SPEED CONTROL OF DC MOTOR USING CHOPPER

ABHISHEK KUMAR SINHA (109EE0309)

BADAL KUMAR SETHY (109EE0304)

Department of Electrical Engineering
National Institute of Technology Rourkela

SPEED CONTROL OF DC MOTOR USING CHOPPER

A Thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology in "Electrical Engineering"

By

BADAL KUMAR SETHY (109EE0304)

ABHISHEK KUMAR SINHA (109EE0309)

Under guidance of

Prof. MonalishaPattnaik

Department of Electrical Engineering

National Institute of Technology

Rourkela-769008 (ODISHA)

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DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ODISHA, INDIA-769008

CERTIFICATE

This is to certify that the thesis entitled "**Speed Control of DC Motor Using Chopper**", submitted by **Abhishek Kumar Sinha (Roll. No. 109EE0309) and Badal Kumar Sethy (Roll. No. 109EE0304) and** in partial fulfilment of the requirements for the award of **Bachelor of Technology** in **Electrical Engineering** during session 2012-2013 at National Institute of Technology, Rourkela. A bonafide record of research work carried out by them under my supervision and guidance.

The candidates have fulfilled all the prescribed requirements.

The Thesis which is based on candidates' own work, have not submitted elsewhere for a degree/diploma.

In my opinion, the thesis is of standard required for the award of a bachelor of technology degree in Electrical Engineering.

Place: Rourkela

Dept. of Electrical Engineering
National institute of Technology
Rourkela-769008

Prof. M. Pattnaik
Assistant Professor

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Badal Kumar Sethy

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B.Tech (Electrical Engineering)

Dedicated TO

BhagawanShriShirdiSaiBaba

&

Our beloved Parents

ABSTRACT

The speed control of separately excited dc motor is carried out by varying the armature voltage for below rated speed and by varying field flux to achieve speed above the rated speed. This thesis presents the speed control methodology by varying armature voltage using chopper by providing control signal to the switches. Speed can be controlled from below and up to rated speed .The firing circuit of chopper receives signal from controller and variable voltage is given to the armature of dc motor according to the desired speed .There are two controllers we are using here one is speed controller and other is current controller. Both controllers are of proportional -integral type .The reason behind using PI type controller is it removes the delay and provide fast control. Now the simulation of model is done and analyzed in MATLAB (Simulink) under varying speed and torque condition.

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ABBREVIATIONS AND ACRONYMS

AC	-	Alternating Current
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
DC	-	Direct Current
PWM	-	Pulse Width Modulation
MATLAB	-	Matrix Laboratory
BJT	-	Bipolar junction transistor
IGBT	-	Insulated gate bipolar junction transistor
EMF	-	Electromagnetic field
GTO	-	Gate turn off thyristor
PI	-	Proportional -integral
PID	-	Proportional –integral-derivative

CHAPTER1

INRODUCTION

1.1 Introduction

An electrical drive consists of electric motors, its 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. The two types differ from each other in 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. Fractional horsepower DC motors are widely used as servomotors for tracking and positioning. 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 thesis mainly deals with controlling DC motor speed using Chopper as power converter and PI as speed and current controller.

CHAPTER 2

CHOPPER

2.1 Introduction of chopper

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 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.

2.2 Principle of Chopper Operation

A chopper is a high speed “on" or “off” semiconductor switch. It connects source to load and load and disconnect the load from source at a fast speed. A constant dc supply of magnitude V_s is given as input voltage and let its output voltage across load be V_o. For the sake of highlighting the principle of chopper operation, the circuitry used for controlling the on, off periods is not shown. During the periodT_{on}, chopper is on and load voltage is equal to source voltageV_s. During the periodT_{off}, chopper is off, load voltage is zero. In this manner, a chopped dc voltage is produced at the load terminals.

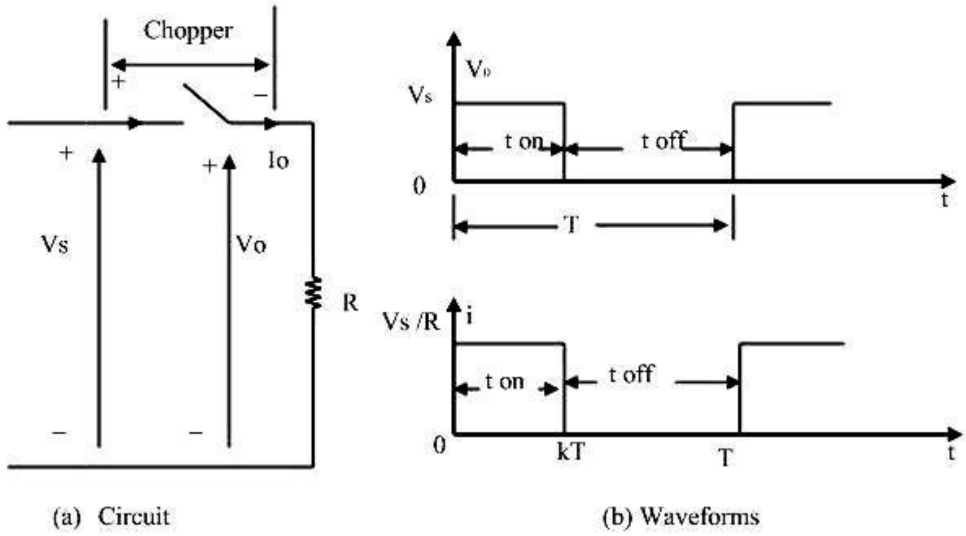


Figure 1: Chopper circuit diagram and its voltage and current waveform

Average Voltage = $V_0 = (T_{on}/(T_{on} + T_{off})) * V_s = (T_{0n}/T) * V_s = \alpha * V_s$ - (i)

Also,$V_0 = f * T_{on} * V_s$

$T_{on} = on\ time$ T_{off} = off-time.

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

α =T_{on}/T_{0ff} , f =1/T =chopping frequency.

Thus the voltage can be controlled by varying duty cycle α

V_0= f* T_{on}*V_s - (ii)

Let Vo be the average voltage, Ton is ON time, Toff is OFF time, T is chopping period, and Vs is input voltage and α is duty cycle.The average output voltage Vo can be controlled by varying duty cycle. There are various control strategies for varying duty cycle. They are time ratio Control and current-limit control.

In time ratio control α is varied by two ways constant frequency method and variable frequency method. In constant frequency method 'f' remains constant and Ton is varied.This scheme is also called pulse-width-modulation scheme. In variable frequency method 'f' varies and either Ton or Toff is kept constant. This method is also called frequency modulation scheme.

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.

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, 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 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.

