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Analyzing Speed Control of Chopper Fed DC Drive Using Open and Closed Loop Techniques

KEYWORDS: PI controller, DC chopper, closed loop operation, open loop operation, MATLAB Simulink

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ABSTRACT *This paper deals with the comparative analysis of an open loop DC drive to a closed loop DC drive. A separately excited DC machine is used for the analysis. The speed of the DC motor is controlled using chopper. Proportional Integral controller is used for chopper control in closed loop drive in order to achieve constant motor speed at variable torque. The simulation and analysis is done on Matlab Simulink under variable torque conditions.*

I.Introduction

High performance drives are necessary parts of industrial equipment. DC motors are well known for their excellent speed control, speed regulation, braking and reversing. In a DC motor the power supply directly connects to the field of motor and causes a voltage control which is essential for controlling the speed and torque. Because of various advantages such as simplicity, ease of application, reliability and low cost, DC drives find various industrial applications. In comparison with the AC drive system DC drives are normally cheaper for low horse power ratings.

In this article open and closed loop speed control of a DC motor is discussed. We have used MOSFET based class A chopper for the speed control of the motor. A MOSFET based chopper provides smooth control, fast response, higher efficiency and regeneration facility. PI and PID controllers are generally used to control the motor in closed loop operation. The comparison of open loop and closed loop drive was performed in MATLAB Simulink. First open loop drive circuit was simulated and was found to operate smoothly for constant load but when variable load was applied, the speed was also observed to vary. This is not a very satisfactory operation for industrial applications requiring constant speed. This disadvantage is overcome by using a closed loop control. Closed loop speed control of motor is used for constant speed applications. We simulated closed loop control under variable load torque and found speed to remain constant. The controller used for the closed loop operation was a Proportional Integral type. Using this controller the delay is removed and fast control is achieved.

II. Conventional Chopper Circuit

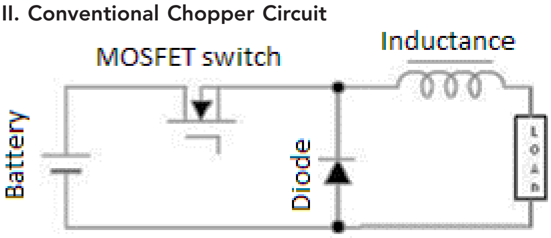


Figure 1: Conventional MOSFET based chopper

A chopper is a switching device that converts fixed DC into variable DC. Here,a class A chopper is used that allows single quadrant operation. Since the switch used(MOSFET) is either fully on or fully off the losses encountered are low. In the model ,we have used a step-down chopper to reduce the input voltage at the output side.

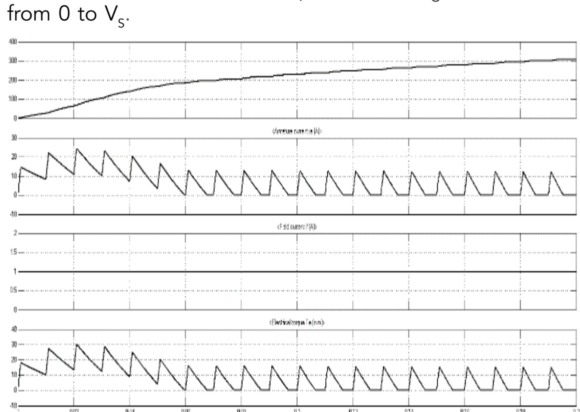
$$\text{Average output voltage } V_O = \frac{1}{T}\int_0^{T_{ON}} V_s\,dt = \frac{V_s T_{ON}}{T} = DV_s$$

During t=0 to T_{on},the switch is turned on and the output voltage equals V_s.When the switch is turned off the the output voltage becomes 0 as the energy contained in the load freewheels into the diode.The output voltage can be calculated by varying the duty cycle of the chopper.This is varied by changing the duty cycle of the pulse generator provided to the MOSFET.Hence,the output voltage is a function of duty ratio and can be calculated as follows:

$$\text{RMS output voltage } V_{or} = \sqrt{\frac{1}{T}\int_0^{T_{ON}} V_s^2\,dt} = V_s\sqrt{\frac{T_{ON}}{T}} = \sqrt{D}V_s$$

$$\text{Therefore, Effective input resistance } R_i = \frac{V_s}{I_{avg}} = \frac{V_s}{DV_s/R} = \frac{R}{D}$$

Where, D is duty cycle = T_{ON}/T. T_{ON} can be varied from 0 to T, so $0 \le D \le 1$. Hence output voltage V_O can be varied from 0 to V_S.



III. Open loop speed control

The open loop speed control circuit brings the motor to the speed set by the user irrespective of the load whereas the speed varies continuously as the load changes. The Simulink model used for analysis open loop speed control of DC motor for variable load is shown in figure 2.

