Motor Control Using Chopper With and Without Filters

Abhishek Ranjan\textsuperscript{1}, Akash Dash\textsuperscript{2}, Sambit Kumar Jena\textsuperscript{3} & Soumya Ranjan Panda\textsuperscript{4}, T. APPA RAO\textsuperscript{1,2,3,4}
\textsuperscript{1,2,3,4} STUDENT, \textsuperscript{5} ASSOCIATE PROFESSOR
DEPARTMENT OF EEE, GIET, GUNUPUR

Abstract: Using chopper as a converter the speed of a dc motor can be controlled as per our requirement below and above the rated speed. The input signal from the controller is sent to chopper firing circuit and then chopper gives required voltage to the armature of the motor for achieving desired speed. There are two control loops, one for speed control and other for controlling current. The controller used is a Proportional-Integral type. A proportional-integral type controller removes the delay and provides fast control. In order to get stable and fast control of DC motor modulus hugging approach method is preferred. After obtaining the model of DC drive system, the model is simulated under MATLAB(SIMULINK). The simulation of DC motor drive is analysed under varying speed and varying load torque conditions.

1. Introduction

DC drives because of their simplicity, ease of application, reliability and cost efficiency have become the backbone of industrial applications. So development of high performance motor drives are very essential. Motor drives are used in applications requiring adjustable speed control, frequent starting, good speed regulation, braking and reversing. It is used in mills, mine winders, hoists, printing presses, machine tools, traction, textile mills, excavators and cranes. DC motors provide excellent control of speed for acceleration and deceleration. The field of a dc motor is directly connected to power supply which allows for precise voltage control, so it is necessary for speed and torque control applications. DC motors are used as adjustable speed machines which paved many ways of its applications in many areas for example cooling blowers and inlet air flanges provide cooling air for a wide speed range at constant torque. DC regenerative drives are preferred for continuous regeneration for overhauling loads over AC drives because of complexity and higher price. DC motors are capable of providing starting and accelerating torques in excess of 400\% of rated [4]. DC motors are conveniently portable and well fit to special applications, like industrial equipments and machineries that are not easily run from remote power sources [7]. By adjusting the terminal voltage dc motors can be adjusted over a wide range of speed. Even then, there is a persistent effort towards making them behave like dc motors through innovative design and control techniques. Hence dc motors are always a good option for advanced control algorithm because the theory of dc motor speed control is extendable to other types of motors as well [4]. Large experiences have been gained in designing trajectory controllers based on self-tuning and PI control. 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. The main objective of this paper is to analyse the simulation results under varying reference speed and varying load.

2. Separately exited DC motors

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{fig1.png}
\caption{Separately Excited DC motor model}
\end{figure}

In case of 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. The 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.

2.1. Operation of separately excited DC motor

When a separately excited dc motor is excited by a field current of $i_f$, an armature current $i_a$ flows. A back EMF is developed and a torque is produced to balance the load torque at a particular speed. The
field current $i_f$ is independent of the armature current $i_a$. Therefore any change in the armature current has no effect on the field current. The $i_f$ is generally much less than the $i_a$. The figure below shows torque vs. speed and power vs. speed characteristic of a separately exited dc motor.

![Torque Vs Speed & Power Vs Speed Characteristic Of Separately Excited DC Motor](image)

By varying the armature voltage for below rated speed and by varying field flux to achieve speed above the rated speed separately exited dc motor speed can be controlled. For controlling speed of dc motor rheostat or PID controllers can be used.

### 3. Choppers

In electronics, a chopper circuit is used to refer to numerous types of electronic switching devices and circuits used in power control and signal applications. A chopper is a device that converts fixed DC input to a variable DC output voltage directly. Essentially, a chopper is an electronic switch that is used to interrupt one signal under the control of another.

![Chopper Circuit (a) Voltage and Current Waveform](image)

Average Voltage, $V_o = (Ton/ (Ton+Toff)) \times V_s$  
$= (Ton/T) \times V_s$  
$= \alpha V_s$  
$Ton=$on-time.  $Toff=$off-time.  
$T=Ton+Toff =$ Chopping period.

In power electronics applications, since the switching element is either fully on or fully off, its losses are low, and the circuit can provide high efficiency. However, the current supplied to the load is discontinuous and may require smoothing or a high switching frequency to avoid undesirable effects. In signal processing circuits, use of a chopper stabilizes a system against drift of electronic components; the original signal can be recovered after amplification or other processing by a synchronous demodulator that essentially un-does the "chopping" process. Nowadays choppers are widely used in many electronic field fields. It is used for Switched mode power supplies (DC to DC converters), Dc motor speed controlling, Switched capacitor filters, Variable-frequency drives, D.C. voltage boosting, Battery-operated appliances.

#### 3.1. Principle of chopper operation

A chopper has a very high responding property. It is used for connecting and disconnecting from load at a very high speed. The result is a chopped load voltage obtained from the supply.

**Chopper Control strategies** The average value of output voltage $V_o$ can be controlled through duty cycle by opening and closing the semiconductor switch periodically. The various control strategies for varying duty cycle are as following:

- **Time ratio Control (TRC)**
- **Current-Limit Control.

**Time ratio Control (TRC)** In this control scheme, time ratio $Ton/T(duty\ ratio)$ is varied. This is realized by two different ways called Constant Frequency System and Variable Frequency System. In a constant frequency system on time is varied but chopping frequency is kept constant. In this system on period is varied so this type of system are also called as pulse modulation system. In variable frequency system frequency is varied. Here either on period or off period is kept constant. This method is called Frequency-modulation scheme.

**Current Limit control**

In this method, current is varied in two value i.e. maximum and minimum values. When the current value is minimum circuit is said to be on or vice versa. When current value increases to maximum value circuit gets turned off and this cycle continues.
4. LAYOUT DESIGN

In order to simplify the circuit it is first represented with the help of control system. Using this approach helps to avoid complexity.

FIGURE 4. Complete layout for DC motor speed control

FIGURE 5. Block model for Speed Controller design

FIGURE 6. Block Model for Current Controller Design

5. MATLAB stimulation

Before implementing a model in real world it must be stimulated first in order to remove the errors in it. For this thesis paper, using MATLAB we obtained the result for motor control using a chopper. Here speed control is done by using current controller and speed controller.

FIGURE 7. Simulink Model for Speed Control of Separately Excited DC motor using Chopper Converter (without filter)

FIGURE 8. Simulink Model for Speed Control of Separately Excited DC motor using Chopper Converter (with filter)

FIGURE 9. Speed Response at reference speed same as rated speed and full Load (without Filter)
The speed of a dc motor has been successfully controlled by using Chopper as a converter. Firstly a closed loop model for speed control of DC motor is made and requirement of current controller is analyzed. A complete layout of DC drive system is obtained and designing of current and speed controller is done. A DC motor specification is taken and by using modulus hugging approach corresponding values are found. Finally simulation is done for model with and without filters. The simulation results under varying speed and varying load are studied and analyzed. The model is feasible and can be implemented during simulation.

6. FUTURE SCOPE

Implementing a model in real world without stimulation can be a failure. So implementing a model in real world simulation is preferred. Simulation offers a fast and inexpensive means to check the efficiency of the system. In this paper, for simulation MATLAB is used and required waveform is obtained. By changing certain motor parameters the change in output waveform is observed. By varying certain parameters of the DC motor block diagram, the output waveform of the simulation would change accordingly. Since the MATLAB simulation is done successfully now it can be implemented in hardware to know its real world efficiency. After implementing the model in hardware system further flaws can be found out and system can be improved.

7. REFERENCE