CHAPTER 3

SEPARATELY EXCITED DC MOTOR

3.1 Introduction

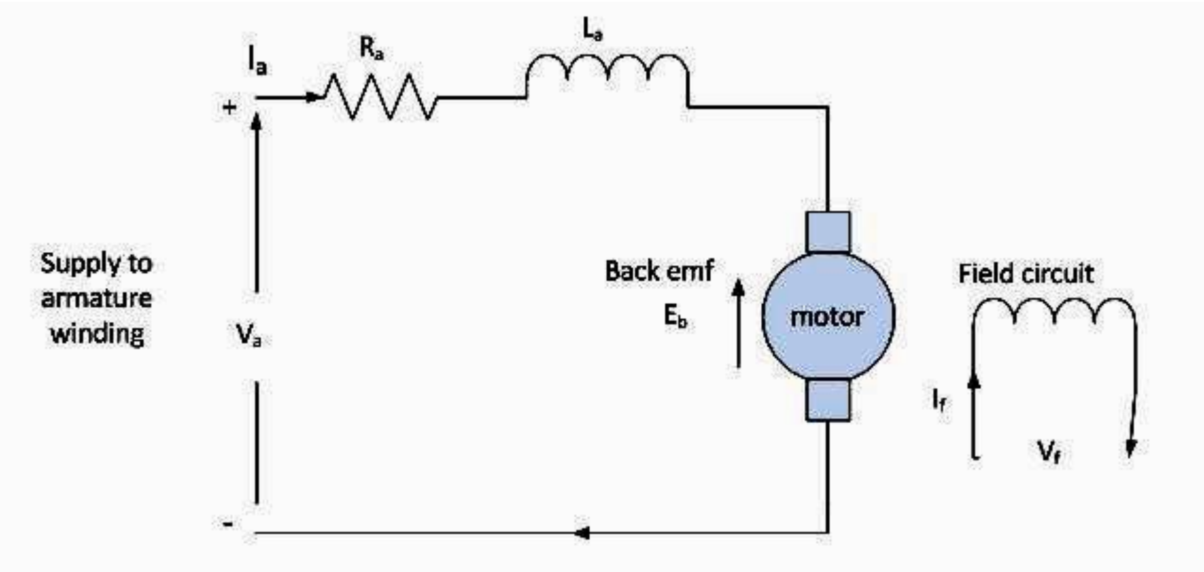


Figure 2: Circuit diagram of separately excited dc motor

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.

3.2 Mathematical analysis of separately Excited DC Motor

When a separately excited dc motor is excited by a field current of $I_f$and an armature current of I_a 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 If is independent of the armature current Ia. 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.

In the above figure 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:

$$V_a = E_g + I_a R_a + L_a \frac{dI_a}{dt} \qquad \text{- (iii)}$$

Now the torque equation will be given by:

$$T_d = J \frac{dw}{dt} + B_w + T_l. \qquad \text{- (iv)}$$

Where, T_l is load torque in Nm, T_d is the torque developed in Nm, J is moment of inertia in kg/m², B is friction coefficient of the motor and ω is angular velocity in rad/sec.

Assuming absence (negligible) of friction in rotor of motor, it will yield B=0. Therefore, new torque equation will be given by:

$$T_d = J \frac{dw}{dt} + T_l \qquad \text{- (v)}$$

Equation for back emf of motor will be:

$$E_g = K\,\Phi\,W \qquad \text{- (vi)}$$

Also, $T_d = K\,\Phi\,I_a$ - (vii)

$$w = (V_a - I_a\,R_a)/\,K\,\Phi \qquad \text{- (viii)}$$

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.

CHAPTER 4

MODELLING OF DC MOTOR FOR DRIVE SYSTEM

4.1 BASIC IDEA

An electrical DC drive is a combination of controller, converter and DC motor. Here we will use 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 Eg 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 show below :

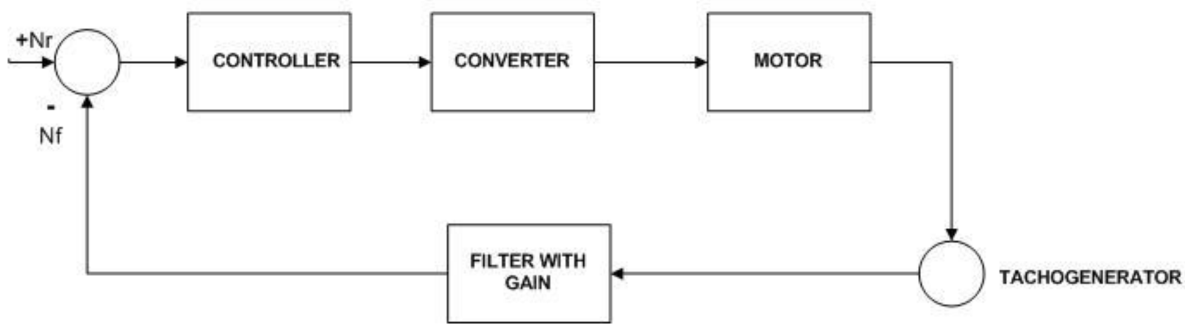


Figure 3: Closed loop model for speed control of dc motor

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.

CHAPTER 5

MATLAB SIMULATIONS, RESULTS AND ANALYSIS

5.1 Simulation of chopper with R-L-E load:

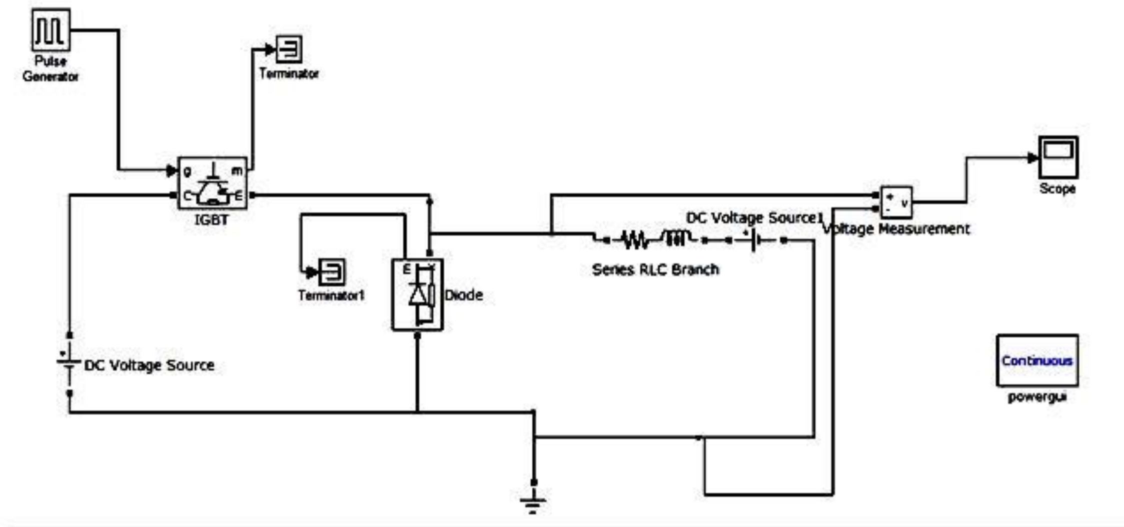


Figure 4: Simulink model of dc chopper with R-L.E load

Rating of the elements used in the above simulation:

Dc voltage source – 100 V

Pulse generator:

Amplitude – 10, period – 2e-3, pulse width (% of period) – 50

Resistance (ohms) – 1, Inductance – 100e-3, E – 50 V

After simulation we are getting a graph of output voltage with respect to time.