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TABLE – 1
Specification of elements

Elements	Ratings
DC Motor	5HP,240V,1750rpm,150V excitation
DC voltage	240V
Gain	-30/pi
Pulse generator	Period:0.05;pulse width:10
Load torque	10Nm
Step size	1

IV. Simulation results

It was observed from figure 3; that as the load torque is varied by the step signal the, neither the electric torque nor speed remain constant.

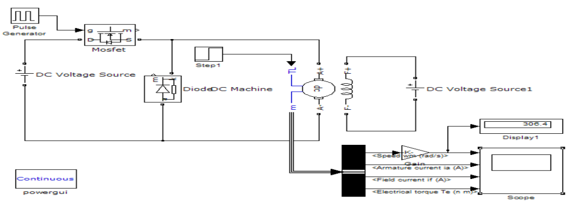

Figure 2: Simulink model for open loop speed control of a DC motor

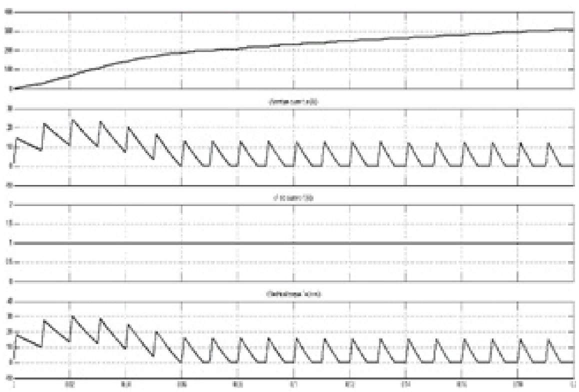

Figure 3: Speed, Armature current, field current and electrical torque waveforms for open loop speed control

V. Modelling of closed loop chopper fed drive using PI controller

Open loop control of the DC motor can be achieved by changing the armature voltage or resistance but it does not provide the same accuracy as that of closed loop control. That is, varying the load will change the motor speed which is undesirable. Closed loop control allows us to give a feedback to the controller to indicate the change in speed due to variation in load. It works as follows:

The variation in load torque causes a difference in speed. The speed is measured at the motor shaft by digital tachometer and compared with the reference speed, this difference is applied to the PI controller which changes the terminal voltage to a value that can maintain constant speed .For example, if the load torque increases this causes the speed of motor shaft to decrease.

The speed is measured and fed to the controller as a feedback. The error fed to the controller is positive and it will increase the terminal voltage in order to increase the speed of motor. This can be demonstrated by the block diagram below

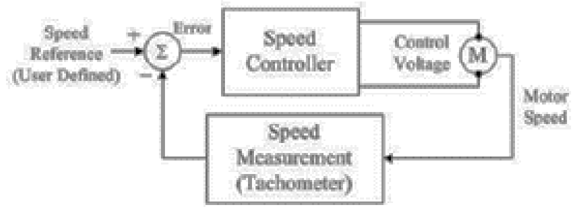

Figure 4: Block diagram for closed loop speed control

Using the above principle a Simulink model was designed as shown in figure 5 and the results were analyzed.

TABLE –II
Specification of elements

Elements	Ratings
Reference speed	1500 rpm
PID controller	P: 1; I: 1; D: 0
DC motor	5HP,240V,1750rpm,150V excitation
Gain	-30/pi
Load torque	10Nm
Step size	1

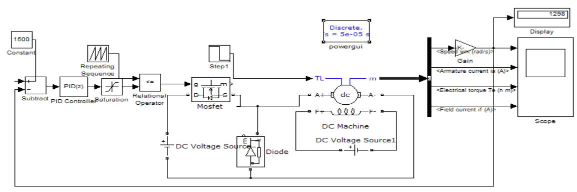

Figure 5: Simulink model for closed loop speed control of a DC motor

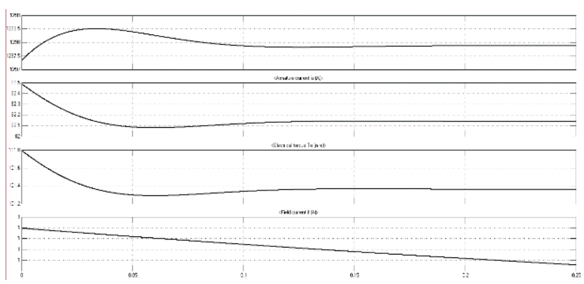

Figure 6: Figure 3: Speed, Armature current, field current and electrical torque waveforms for closed loop speed control

VI. Simulation results

VII. Conclusions

In this paper initially the open loop speed control of the DC motor is simulated and its results are analyzed. Then a generalized modelling for a closed loop speed control is done. Based on the model a closed loop speed control system is designed using a PI controller. Finally the simulation is performed for the system and the results for both closed loop and open loop speed control are compared. We can observe_that closed loop control of DC motor provides constant speed and constant electric torque in the presence of variable torque, whereas this is not the case for open loop control of the same DC motor. Hence, it can be established that closed loop control of chopper fed drive is more suitable for constant speed and torque ap-

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plications.

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