Effects Of PWM Chopper Using IGBT On The Torque And Speed Characteristic Of DC Motor

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Abstract

The motto of this paper is to enhancement of speed control of dc motor by using PWM Chopper technique through IGBT. This technique is propose to achieve better performance for a DC motor compared to phase-angle control line-commutated voltage controllers and integral-cycle control of thyristors. DC Motor speed control is carried out by use of Four Insulated Gate Bipolar Transistors are used with PWM (Pulse Width Modulation) Chopper for speed control of the motor and the IGBT triggering is carried out by varying armature voltage, field voltage and armature resistance. There are some advantages to use this technique, Speed varies proportionally with armature voltage by keeping field voltage constant. Speed varies inversely with field voltage by keeping armature voltage constant. The IGBT based circuit gives smoother control over the entire speed range as compared with the SCR based circuit. By using this technique, we can chop the frequency and control the speed of DC motor. In this paper the Matlab/Simulink model of a simple IGBT and Chopper controller has been developed which showed good results [1,2].

Keywords *- DC Motor, MATLAB/ Simulink , IGBT*

I. Introduction

Now a days industries are increasingly demanding process automation in all sectors. Automation results into better quality, production and reduced costs. The variable speed drives, which can control the speed of A.C/D.C motors are indispensable controlling elements in automation systems. The variable speed drives, till a couple of decades back, had various limitations, such as poor efficiencies, larger space, lower speeds, etc. However, the advent of power electronic devices such as power MOSFETs, IGBTs etc., and also with the introduction of micro-controllers with many features transformed the scene completely and today we have variable speed drive systems which are not only smaller in size but also very efficient, highly reliable and meeting all the stringent demands of the various industries of modern era. Direct current (DC) motors have been used in variable speed drives for a long time. The versatile control characteristics of DC motors can provide high starting torques which is required for traction drives. Control over a wide speed range, both below and above the rated speed can be very easily achieved. The methods of speed control are simpler and less expensive than those of alternating current motors. There are different techniques available for the speed control of DC motors. The phase control method is widely adopted, but has certain limitations mainly, it generates harmonics on the power line and it also has got poor p.f when operated at lower speeds. The second method is of PWM chopper through IGBT technique, which has got better advantages over the phase control. In a Dc motor, the back emf depends on armature speed, governed as follows ;

(1) If the speed is high, back emf is high hence Ia decreases.
(2) If the speed is low, more current flows which develops more torque resulting in acceleration.

Because of these two reasons, the speed of a Dc motor is regulated automatically. Among all existing electric motors, the separately excited Dc machines has the best ability to fulfil the demands of adjustable drive systems, as its speed can be varied over a wide range through voltage and field flux control.

II. Torque And Speed Control Methods

The dynamic and steady-state models are needed to Examine the response of the motor speed to sudden changes using feedback control system. In figure 1, V_t is the terminal voltage applied to the motor, if , Rf , and Lf are the current, resistance, and inductance of the field circuit, respectively; i_a , R_a and L_a are the current, resistance, and inductance of the armature circuit; respectively; e_a is the generated speed voltage; ω_m is the angular speed of the motor; T_e and T_l are the electromagnetic torque developed by the motor and the mechanical load torque opposing direction. The generated speed voltage and electromagnetic torque are given by [6, 8]:

$$e_a = K\varphi\omega \quad (1)$$

$$T_e = K\varphi i_a \quad (2)$$

where K is the design constant depending on the Construction of the motor. The dynamic performance of the motor is described by these equations together with the differential equation of the mechanical system and volt-ampere equations of the armature circuit. These equations are given by

$$J\, d\omega_m/dt + B\omega_m + T_l = T_e \quad (3)$$

$$v_t = v_a = e_a + R_a\, i_a + L_a\, di_a/dt \quad (4)$$

$$E_a = K\varphi\omega \quad (5)$$

$$T_e = K\varphi\, i_a \quad (6)$$

$$V_t = V_a = E_a + R_a I_a \quad (7)$$

$$\omega_m = Vt/K\varphi - Ra/(K\varphi)^2\, Te \quad (8)$$

Equation (8) indicates the speed of a DC motor can be Varied by controlling the field flux, the armature resistance or the terminal voltage applied to the armature. The three most common speed control methods are field resistance control, armature voltage control and armature resistance control methods. Since this paper presents Simulink model of speed control method by controlling the terminal voltage applied to the armature using a PWM chopper drive, only the armature voltage control method is briefly described in this section.

In the armature voltage control method, the voltage applied to the armature circuit, V_t is varied without changing the voltage applied to the field-circuit of the motor. As (8) indicates, the torque-speed characteristic is represented by a straight line with a negative slope when the DC motor is driven from an ideal DC source. This characteristic is illustrated in Fig. 2. In order for the speed of the motor vary linearly with torque, the terminal voltage V_t and the flux must remain constant as the load changes. Typically a rectifier or a motor-generator set is required to provide the controlled armature voltage for the motor whose speed is to be controlled. Observe that the no-load speed of the motor increases while the slope of the curve remains unchanged since the flux is kept constant in this method. By the armature voltage control method, it is possible to control the speed of the motor for speeds below base speed but not for speeds above base speed. In order to achieve a speed faster than the base speed, an excessive armature voltage is required, which possibly damages the armature circuit.