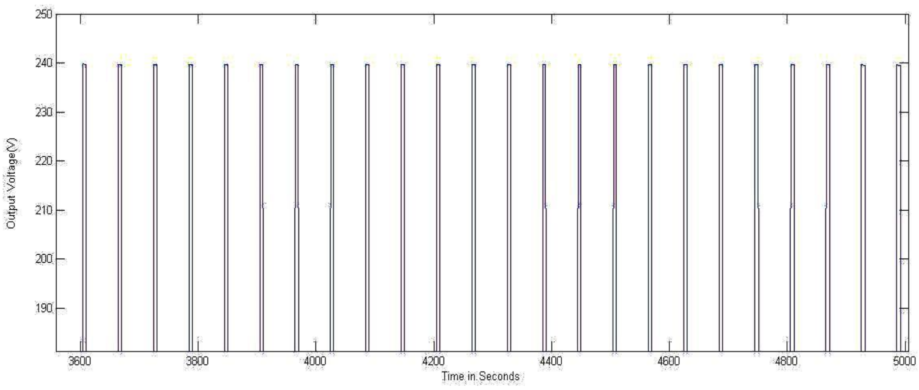


Figure 5: Simulation output of dc chopper with R-L.E load

5.2 Simulation of open loop model of chopper with dc machine:

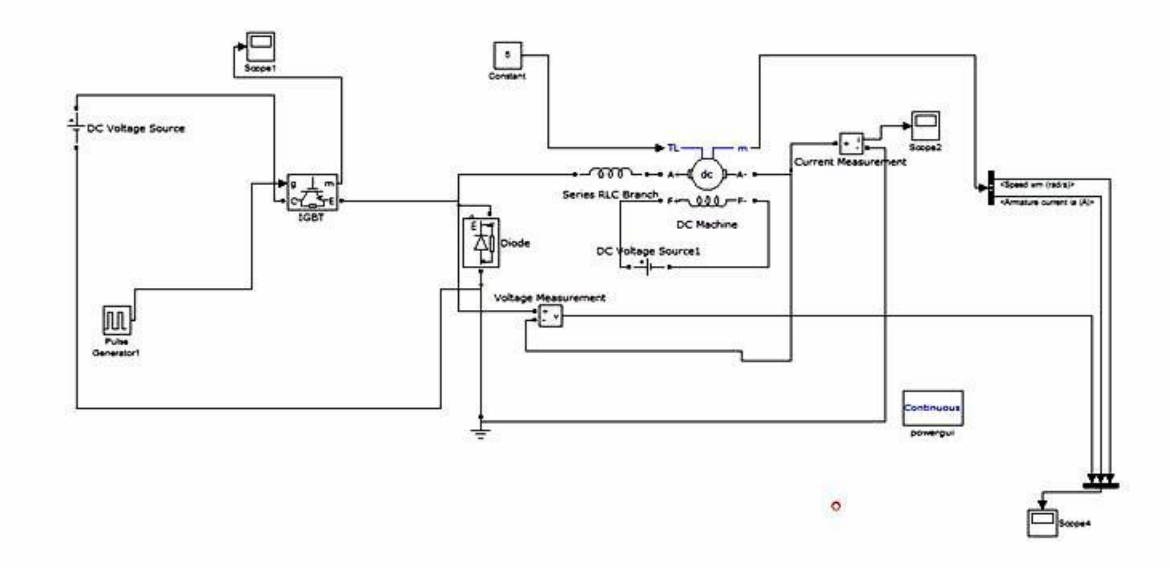


Figure 6: Simulink model of open loop model of chopper with dc machine

Rating of the elements used in the above simulation:

Dc voltage source – 280 V

Pulse generator:

Amplitude – 10, period – 2e-3, pulse width (% of period) – 50

Dc motor specification:

Rating – 50 HP, 500 V, 1750 rpm, Field – 300 V

Torque – 5 N-M

After simulation of the above model we are getting a graph of armature voltage, armature current and armature speed with respect to time.

