Performance Improvement in Separately Excited DC Motor Using PI Controller

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***Abstract :* - This paper presents an overview MATLAB simulation of chopper based speed control of DC motor. The speed control of DC motor for different applications is very important. The speed control strategies of DC motor plays an important role in the drive performance. The use of speed controller is to take a signal sample of speed and to bring the motor to that desired speed. The base line objective of DC drive is to maintain the stable speed of the system irrespective of load condition. In a particular requirement, setting a speed of DC motor as the driving equipment must be performed remotely. Electric drives have number of applications in diverse areas such agriculture, transport, industry and domestic purpose. The operation of electric drives are selectively regulated and made partly or fully automatic to increase the productivity and efficiency of the industry. The DC drives play a significant role in modern industrial drives due to its higher performance, reliability, adjustable speed control etc. This paper presents the speed control method of DC motor by varying armature voltage using chopper as a converter. The proportional-integral type controller is used for controlling. Now, to get stable and high speed control of DC motor, the overall chopper Simulink model is done and analysed in MATLAB/Simulink and also comparing with different types of controllers P, PD, PI and PID, the speed and performance of the DC machine is measured.**

Key Words: MATLAB, PI Controller, DC motor.

I. INTRODUCTION

An electrical drive system consists of electric motors, power circuit, 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 [1]. 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. The DC motors are used extensively in adjustable speed drives and position control system. The speed of DC motors can be adjusted by below the rated speed and above the rated speed. Their speed below rated speed is controlled by armature voltage. The development of high performance motor drives is very essential for industrial applications [2]-[4]. A high performance motor drive system must have good dynamic speed command tracking and load regulating response. The DC drives are widely used in applications requiring adjustable speed control, frequent starting, and 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. There are various types of speed control techniques are available for DC drives, such as, 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 [5]-] 7].

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 the DC motor speed using chopper as power converter and PI as speed and current controller. Now days Induction motors, brushless D.C motors and synchronous motors have gained widespread use in electric traction system. Hence DC motors are always a good option for advanced control algorithm because the theory of DC motor speed control is known more than other types [8]. [9]. The speed control techniques in separately excited DC motor, by varying the armature voltage for below rated speed. The power semiconductor devices used for a chopper circuit can be force commutated thyristor, power BJT, MOSFET, IGBT and GTO based chopper are used. It having very low switching losses that means total voltage drop has 0.5V to 2.5V across them [10]. The various controllers that can be used in speed control operation are available. Proportional plus Integral (PI) is the most preferred controller, which is designed to eliminate the need for continuous operator attention thus provides automatic control to the system [11]-[14].

II. DC/DC BUCK CONVERTER

A chopper is a high speed on-off switch which converts fixed DC input voltage to a variable DC output voltage. A Chopper is considered as a DC equivalent of an AC transformer as they behave in an identical manner. The Figure.1 shows the basic chopper circuit, output voltage and current waveform. The choppers are more efficient as they involve one stage conversion [15], [16].

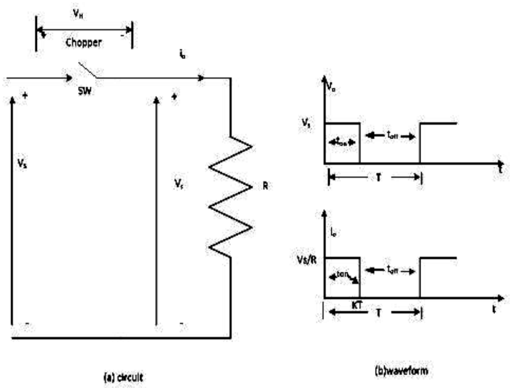

Figure 1: Chopper, Voltage and Current Waveform
Average Voltage,

$$V_O = \frac{T_{on}}{(T_{on} + T_{off})} \times V_s \qquad (1)$$

$$V_O = \left(\frac{T_{on}}{T}\right) \times V_s = \alpha V_s \qquad (2)$$

Ton = on-time. T_{off} = off-time.

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

$$\propto \equiv \frac{T_{on}}{T_{off}} \qquad (3)$$

Hence, the voltage can be controlled by varying duty cycle α.

Buck converter is a DC - DC power converter shown in Fig.1. It steps down voltage from its input supply to its output load. It consists of DC input voltage source Vin, controlled switch S, diode D, filter inductor L, filter capacitor C, and load resistance R. The typical voltage and current waveform of buck converter are shown in Fig.2. Under the assumption the inductor current is always positive. It can be seen from the circuit that when the switch S is commanded to the on state, the diode D is reverse-biased. When the switch S is off, the diode conducts to support an uninterrupted current in the inductor [17] - [19].

