

Speed Control of D.C. MOTOR Using Chopper

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Abstract: This paper deals with speed control of separately excited DC motor control in a high performance manner. There are four different parts of control of DC motors used in this project. Using chopper as a converter the speed of DC motor is controllable. The chopper firing circuit gets signal from controller and then by supplying variable voltage to the armature of the motor the desired speed chopper is achieved. There are two different types of control loops, current controller and speed controller. The controller used is Proportional-Integral type. Using this controller the delay is removed and fast control is achieved. Separately excited DC motor is designed. The current and speed controller is designed and in order to get stable and high speed control of DC motor. The simulation of model is done and analyzed in MATLAB (Simulink) under varying speed and torque condition.

Keywords: chopper circuit, DC motors, open and closed loops, MATLAB (SIMULINK).

1. INTRODUCTION

An electrical drive consists of electric motors, power controller and energy transmitting shaft. In modern electric drive system power electronic converters are used as power controller. Electric drives are mainly of two types: DC drives and AC drives. They differ from each other in this way that the power supply in DC drives is provided by DC motor and power supply in AC drives is provided by AC motor. DC drives are widely used in applications requiring adjustable speed control, frequent starting, good speed regulation, braking and reversing. Some important applications are paper mills, rolling mills, mine winders, hoists, printing presses, machine tools, traction, textile mills, excavators and cranes.. For industrial applications development of high performance motor drives are very essential. DC drives are less costly and less complex than AC drives. DC motors are used extensively in adjustable speed drives and position control system. The speed of DC motors can be adjusted above or below rated speed. Their speed above rated speed are controlled by field flux control and speed below rated speed is controlled by armature voltage. DC motors are widely used in industry because of its low cost, less complex control structure and wide range of speed and torque. There are various methods of speed control of DC drives – armature voltage control, field flux control and armature resistance control. For controlling the speed and current of DC motor, speed and current controllers are used. The main work of controller is to minimize the error and the error is calculated by comparing output value with the set point. This paper mainly deals with controlling DC motor speed using Chopper as power converter and PI as speed and current controller.

2. INTRODUCTION TO CHOPPERS

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. 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 generally represented by a switch. When the switch is OFF, no current will flow. Current flows through the load when switch is ON.

A chopper is a "on" or "off" semiconductor switch which is so high in speed. It connects source to load and disconnect the load from source at a fast speed. As shown in Fig1. During the period T_{on} , chopper is on and load voltage is equal to

source voltage V_s . During the period T_{off} , load voltage is zero and chopper is off. In this manner, a chopped dc voltage is produced at the load terminals

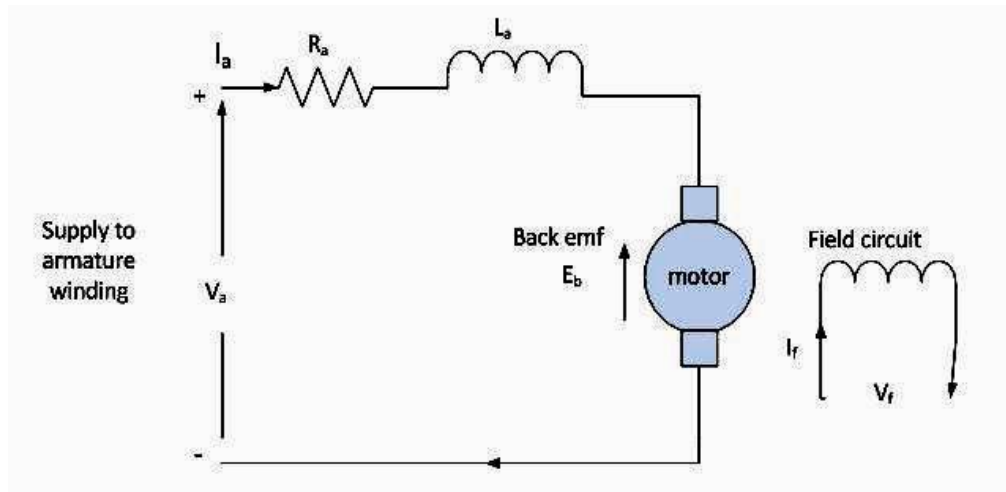


Figure 1. Chopper circuit and voltage and current waveforms

Average Voltage,

$$V_o = (T_{on} / (T_{on} + T_{off})) * V_s \quad (1)$$

$$= (T_{on} / T) * V_s$$

$$= a V_s$$

T_{on} =on-time.

