Speed Control of DC Motor Drive System using Choppers by Pulse Width Modulation Technique

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Abstract

Chopper can be used as a converter to control the speed of separately excited DC motor. The speed control can be achieved above or below the rated speed. Controller receives the signal from the chopper firing circuit and then the 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. After obtaining the complete model of DC drive system, the model is simulated using MATLAB (SIMULINK).
Keywords: separately excited DC motor, Proportional-Integral type converter, Simulink, PWM control

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I. INTRODUCTION

Development of high performance motor drives is very essential for industrial applications. A high performance motor drive system must have good dynamic speed command tracking and load regulating response. DC motors provide excellent control of speed for acceleration and deceleration. DC drives, because of their simplicity, ease of application, reliability and favorable cost have long been a backbone of industrial applications. DC drives are less complex and less expensive as compared to AC drives system. DC motors are conveniently portable and well fit to special applications. Speed control techniques in separately excited dc motor: By varying the armature voltage for below rated speed. By varying field flux should to achieve speed above the rated speed. The PI based speed control has many advantages like fast control, low cost and simplified structure. This thesis mainly deals with controlling DC motor speed using Chopper as power converter and PI as speed and current controller.

Copper is a static power electronic device that converts fixed dc input voltage to a variable dc output voltage. A Chopper may be considered as dc equivalent of an ac transformer since they behave in an identical manner. As chopper involves one stage conversion, these are more efficient. Choppers are now being used all over the world for rapid transit systems. These are also used in trolley cars, marine hoist, forklift trucks and mine haulers. Chopper systems offer smooth control, high efficiency, faster response and regeneration facility. The power semiconductordevices used for a chopper circuit can be force commutated thyristor , power BJT, MOSFET and IGBT,GTO.

II. PRINCIPLE OF CHOPPER OPERATION

A chopper is a high speed “on" or “off” semiconductor switch. It connects source to load and disconnect the load from source at a fast speed. In this manner, a chopped load voltage as shown in Fig is obtained from a constant dc supply of magnitude Vs. During the period Ton, chopper is on and load voltage is equal to source voltage Vs. During the period Toff, chopper is off, load voltage is zero. In this manner, a chopped dc voltage is produced at the load terminals.

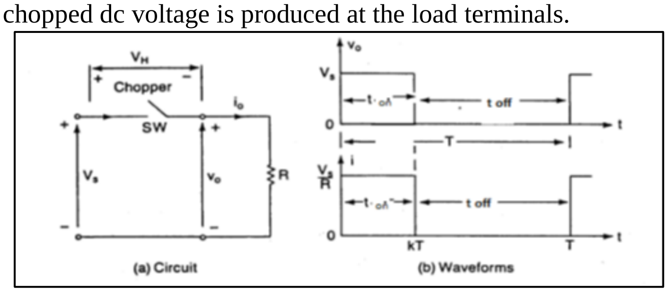

Fig. 1: Chopper Circuit and Voltage and Current Waveform.

Average Voltage, Vo= (Ton/ (Ton + Toff))*Vs

$$Vo = (Ton/T)*Vs$$

Vo=α Vs
Ton=on-time.

Toff=off-time.
T=Ton+Toff = Chopping period.
α=Ton/Toff.
Thus the voltage can be controlled by varying duty cycle α.

$$Vo = f * Ton * Vs$$

f=1/T=chopping frequency.
Separately excited dc motor

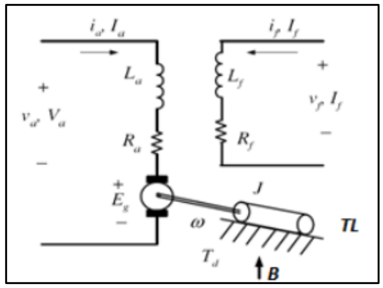

Fig. 2: Separately Excited DC motor drive

Separately Excited DC motor has field and armature winding with separate supply.The field windings of the dc motor are used to excite the field flux. Current in armature circuit is supplied to the rotor via brush and commutator segment for the mechanical work.The rotor torque is produced by interaction of field flux and armature current.

III. Operation of Separately Excited DC Motor

When a separately excited dc motor is excited by a field current of if and an armature current of ia 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 if is generally much less than the ia.

A. Field and Armature Equations:

$$Vf = Rf * if + Lf (dif/dt)$$

Where, Rf and Lf are the field resistors and inductor respectively.

$$Va=Ra * ia+ La(dia/dt)+eg$$

Where Ra and la are the armature resistor and inductor respectively.
The motor back emf, which is also known as speed voltage ,is expressed as:
Eg= ω if.
Kv is the motor voltage constant (in V/A –rad/sec) And ω is themotor speed (in rad/sec).