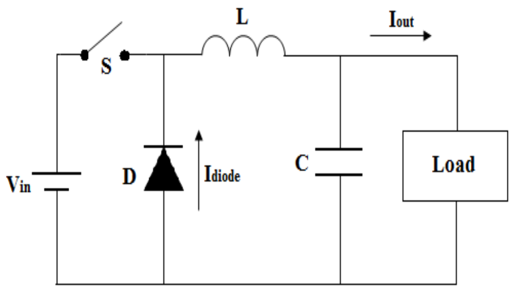

Figure 2:. Buck Converter

Figure.2 shows the relationship among the input voltage and output voltage, inductor current I_L, capacitor current I_C, and the switch duty ratio D can be derived, for instance, from the inductor voltage V_L. According to Faraday's law, the inductor volt-second product over a period of steady-state operation is zero. For the buck converter [20], [21]

$$(Vs - Vo)DT = -Vo(1 - D)T$$

Hence, the DC voltage transfer function, defined as the ratio of the output voltage to the input voltage, is

$$Mv \equiv \frac{Vo}{Vs} = D \qquad (4)$$

It can be seen from that equation the output voltage is always smaller that the input voltage. The converter maintains the constant output voltage. Figure 3 shows the voltage and current waveform of the buck converter.

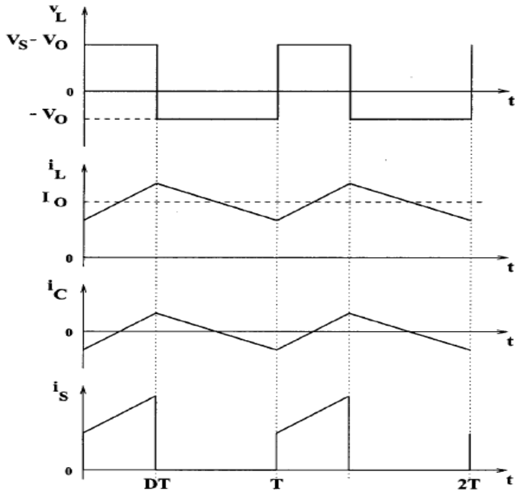

Figure 3: Voltage and Current Waveform of Buck Converter

III.SEPARATELY EXCITED DC MOTOR

Figure 4 shows the equivalent circuit of the separately excited DC motor. The separately excited DC motor has armature and field 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 [22], [23]. 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 i_f is independent of the armature current i_a. Each winding is supplied separately [24]. Any change in the armature current has no effect on the field current. The i_f is generally much less than the i_a.

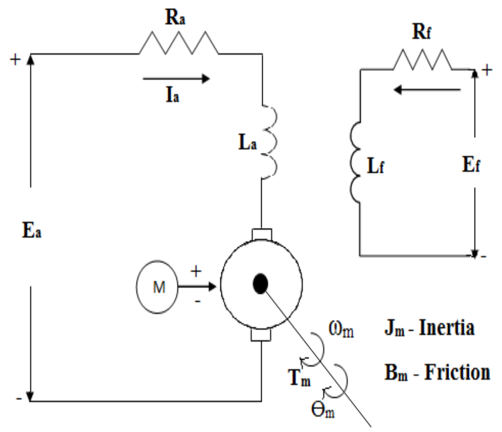

Figure 4: Equivalent Circuit of Separately Excited DC Motor

IV. PI CONTROLLER

The proportional and Integral controller produces an output signal, u (t) proportional to both input signal, V_i (t) and integral of the input signal, V_i (t) and is given by,

$$u(t) = K_p V_i(t) + K_i \int V_i(t) \quad (5)$$

From the comparator the reference speed is compared with the actual speed and an error signal is obtained and is given to the PI control. By properly selecting the proportional gain (K_p) and integral gain (K_i) the desired response can be obtained. Once buck converter is injected with the speed from the reference and the PI controller starts function, it varies the value of the duty cycle which will change the input value that is sensed by the PI controller [25]-[27].

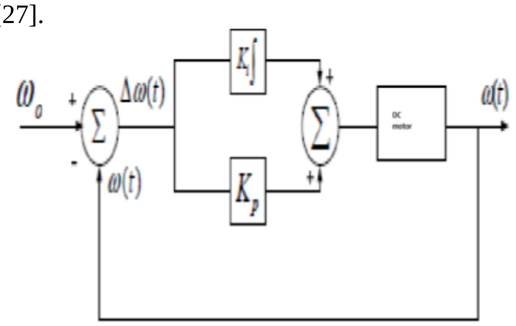

Figure 5: PI controller with DC motor

The Figure 5 shows the proportional band of the controller. The process of selecting controller parameter to meet given performance specification is known as controller tuning. Ziegler and Nichols suggested rules for tuning PI controller (mean to set the values of K_p and K_i) based on the experimental step response or based on the value of $K_p$that result is marginal stability, when only proportional control action is used [28].