T_{off} =off-time.

$T = T_{on} + T_{off}$ = Chopping period.

$a = T_{on} / T_{off}$.

3. INTRODUCTION TO SEPARATELY EXCITED D.C.MOTOR

Separately excited dc motor has field and armature winding with separate supply voltage. Field winding supplies field flux to armature. When DC voltage is applied to motor, current is fed to the armature winding through brushes and commutator. Since rotor is placed in magnetic field and it is carrying current also. So motor will develops a back emf and a torque to balance load torque at particular speed.

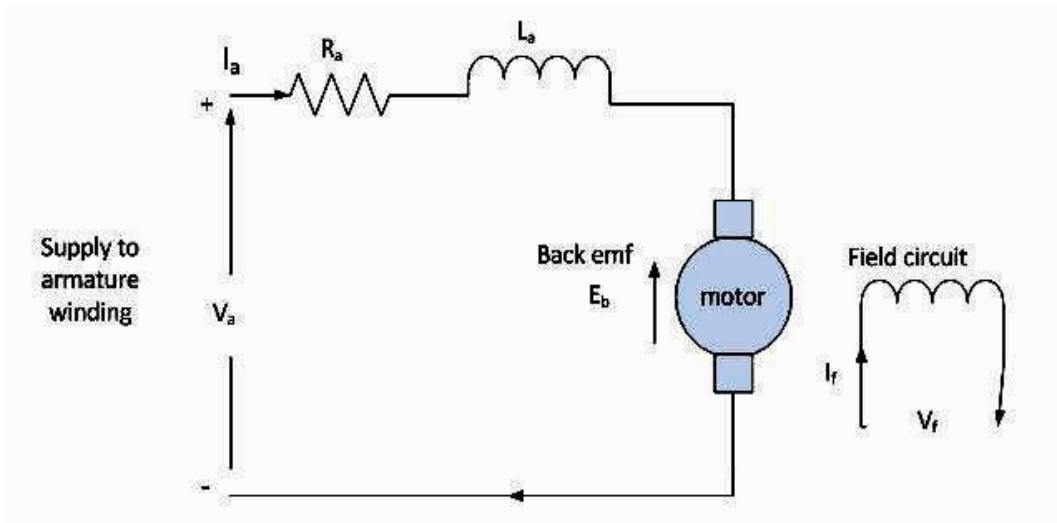


Figure .2. Circuit diagram of separately excited D.C.Motor

When a separately excited dc motor is excited by a field current I_f of and an armature current I_a of flows in the circuit, the motor develops a back EMF and a torque to balance the load torque at a particular speed. The field current I_f is independent of the armature current I_a . Each winding is supplied separately. Any change in the armature current has no effect on the field current . The I_f is generally much less than the I_a .

Suppose V_a is the armature voltage in volt, I_a is the armature current in ampere, E_g is the motor back emf in volt, L_a is the armature inductance in Henry, R_a is the armature resistance in ohm.

The armature equation is shown below:

$$V_a = E_g + I_a R_a + L_a \frac{dI_a}{dt}$$

The torque equation is given by :

$$T_d = J \frac{dw}{dt} + B_w + T_l.$$

Equation for back emf of motor will be:

$$E_g = K \Phi W$$

$$\text{Also, } T_d = K \Phi I_a$$

$$w = (V_a - I_a R_a) / K \Phi$$

Now, from the above equation it is clear that speed of DC motor depends on applied voltage, armature current, armature resistance and field flux. So, there are three ways of controlling speed of DC motor – armature voltage control, armature resistance control and field flux control .

4. MODELLING OF D.C. MOTOR FOR DRIVE SYSTEM

An electrical DC drive is a combination of controller, converter and DC motor. Here we are using chopper as a converter. The basic principle behind DC motor speed control is that the output speed of DC motor can be varied by controlling armature voltage keeping field voltage constant for speed below and up to rated speed . The output speed is compared with the reference speed and error signal is then fed to speed controller. If there is a difference in the reference speed and the feedback speed, Controller output will vary. The output of the speed controller is the control voltage E_g that controls the operation duty cycle of converter. The converter output gives the required voltage V to bring motor speed back to the desired speed. The Reference speed is provided through a potential divider because it is linearly related to the speed of the DC motor. Now the output speed of motor is measured by Tacho-generator. The tacho voltage we will get from the tacho generator contains ripple and it will not be perfectly dc. So, we require a filter with a gain to bring Tacho output back to controller level. The basic block diagram for DC motor speed control is shown below :