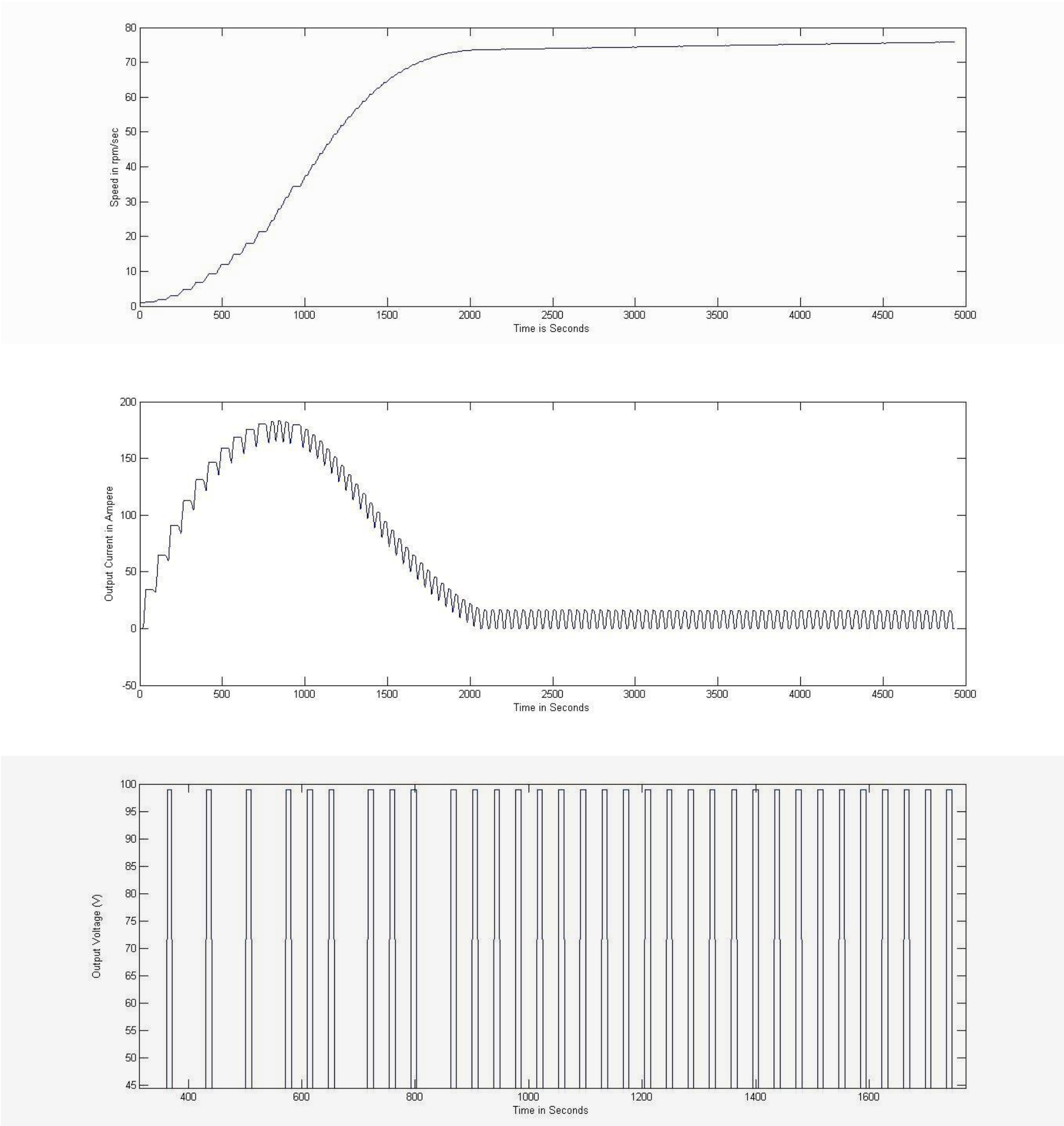


Figure 7: Simulation output of open loop model of chopper with dc machine

5.3 Simulation of closed loop model of chopper with dc machine (using IGBT as a switch):

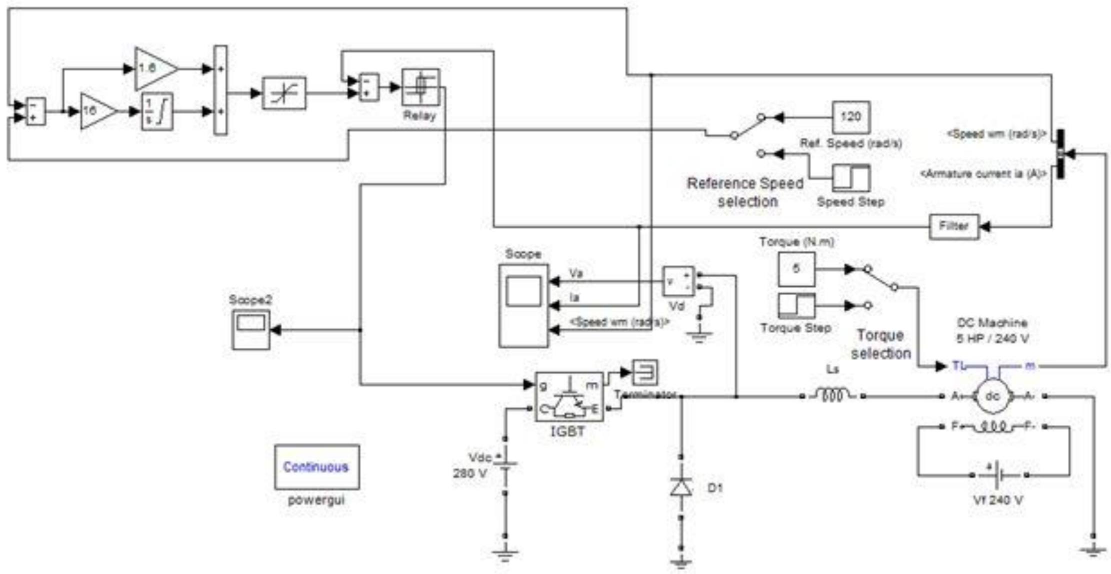


Figure 8: Simulink model of closed loop model of chopper with dc machine

Rating of the elements used in the above simulation:

Dc voltage source – 280 V

Rating of dc machine – 5 HP, 240 V

Torque – 5 N-M, Field voltage – 240 V

Reference speed – 120 rad/sec

After simulation of the above model we are getting a graph of armature voltage, armature current and armature speed with respect to time.

