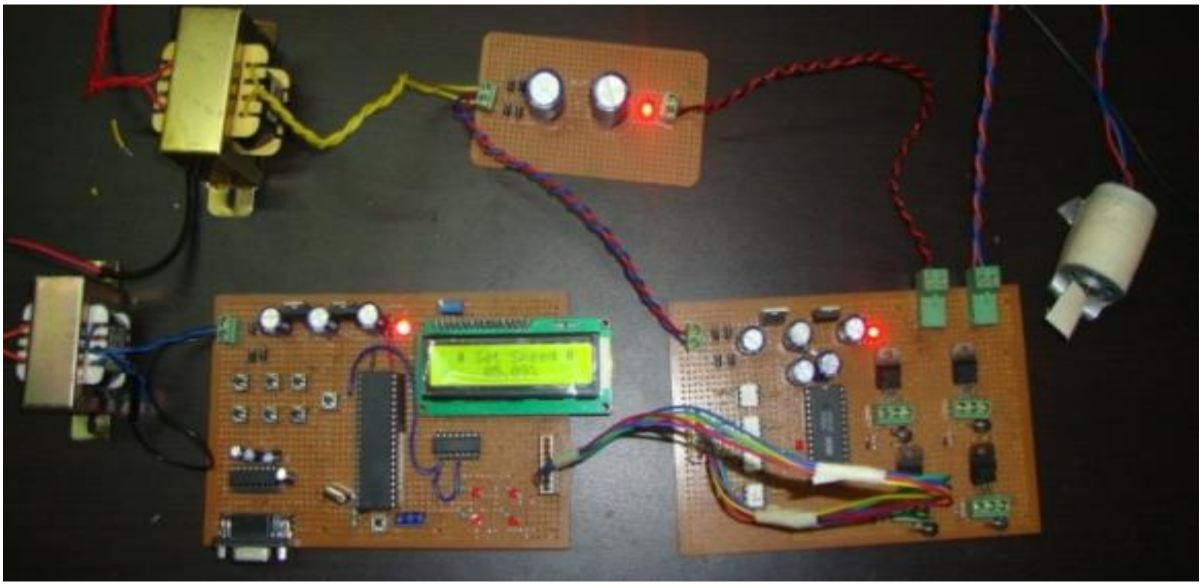

Fig. 10 Hardware Set-up

VI. HARDWARE IMPLEMENT AND VOLTAGE WAVEFORMS FOR DIFFERENT DUTY CYCLES

Fig. 10 is for micro-controller P89V81RD2 (8051) design with switches to perform operation like Start, Stop etc. as discuss earlier. Initially speed is set to be 50% duty cycle means half of the full speed in operated at starting. According to the Switches operation, speed can be increased or decreased as require condition at a particular time. Four LED are put in this card to know the position of MOSFETs with which MOSFET running and which are not. Driver card designed with IC IR2130 and opto-coupler MCT2E for isolation between driver card and micro-controller card. MOSFET STP80NF55 are used as a switch. Four MOSFETs are used here as shown in fig.10. It is overall hardware of this project. For simplicity only this small rating motor is used. This drive is capable of driving DC motor up to 4.4KW rating with extra heat sink providing to each MOSFET. At this particular time to operate motor with higher than 4.4KW, transformer rating will be change and also MOSFETs require with higher ratings. So by changing rating of motor, only supply is changed and higher range MOSFETs are selected.

A. Voltage Wavefroms for Duty Cycles

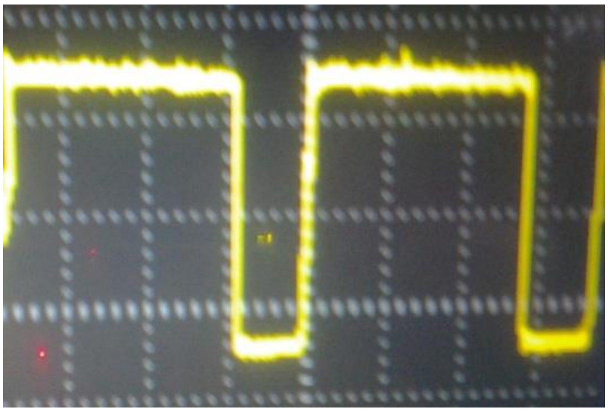

Fig. 11 80% duty cycle **Fig.12** 50% duty cycle

By taking different voltage waveforms for different duty cycles, speed also varying according to the duty cycle. In fig 11and fig. 12, we observe some distortion present in voltage waveform across the motor, it is due to the back emf present in the motor. Here from the above waveforms, we can conclude that back emf of motor is directly proportional to the speed of the motor.

VII. APPLICATION

When motor is working in normal condition with positive current and voltage, it operates in first quadrant. To stop the motor instantly from running condition, it shifted to fourth quadrant. When motor running with negative current and voltage, e.g. train runs on steeply region, third quadrant mode is achieved. While during this condition to stop the motor instantly, second quadrant is obtained when voltage is positive and current is negative. Hoist application and traction are widely used this application.

VIII. CONCLUSION

The speed of DC motor has been successfully controlled by using chopper as a converter. In simulation, all four quadrant operation of the chopper is done in MATLAB Simulink. The results also similar to the identical. In hardware design of drive, using microcontroller 8051 and pulse width modulation scheme desired speed of the DC motor is achieved easily. All operation of motor like Start, Stop, Forward braking, Reverse Braking, Increasing the speed and also Decreasing the speed is also achieved.

The motor can be run as low as 2% to as high as 98% of the duty cycle. Program interface is user friendly enabling flexible and simple operation. Since we control the average armature voltage, speed could be control only below the rated speed.

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