III. Simulink Model Of The Speed Control Method

In this section, MATLAB/Simulink model of PWM chopper based speed control method is presented and performance of the DC motor driven from a PWM chopper drive is analyzed. A 5-HP DC motor of 240-V rating 1750 rpm is used in the simulation model. The equivalent circuit parameters of DC motor used in the simulation are R_f = 281.3 Ω, L_f = 156 H , R_a = *2.581* Ω , L_a = .028 H.

Figure 1 shows the Simulink realization of this method. There is 240V DC supply connected by four quadrant chopper circuit created by four IGBTs which is combines the advantages of BJTs and MOSFETs. An IGBT has high input impedance, like MOSFETs, and low on state conduction losses, like BJTs. However, there is no second breakdown problem, as with BJTs. An IGBT is turned on by just applying a positive gate voltage to open the channel for n carriers and is turned off by removing gate voltage to close the channel.

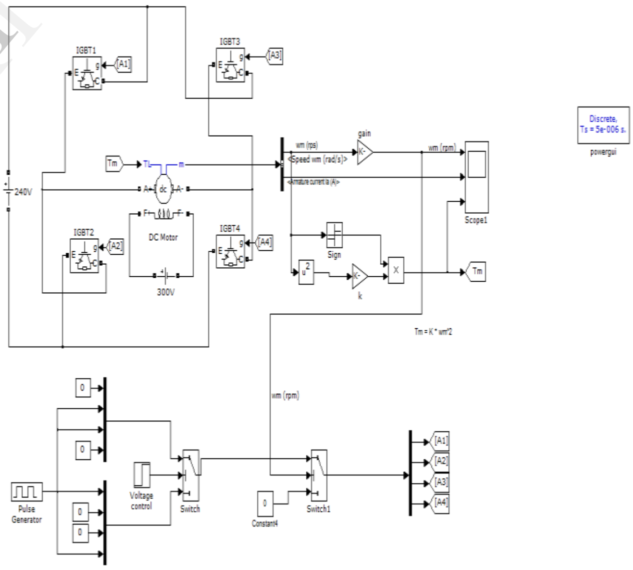

Figure 1: Simulink realization of armature voltage speed control method using a PWM chopper drive.

It requires a driver circuit which is provided by pulse generator. In this four quadrant chopper circuit, four IGBTs are used named IGBT1, IGBT2, IGBT3 and IGBT4, as shown in the figure 1. IGBT 1 and IGBT4 turn on in positive half cycle at this time speed will increases smoothly and Armature current slowly decreases and as we know that,

$$Tm = K^*Wm^2$$

Where K stands for gain and Wm is speed (rpm).

So the motor torque also increases. After that in negative half cycle IGBT2 and IGBT3 turn on, now speed will deceases, as shown in figure 2.

IV. Simulink Result

Speed is increasing from 0 to 620 rpm and vice versa. At time 1.7 sec motor will stop now speed is control.

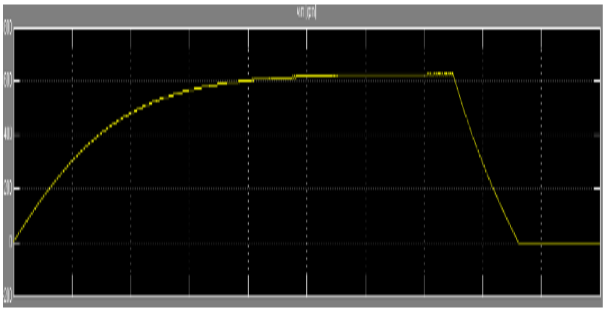

Figure 2: Speed Vs Time

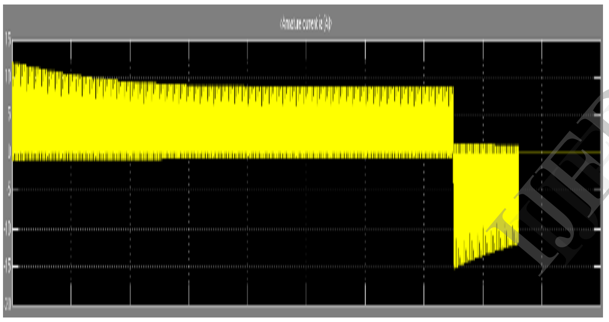

Figure 3: Armature Current Vs Time

At starting I_a is 12A after increasing the speed of motor I_a will decreases and at time 1.7 sec it will be zero.

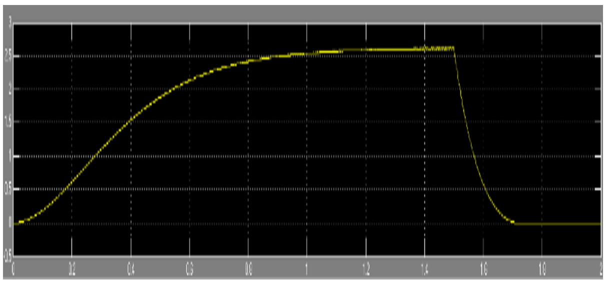

Figure 4: Torque Vs Time

We known that, $Tm = K*Wm^2$
So torque will rises when speed rises.

V. Conclusion

Insulated Gate Bipolar Transistors are used for speed control of the motor and the IGBT triggering is carried out by use of converters under various loading conditions and by varying armature voltage and field voltage. The IGBT based circuit gives smoother control over the entire speed range.

VI. References

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