B. Basic Torque Equation:

The torque developed by the motor is:
Td=Kt if ia
Where (Kt=Kv)is the torque constant(in V/A –rad/sec)
Sometimes it is written as:
Td+Kt Ǿ ia
For the normal operation ,the developed torque must be equal to the load torque plus the friction and inertia, i.e.:

$$Td=J(dω/dt)+B ω+TL$$

Where
B=viscous friction constant.(Nm/rad/s)
TL=load torque(Nm)
J=inertia of the motor(g m2)
STEADY STATE TORQUE AND SPEED
The motor can be easily derived:
ω=(Va –IaRa)/(Kv If)
If Ra is a small value(which is usual) or when the motor is lightly loaded.i.e. Ia is small.
ω=Va/(Kv If)
That is if the field current is kept constant the motor speed depends only on supply voltage
Td=Kt If Ia=B ω +TL
The required power is
Pd=Td ω

IV. CONTROLLER DESIGN

The controller used in a closed loop 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. DECIDING THE TYPE OF CONTROLLER

When the motor is at the set-point speed under no load there is no error speed so the motor free runs. If a load is applied, the motor slows down and a positive error speed is observed. Then the output increases by a proportional amount to try and restore the desired speed. However, when the motor speed recovers, the error reduces drastically. The result is that the motor speed will stabilize at a speed below the set-point speed at which the load is balanced by the product of error speed and the gain. This basic technique discussed above is known as "proportional Integral control".

The proportional term does the job of fast-acting correction which will produce a change in the output as quickly as the error arises. The integral action takes a finite time to act but has the capability to make the steady-state speed error zero.

The derivative action causes the noise 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.

A. Importance of Current Controller in A Dc Drives System:

When the machine is made to run from zero speed to a high speed then motor has to go to specified speed. But due to electromechanical time constant motor will take some time to speed up. But the speed controller used for controlling speed acts very fast. Speed feedback is zero initially. So this will result in full controller output Ec and hence converter will give maximum voltage. So a very large current flow at starting time because back Emf is zero at that time which sometime exceeds the motor maximum current limit and can damage the motor windings. Hence there is a need to control current in motor armature. To solve the above problem we can employ a current controller which will take care of motor rated current limit. The applied voltage Va will now not dependent on the speed error only but also on the current error.

B. Current Controller Design:

We need to design current controller for the extreme condition when back emf is zero that is during starting period because at that time large current flows through the machine.

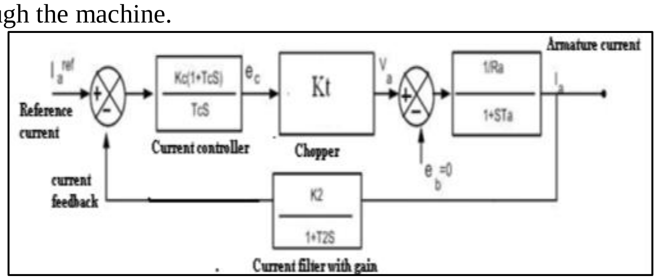

Fig. 3: Block Model for Current Controller Design.

C. Speed Controller Design:

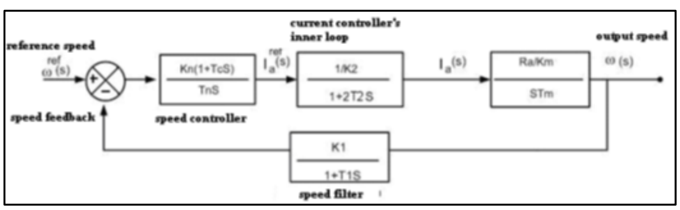

Fig. 4: Block model for Speed Controller design

V. MODELING OF DC MOTOR FOR DRIVE SYSTEM

The basic principle behind DC motor speed control is that the output speed of DC motor can be varied by controlling armature voltage for speed below and up to rated speed keeping field voltage constant. The output speed is compared with the reference speed and error signal is fed to speed controller. Controller output will vary whenever there is a difference in the reference speed and the speed feedback. The output of the speed controller is the control voltage Ec that controls the operation duty cycle of (here the converter used is a Chopper) converter. The converter output give the required Va required to bring motor back to the desired speed. The Reference speed is provided through a potential divider because the voltage from potential divider is linearly related to the speed of the DC motor. The output speed of motor is measured by Tacho-generator and since Tacho voltage will not be perfectly dc and will have some ripple. 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:

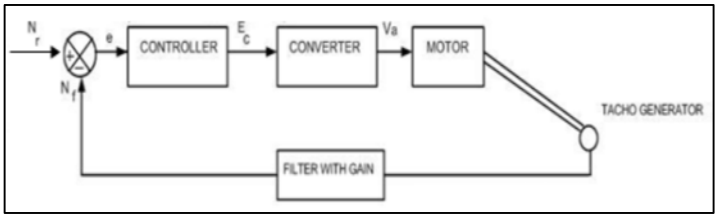

Fig. 5.Closed loop system model for speed control of dc motor.