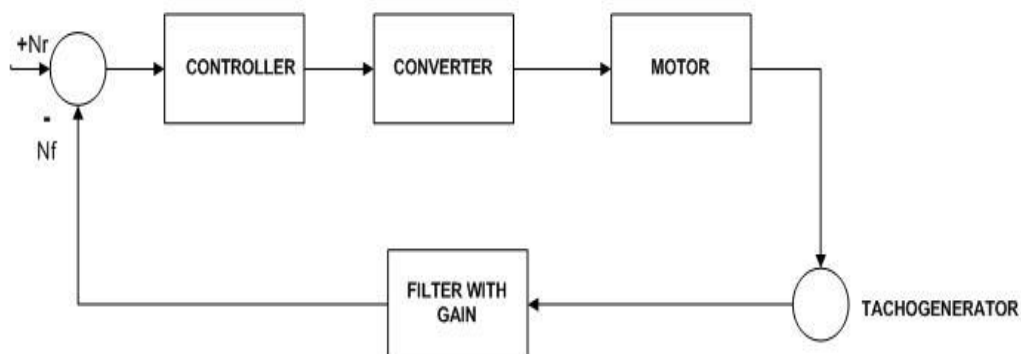


Figure 3: Closed loop model for speed control of dc motor

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 is obtained from the 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 – proportional controller ,on–off controller, integral controller, derivative controller and PID controller. In 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 very difficult to generate a derivative term in the output that has any significant effect on speed of motor. It can be deployed to reduce the rapid speed oscillation caused by high proportional gain. Therefore, 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.

5. MATLAB SIMULATION AND RESULTS

In this paper the speed control of D.C.MOTOR is done by using current controller and speed controller. In the open loop model the output speed is uncontrolled as shown in below fig.

