International Journal of Scientific Research & Engineering Trends
Volume 5, Issue4, July-Aug-2019, ISSN (Online): 2395-566X

Enhancement of Performance Speed Control of DC Motor Using Chopper

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Abstract **- The speed of separately excited DC motor can be controlled from below and up to rated speed using chopper as a converter. The chopper firing circuit receives signal from controller and then chopper gives variable voltage to the armature of the motor for achieving desired speed. There are two control loops, one for controlling current and another for speed. The controller used is Proportional-Integral type which removes the delay and provides fast control. Modeling of separately excited DC motor is done. The complete layout of DC drive mechanism is obtained. The designing of current and speed controller is carried out. The optimization of speed controller is done using modulus hugging approach, in order to get stable and fast control of DC motor. After obtaining the complete model of DC drive system, the model is simulated using MATLAB(SIMULINK).The simulation of DC motor drive is done and analyzed under varying speed and varying load torque conditions like rated speed and load torque, half the rated load torque and speed, step speed and load torque and stair case load torque and speed.**

Keywords- **chopper circuit, four quadrant control, DC motors, control loops, MATLAB (SIMULINK).**

I. INTRODUCATION

Four Quadrant DC motor are extremely used in adjustable speed drive and position control application. Their speeds below the base speed can be controlled by armature-voltage control. Speeds above the base speed are obtained by field-flux control. As speed control method for DC motors are simpler and less expensive than those for the AC motors, DC motors are preferred where wide speed range control is required. DC choppers also provide variable dc output voltage from a fixed dc input voltage.

Chopper circuit are operate in four quadrant ie. Forward Motoring, Forward Braking, and Reverse Motoring and Reverse braking. This type of chopper is widely use in reversible motor drive. Insulated Gate Bipolar transistor is combination of Bipolar Junction Transistor (BJT's) and Metal Oxide Semiconductor Field Effect Transistor (MOSFET's). It carries positive attributes of BJT's and MOSFT's. Four Quadrant Chopper is used for conversion of fixed DC into variable DC.

Operation of four quadrant chopper is shown in figure1. In the first quadrant operation power can be flow from source to load and hence, current and voltage in the first quadrant are assumed to be positive. Similarly, in second quadrant operation voltage remain positive but change in direction of current ie. negative this condition happened when load is inductive such as a DC motor in third quadrant operation current and the voltage are both in negative but the power is positive. Similarly in four quadrant operation current is positive and voltage is negative and therefore power is negative which is shown in figure1.
At the first quadrant current and voltage are positive then the motor can rotate in the forward direction ie. Forward

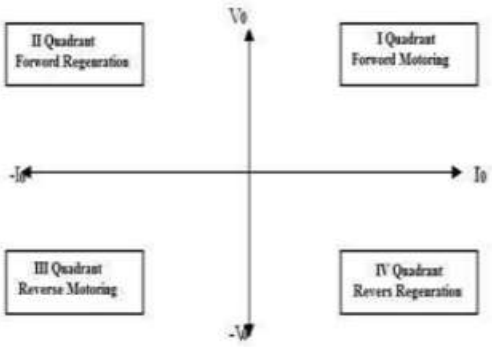

Fig. 1 Basic operation of Four quadrant chopper.

Motoring. If the polarity of armature current and armature voltage changing then the motor can operated as reveres motoring ie. (III Quadrant) and when direction of energy is reveres in II and IV Quadrant the motor can operated as a generator braking. The chopper will give the facility of regenerative braking. The regenerative braking is Four quadrant chopper circuit Four quadrant operations can be carried out by the four switching devices with the diode connected in anti-parallel with switching diode, the motor is connected between the two arm A and B.

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1. **First Quadrant-** When the supply is given to the circuit the T1 and T4 is ON, current flowing through the path,(Vdc+) -T1 – Load (A-B) -T4 –(Vdc-).hence both current and voltage are positive. During this condition the inductance get charge by positive polarity. The first quadrant operation can be achieved
2. **Second Quadrant:-** During third quadrant operation inductor get fully charge it find path to get discharge during discharge the energy can dissipated through Load(B) –D1 – (Vdc+) –(Vdc-) –D4 –Load(A) since the voltage is positive and current is negative and second quadrant operation can be achieved.
3. **Third Quadrant;-** When T2 and T3 are turned-on current start to flow through path (Vdc+) –T3 –Load (B-A) –T2 – (Vdc-),the current and voltage are negative. the second quadrant operation can be achieved. the inductor get charge again with the same polarity.
4. **Fourth Quadrant:-** During first quadrant operation inductor get fully changed it will find the path to discharge for that inductor change the polarity and get discharge through path Load(B) -D3 –(Vdc+) –(Vdc -) – D2 – Load(A) in that case voltage negative and current is positive the fourth quadrant operation can be achieved.

If we consider the power in the electrical system is given below Po= Vo * Io (1) Where, Po=Output power in the circuit Vo=Output voltage Io= Output current This gives the result that the system can allow the power flow in both direction while reversing the current and changing the polarity of the voltage, that way motor operated in both direction. The switches in the four quadrant chopper can be switched in two different modes:

- The output voltage swings in both directions i.e. from +Vdc to -Vdc. This mode of switching is referred to as PWM with bipolar voltage switching.
- The output voltage swings either from zero to +Vdc or zero to -Vdc. This mode of switching is referred to as PWM with uni polar voltage switching.