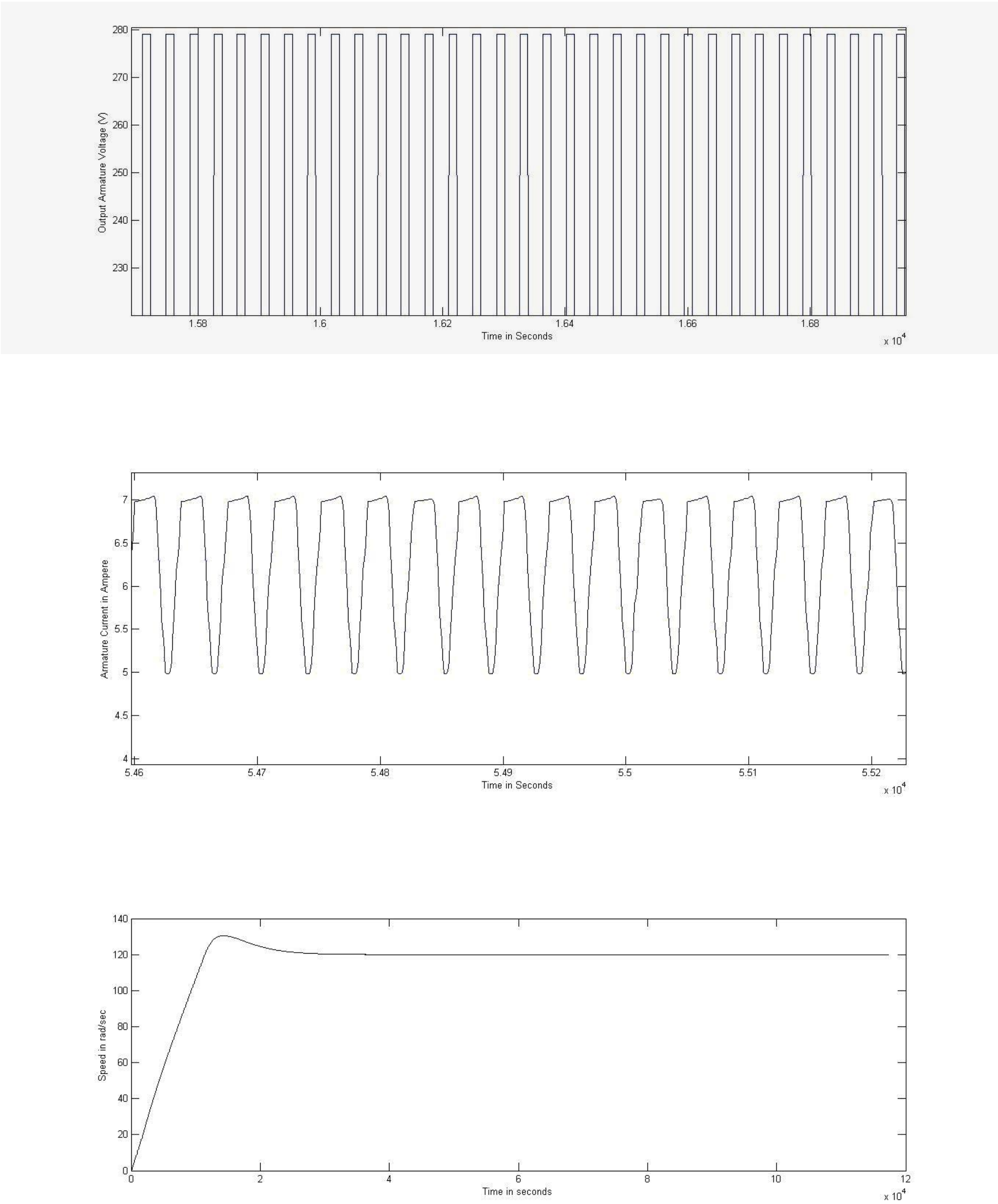


Figure 9: Simulation output of closed loop model of chopper with dc machine

5.4 Simulation of closed loop model of chopper with dc machine (using GTO as a switch):

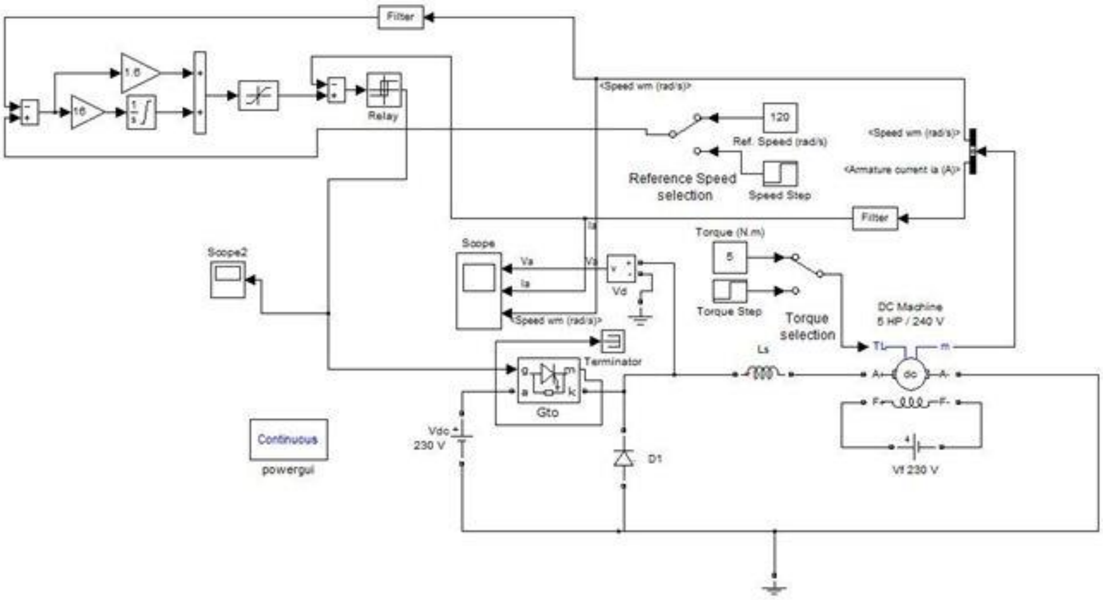


Figure 10: Simulink model of closed loop model of chopper with dc machine

Rating of the elements used in the above simulation:

Dc voltage source – 230 V

Rating of dc machine – 5 HP, 240 V

Torque – 5 N-M, Field voltage – 240 V

Reference speed – 120 rad/sec

After simulation of the above model we are getting a graph of armature voltage, armature current and armature speed with respect to time.