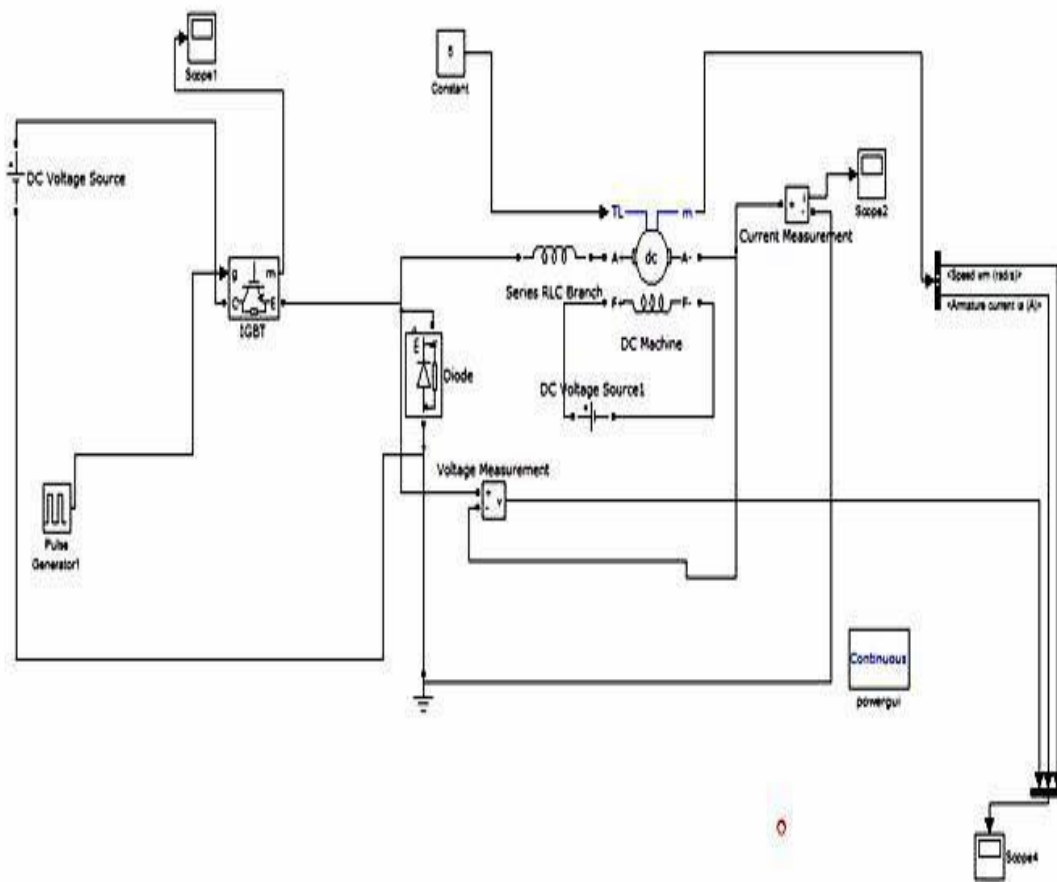
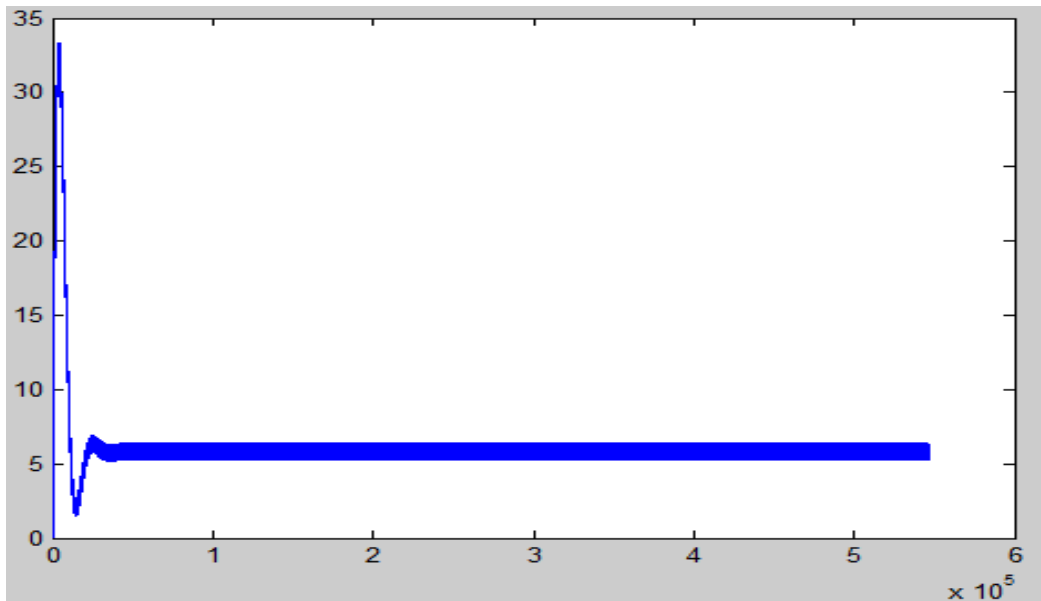


Figure 4: Simulink model of open loop model of chopper with dc machine

Specifications of elements used in open loop model:

ELEMENTS	RATINGS
D.C.Voltage source	280v
Pulse Generator:	
Amplitude	10
Period	2e-3
Pulse Width (% of period)	50
D.C.MOTOR:	5H.P. 500V 1750RPM
Field	300v
TORQUE	5 N-M