II. DIFFERENT METHODS FOR SPEED CONTROL OF DC MOTOR

Traditional armature voltage control method using rheostat method for low power DC motors.

- Use of Pulse Width Modulation Techniques.
- Neural Network Controllers.
- Constant power motor field weakening controller based on load-adaptive multi-input multi-output linearization technique (for high speed regimes).
- Single phase uniform PWM AC-DC buck-boost converter with only one switching device used for armature voltage control.
- Using NARMA-L2 (Non-linear Auto-regressive Moving Average) controller for the constant torque region.

III. PRINCIPLE OF CHOPPER OPERATION

The chopper is a convertor which is controlled commutation convertor. The chopper use is to provide with extinguishing auxiliary circuit or completely controlled device in four thyristors. This device called as controlled commutation convertor because of the any device control is much these device both time i.e. entrance time and for blocking their conduction is achieved only at well-defined point in time. In adjustable speed drive and position control application for four quadrant DC motor are mostly used. The speed of base speed of DC motor can be controlled their speeds will be decrease by armature voltage control. The base speed of DC motor can be increase by field flux control. As speed control of AC motor is not a good because of are simper and less costly. For DC motor of speed control method. The use of DC motor where more speed range control will be required. DC chopper also provided for conversion variable DC output voltage from fixed DC input voltage. The forward motoring, forward breaking, reverse motoring and reverse breaking this are four quadrant and this quadrant chopper circuit will be operated the application of this type of chopper in reversible motor drive Classification of Chopper may be classified as following 1. On basis of input and output voltage level

1. Step-down chopper

- Class A
- Class B
- Class C
- Class D
- Class E

2. Step-up chopper

- Class B 2. On basis of circuit operation:
- First quadrant
- Second quadrant
- Four quadrant 3. On basis of commutation method
- Voltage commutation
- Current commutation
- Load commutation
- Impulse commutation

A chopper is a static power electronic device which converts fixed dc input voltage to a variable dc output voltage. It can be step up or step down. It is also considered as a dc equivalent of an ac transformer since they behave in an identical manner. Due to its one stage conversion, choppers are more efficient and are now being used all over the world for rapid transit systems, in marine hoist, in trolley cars, in mine haulers and in forklift trucks etc. The future electric automobiles are likely to use choppers for their speed control and braking.

Chopper systems offer smooth control, high efficiency, faster response and regeneration facility. The power semiconductor devices used for a chopper circuit can be force commutated thyristor, BJT, MOSFET, IGBT and GTO. Among above switches IGBT and GTO are widely used. These devices are

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generally represented by a switch. When the switch is OFF, no current will flow. Current flows through the load when switch is ON. The power semiconductor devices have on-state voltage drop of 0.5V to 2.5V across them. For the sake of simplicity, this voltage drop across these devices is generally neglected. In current-limit control scheme, the switching of chopper circuit is decided by the previous set values of load current. The two set values should be maximum load current and minimum load current. When the load current reaches the value more than maximum value of load current then chopper is switched off and it falls below minimum value, the chopper is switched on. Here Switching frequency of chopper is controlled by setting maximum and minimum level of current. Current limit control also involves feedback loop and therefore the trigger circuit for the chopper becomes more complex .PWM technique is the most common control strategy for the power control in chopper circuit. AC drives with this capability would be more complex and expensive.

Properly applied brush and maintenance of commentator is minimal. DC motors are capable of providing starting and accelerating torques in excess of 400% of rated. Separately excited DC drives have been used for variable speed applications for many decades and historically was the first choice for speed control applications requiring accurate, speed control, controllable torque, reliability and simplicity. The basic principle of a DC variable speed drive is that the speed of a separately excited DC motor is directly proportional to the voltage applied to the armature of DC motor. The main changes over the years have been concerned with the different methods of generating the variable DC voltage from the 3- phase AC supply.

In case of WARD-LEONARD SYSTEM, the output voltage of the DC generator, which is adjusted by controlling the field voltage, is used to control the speed of the DC motor. This type of variable speed drives had good speed and torque characteristics and could achieve a speed range of 25:1. It is no longer commonly used because of high cost of 3 separate rotating machines. In addition, the system requires considerable maintenance to keep the brushes and commutators of the DC machines in good condition maintenance to keep the brushes and commutators of the DC machines in good condition. [2]

IV. ROLL OF CONTROLLER TO CHOPPER PERFORMANCE

The controller used in a closed loop model of DC motor provides a very easy and common technique of keeping motor speed at any desired set-point speed under changing load conditions. This controller can also be used to keep the speed at the set-point value when the set-point is ramping up or down at a defined rate. In this closed loop speed controller, a voltage signal obtained from a Tacho-generator attached to the rotor which is proportional to the motor speed is fed back to the input where signal is subtracted from the set-point speed to produce an error signal. This error signal is then fed to controller to make the motor run at the desired set-point speed. If the error speed is negative, this means the motor is running slow so that the controller output should be increased and vice-versa. There are different types of controller available and its selection is also an important work. Some of the controllers which are most widely used are – on–off controller, proportional controller, integral controller, and derivative controller and PID controller. In 7 proportional controller error speed is proportional to the measured output. This controller has the limited use and can never force the motor to run exactly at the set point speed.