VI. MATLAB SIMULATION, RESULTS AND ANALYSIS

Simulink Model

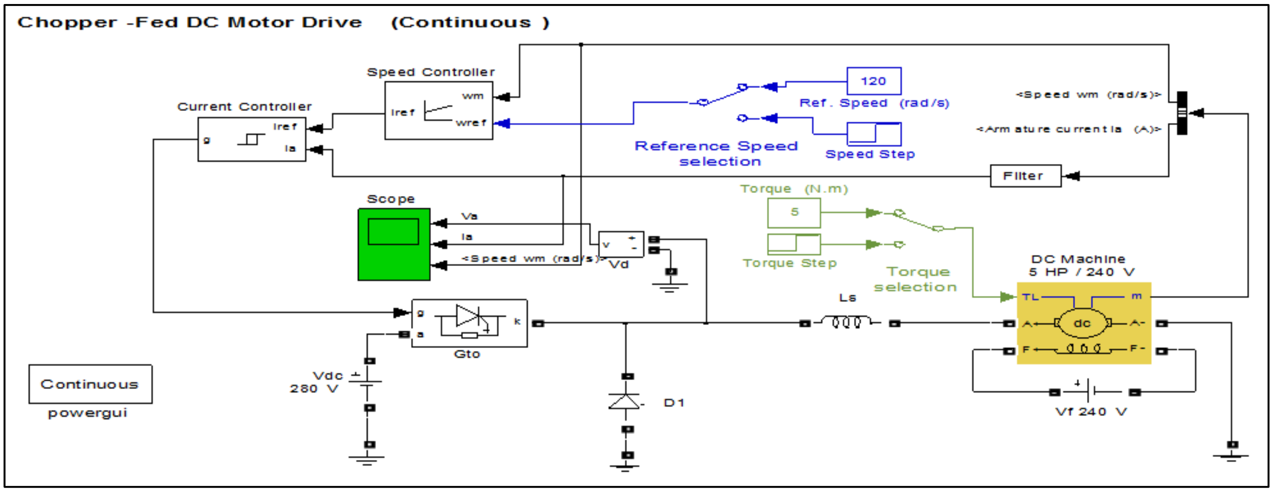

Fig. 6: Simulink Model for Speed Control of Separately Excited DC motor using chopper converter

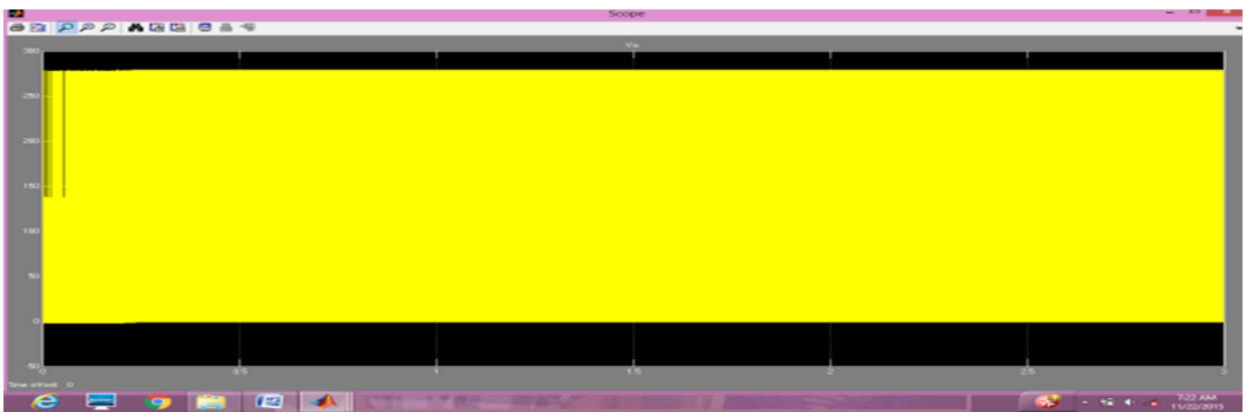

Fig. 7: voltage response at reference speed as rated speed

Fig. 8: Current Response at reference speed as rated speed.

Fig. 9: Speed Response at reference speed same as rated speed and full Load.

VII. 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 closed loop system model. Initially a simplified closed loop model for speed control of DC motor is considered and requirement of current controller is studied. Then a generalized modeling 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.

MATLAB simulation for speed control of separately excited DC motor has been done which can be implemented in software to observe actual feasibility of the approach applied in this project work. This technique can be extended to other types of motors. In this project work, we have done speed control for rated and below rated speed. So the control for above the rated speed can be achieved by controlling field flux.

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