Simulation output of open loop model of chopper with dc machine

Figure 5. Armature current waveform

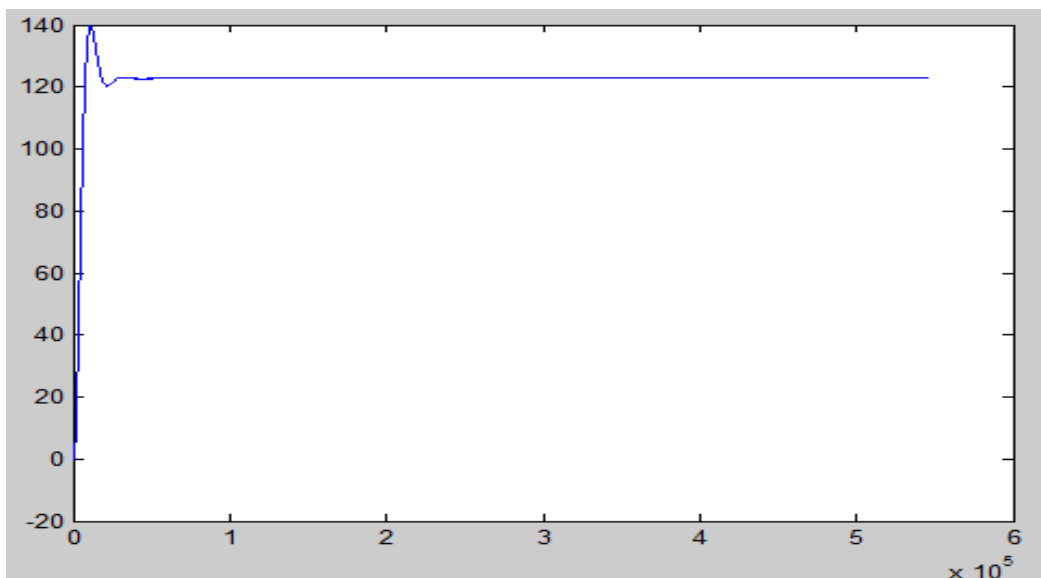


Figure 6. Speed waveform

In the open loop model of speed control of separately excited D.C.Motor for the machine the output speed is more than 120rad/sec, and the armature current is observed to be above the rated value. These two parameters can be controlled by using closed loop model.

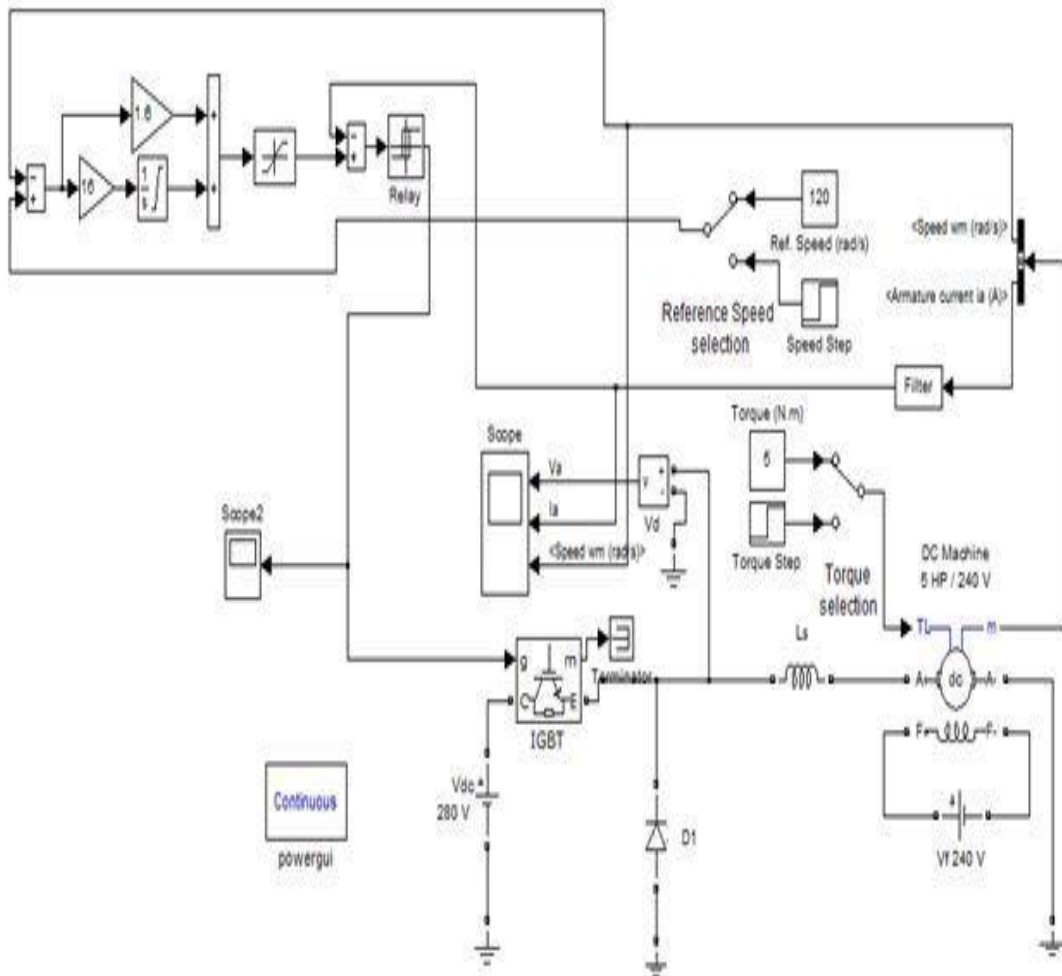


Figure 7. Simulink model of closed loop model of chopper with D.C.Machine

For the same ratings of the machine as in case of open loop model, the controlled output is as shown below:

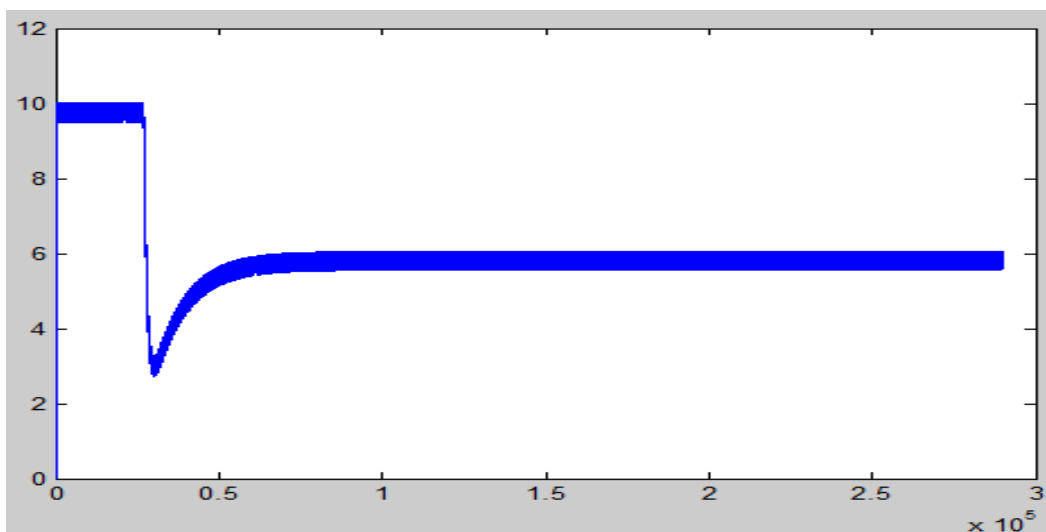


Figure 8. Armature current waveform

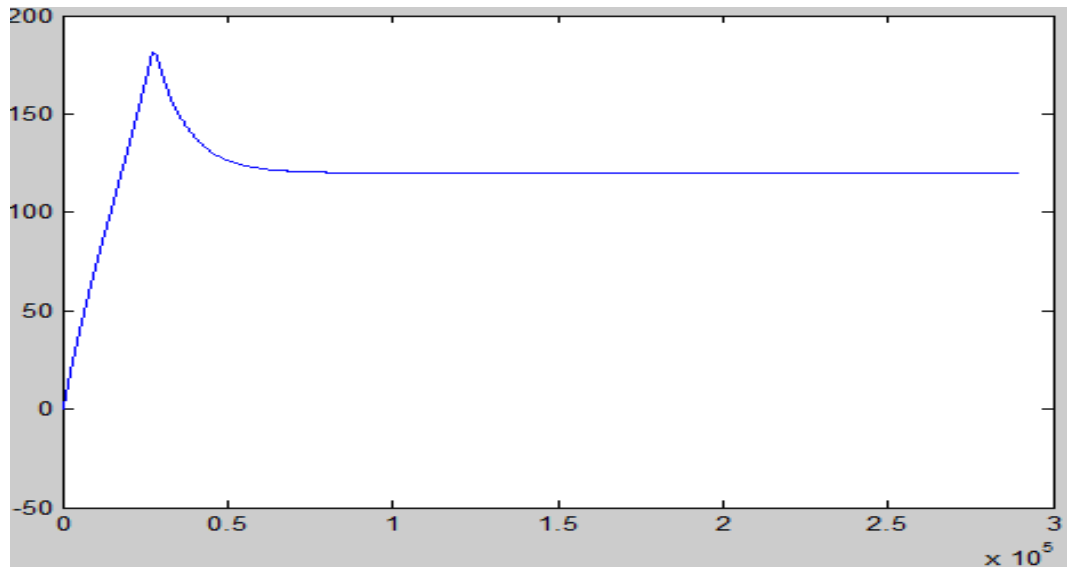


Figure: 9. Speed waveform

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

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