Ziegler-Nichols rules, which are briefly presented in the following, are useful when mathematical models of plans are not known. These rules can, of course, be applied to design of system with known mathematical models. Such rules suggest a set of values of K_p and K_i that will give a stable operation of the system. However, the resulting system may exhibit a large maximum overshoot in step response, which is unacceptable. In such a case, we need series of fine tunings until an acceptable result is obtained. In fact, the Ziegler-Nichols tuning rules give an educated guess for parameter values and provide a starting point for fine tuning, greater than giving the final settings for K_p and K_i in a single shot [29].

V. SIMULATION RESULTS

The MATLAB simulation modeling is given the Figure 6. In that modeling we are using IGBT. Because of IGBT are given the best performance of speed control, fast switching and losses are low. Here 5HP, 240V separately excited DC motor and additionally 300V DC supply are given to the field. To take the constant load of the circuit consider its load 20Kg at constantly. In that simulation we are taking totally 4 displays. Display1 will be displayed input supply voltage 240V. Display 2, 3 and 4 are displayed Speed (ω), Current (I), Voltage (V) of the DC Motor.

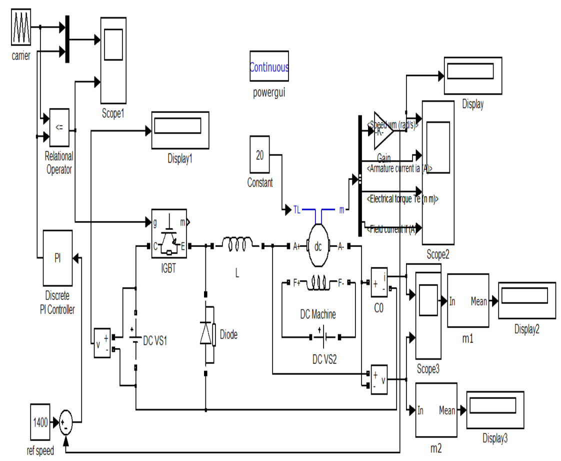

Figure 6: Simulation Model for Speed Control of Separately Excited DC Motor using PI Controller

Here using diode act as a freewheeling diode. It provides the freewheeling current flow of the circuit. The discrete PI controller is choosing the proportional gain (Kp) and integral gain (Ki) values are0.05 and 1.5. We are trying different values but in this values only we got exact output of the simulation so we choose that Kp and Ki values. In that PI controller to the relational operator can be compare the reference signal to the carrier signal. To set the reference value of PI controller output is 0.9V. When the carrier signal voltage is more than reference voltage that time IGBT go to OFF state otherwise ON state.

The output wave form of the scope 1 is to consider the Figure 7. It will be to consider the whenever the motor reference signal is less than or equal to the 0.9V that time its gate terminal voltage is high and otherwise its value will be low.

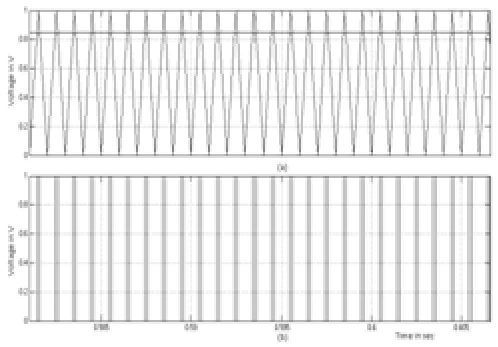

Figure 7: Triangular Carrier, Reference Signal and Gate Pulse

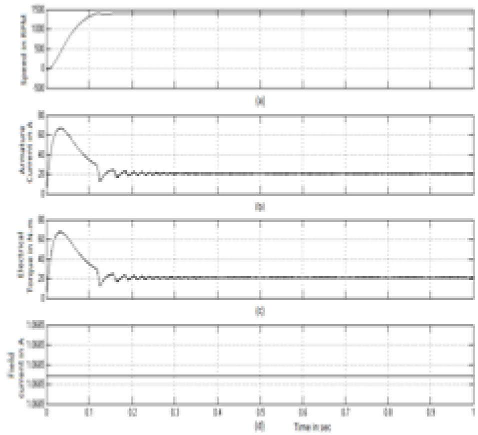

Figure 8:.Simulation output of Speed, Armature current, Torque and Field current

We are successfully done the simulation for the Chopper fed speed control of separately excited DC motor using PI controller. The outputs of the simulation are show in Figure 7 and Figure 8. The simulations are mainly concentrating on the control motor speed at below the rated speed. In that simulation model we are monitoring the motor speed, voltage, current and Input voltage is displayed. Here using the constant load of the DC motor and takes the 20 Relational operator will be choose the value of PI controller output signal taken as a reference signal. The condition of the relational operator is whenever the carrier signal is less than or equal to 0.9 that time its output consider 1 otherwise consider its output 0. Here DC motor mean current and voltage value should be displayed.

VI. CONCLUSION

This paper presents the literature review on MATLAB simulation of speed control of DC motor using Chopper. The speed below rated speed is controlled by using armature voltage control method. The closed loop control system is used for speed control. The PI controller and current controller are studied as well. Similarly by using field flux control the speed above rated speed can be controlled.

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