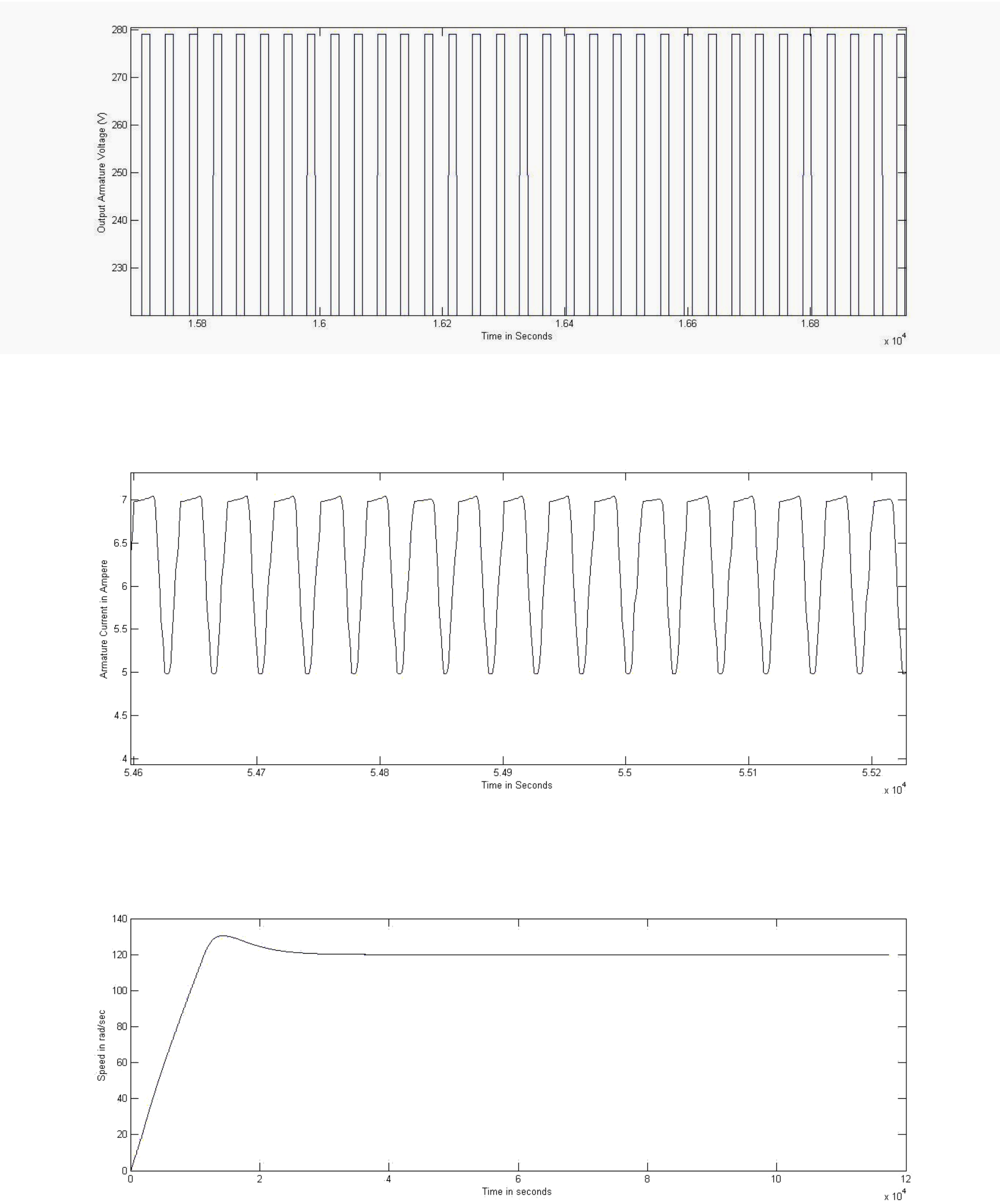


Figure 11: Simulation output of closed loop model of chopper with dc machine

5.5 Simulation of boost converter with R-load:

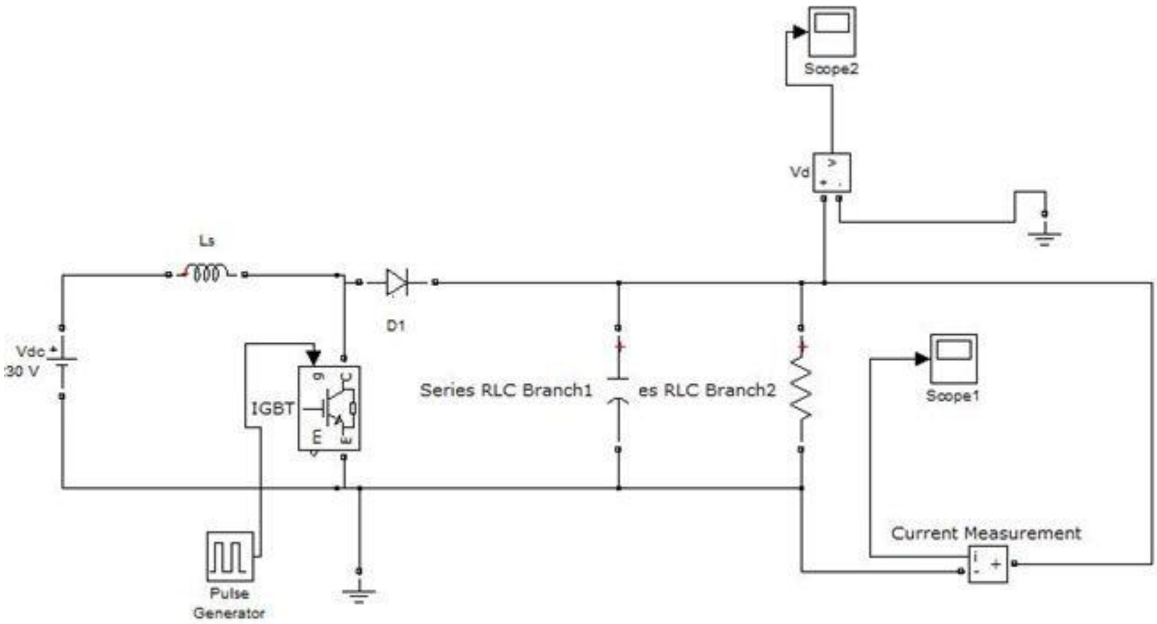


Figure 12: Simulation model of boost converter with R-load

Rating of the elements used in the above simulation:

Dc voltage source – 230 V

Load resistance – 10 ohm

After simulation of the above model we are getting a graph of output voltage, and output current with respect to time

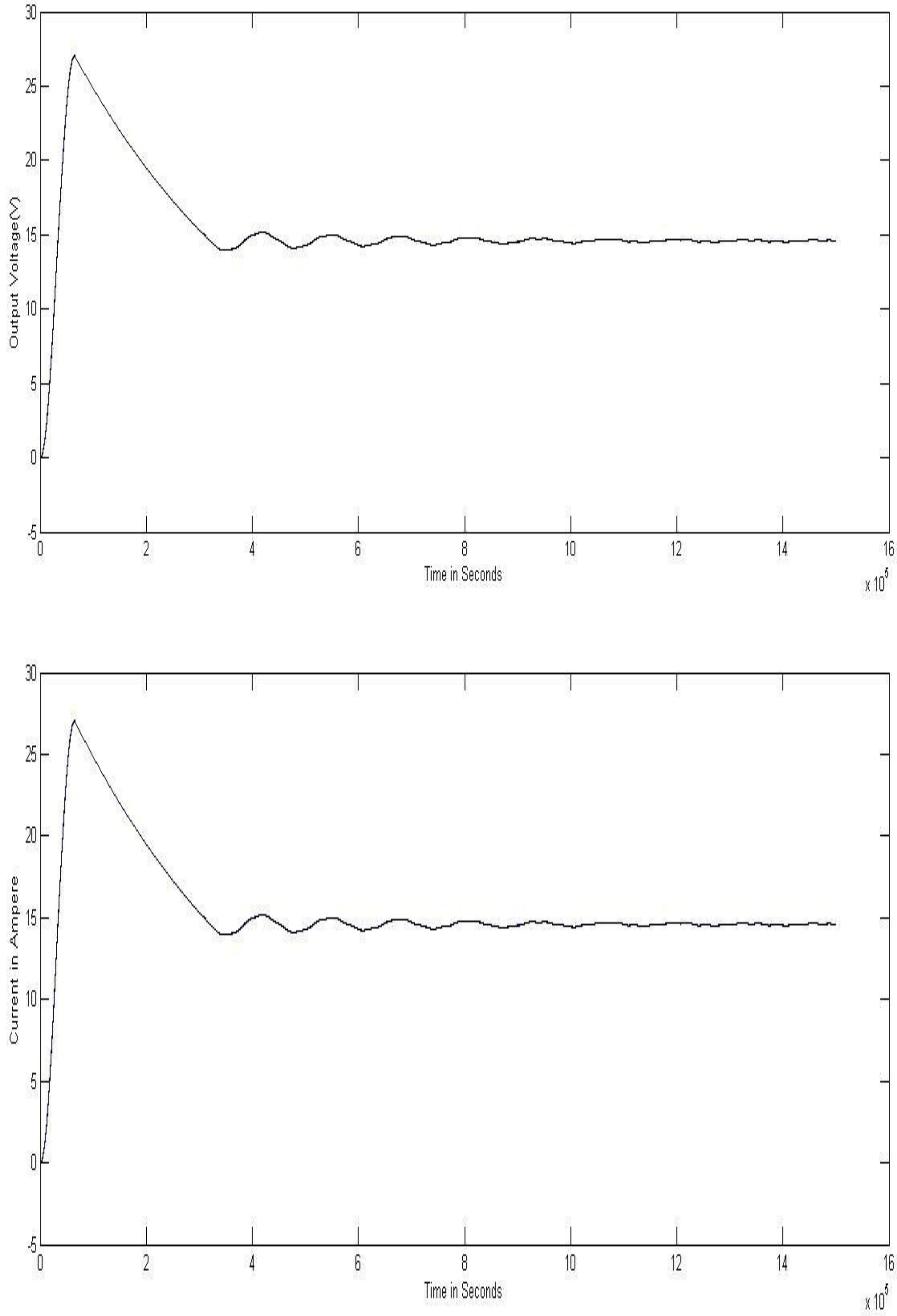


Figure 13: Simulation output of boost converter with R load.