Therefore an improvement is required for correction in the output. In PI controller, the proportional term does the job of fast correction and the integral term takes finite time to act and makes the steady state error zero. In derivative approach further refinement is done. This controller will allow the rate of change of error speed to apply an additional correction to the output drive. It can be used to give a very fast response to sudden changes in motor speed. In simple PID controllers it becomes difficult to generate a derivative term in the output that has any significant effect on motor speed. It can be deployed to reduce the rapid speed oscillation caused by high proportional gain. However, in many controllers, it is not used. The derivative action causes the noise (random error) in the main signal to be amplified and reflected in the controller output. Hence the most suitable controller for speed control is PI type controller.

V. METHODOLOGY MODELLING OF DC MOTOR FOR DRIVE SYSTEM

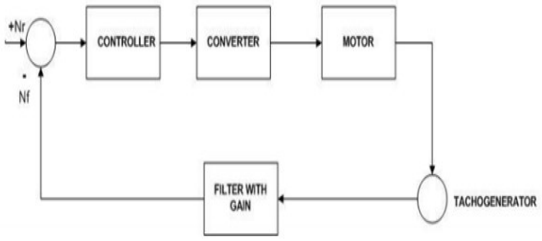

Fig. 2 Closed loop model for speed control of dc motor.

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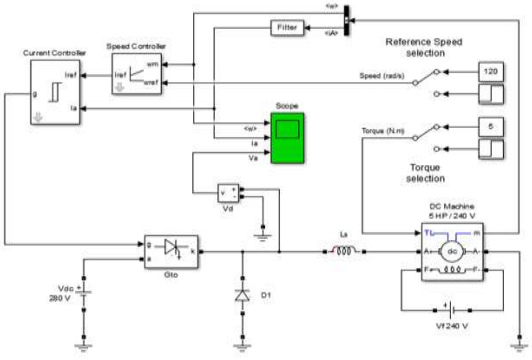

Fig. 3 Modeling of motor control.

It used as switching device because it has High-current handling capability like BJT, Ease of control of a MOSFET, can withstand High-voltage applications and Operation at high junction temperature is allowed (>100°C).Fixed frequency operation i.e. pulse width modulation technique is used under Time Ratio control. PWM technique is used as the power loss in the switching devices is very low. When switch is off there is practically no current and when it is on, there is almost no voltage drop across the switch, power loss being the product of voltage and current, in thus both cases close to zero. It also works well with digital control. Now Chopper provides variable voltage across the armature of separately excited DC motor due to which speed of the motor changes.

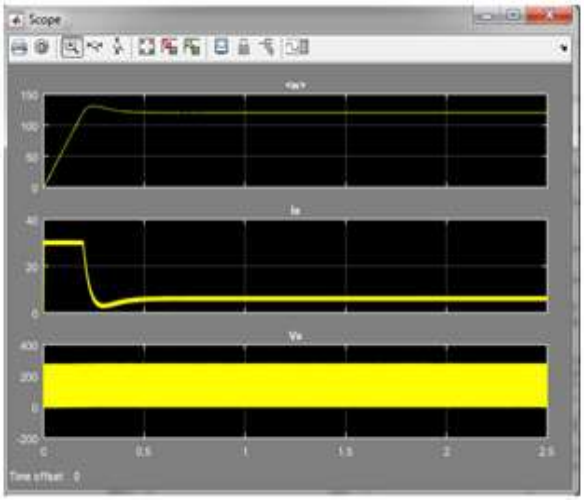

Fig. 4 Output waveforms.

VI. CONCLUSION

The speed of a dc motor has been successfully controlled by using Chopper as a converter and Proportional-Integral type Speed and Current controller based on the closed loop model of DC motor. Initially a simplified closed loop model for speed control of DC motor is considered and requirement of current controller is studied. Then a generalized modelling of dc motor is done. After that a complete layout of DC drive system is obtained. Then designing of current and speed controller is done. Now the simulation is done in MATLAB under varying load condition, varying reference speed condition and varying input voltage. The results are also studied and analyzed under above mentioned conditions. The model shows good results under all conditions employed during simulation. Since, the simulation of speed control of DC motor has been done. We can also implement it in hardware to observe actual feasibility. Here speed control of DC motor is done for rated and below rated speed. We

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can also control the speed of DC motor above rated speed and this can be done by field flux control.

VII. FUTURE SCOPE

The speed of the motor has been varied successfully in an open loop manner in accordance with the change in duty ratio. Future scope is to control the speed of the motor in a closed loop manner by taking a feedback from the taco generator and giving it as a feedback to the DSP. Where in the DSP, it compares the desired value and the actual value and gives an error voltage which is given to the motor through an interface circuit. In this manner, the speed of the motor can be controlled as per the user.

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