5.6 Simulation of boost converter with DC machine:

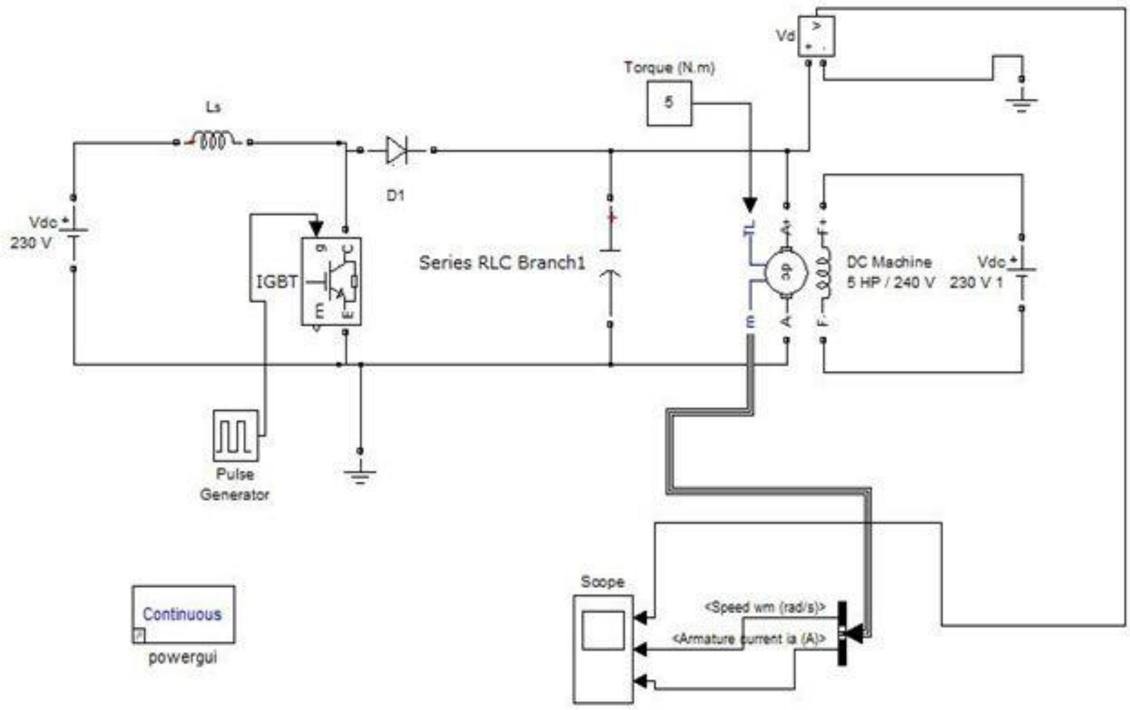


Figure 14: Simulation model of boost converter with dc machine

Rating of the elements used in the above simulation:

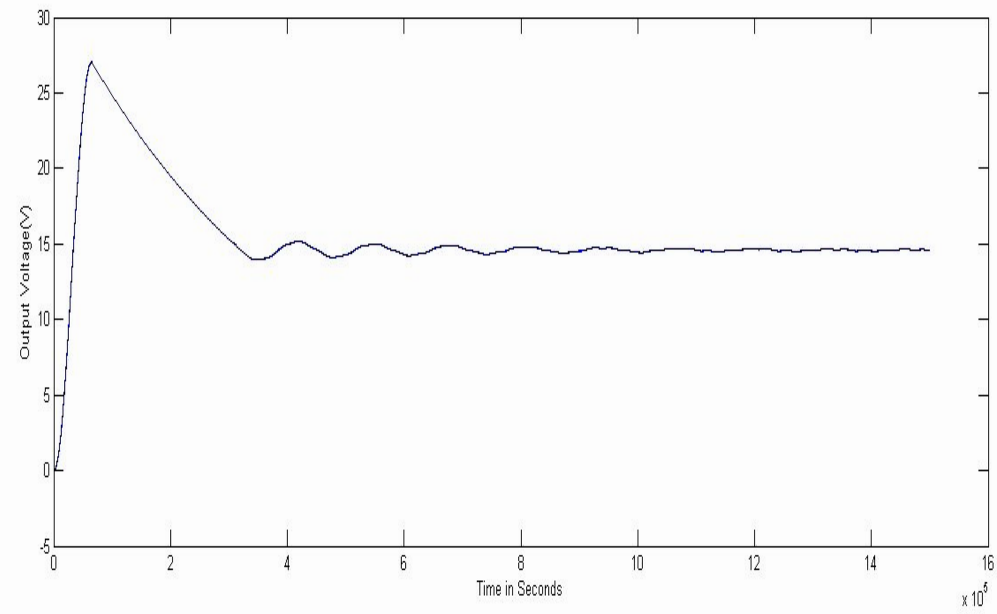
Dc voltage source – 230 V

Rating of dc machine – 5 HP, 240 V

Torque – 5N-M, Field voltage – 240 V

Reference speed – 120 rad/sec

After simulation of the above model we are getting a graph of armature voltage, armature current and armature speed with respect to time.



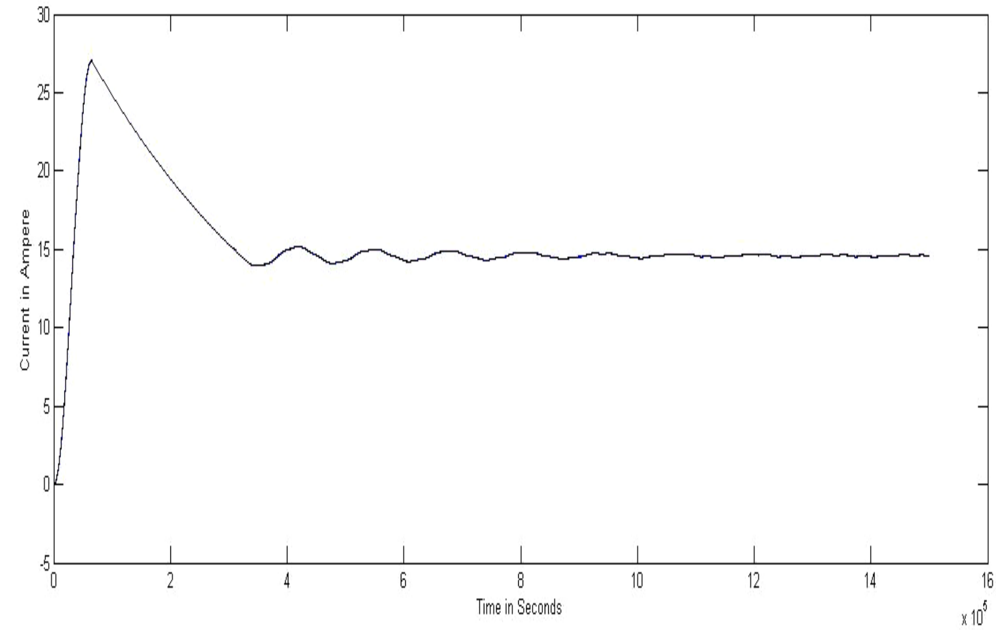


Figure 15: Simulation output of boost converter with dc machine

5.7 Simulation of chopper fed DC drive:

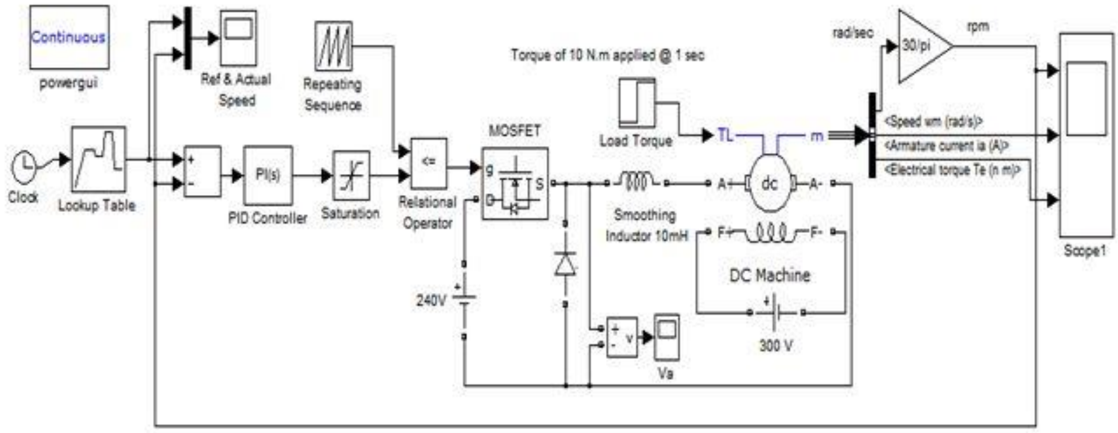


Figure 16: Simulink model of chopper fed dc drive

Rating of the elements used in above simulation:

DC input voltage – 240 V

DC machine rating – 5HP, 240 V, 1750rpm

Applied field voltage – 300 V

Torque of 10 N-m is applied @ 1 sec , L – 10mH

After simulation of the above model we are getting a graph of armature speed, armature current, electrical torque and armature voltage with respect to time.

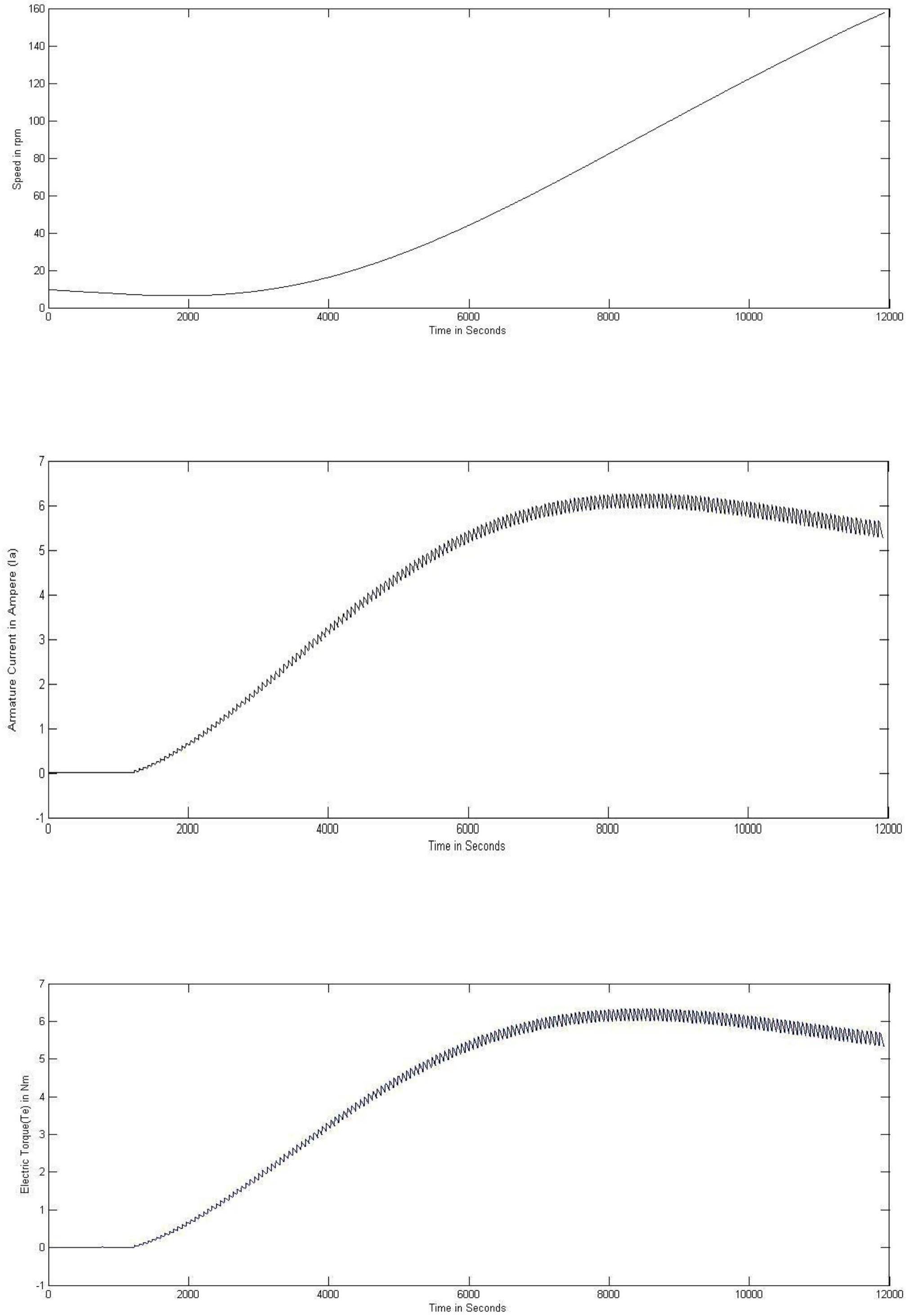


Figure 17: Simulation output of chopper fed dc motor

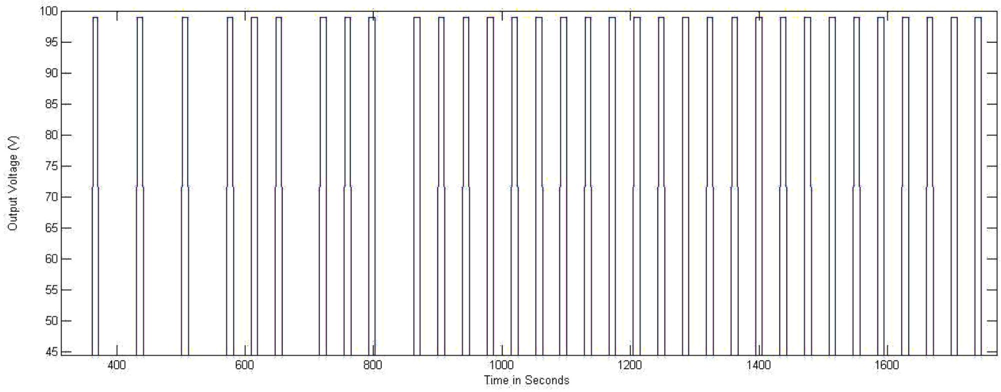


Figure 18: Simulation output of chopper fed dc drive

CHAPTER 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.Afterthat 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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