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Implementation of Chopper Fed Speed Control of Separately Excited DC Motor Using PI Controller

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Abstract: ***This paper presents a speed control of a separately excited DC motor by using PI (Proportional Integral). The speed of the separately excited DC motor can be varied below and above the rated speed by various speed control techniques. It can be varied above the rated speed by field flux control and below the rated speed by armature terminal voltage control. The conventional controllers are commonly being used to control the speed of the DC motors in various industrial applications. It's found to be simple, robust and highly effective, when the load disturbance is small. Here, we using chopper as a converter the speed of DC motor is controllable. The chopper firing circuit gets signal from controller and then by supplying variable voltage to the armature of the motor then to obtain the desired speed of the motor. There are two different types of control loops, current controller and speed controller. The controller used is Proportional-Integral type. The current and speed controller loop is designed and in order to get stable and high speed control of DC motor. The simulation of the above model is done in MATLAB/SIMULING under varying speed and torque condition.***

Keywords: ***Chopper circuit, DC motors, PI-controller, MATLAB (SIMULINK).***

1. 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. 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 [1]. 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 [2]. The 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 [3]. The DC drives are widely used in applications requiring adjustable speed control, frequent starting, 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 [4]. 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]. 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 [6]. Now days Induction motors, brushless DC 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. The speed control techniques in separately excited DC motor, by varying the armature voltage for below rated speed [7]. 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 [8]. The various controllers that can be used in speed control operation are available. Proportional plus Integral (PI) is the most preferred controller, which are designed to eliminate the need for continuous operator attention thus provide automatic control to the system [9].

II. CHOPPER

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 [10], [11].

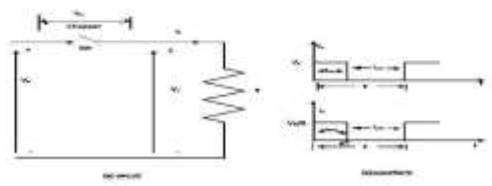

Figure 1: Chopper circuit, voltage and current waveform.

Average Voltage,

$$V_o = (T_{on}/(T_{on}+T_{off}))*V_s \quad (1)$$
$$= (T_{on}/T)*V_s$$

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$= \alpha V_s$

Ton = on-time.

Toff = off-time.

T = Ton + Toff = Chopping period.

α=Ton/T.

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

III. BUCK CONVERTER

A chopper is a static power electronic device, which converts fixed DC input voltage to a variable DC output voltage. It can be step up or step down. It also considered as a DC equivalent of an AC transformer since they behave in an identical manner. Due to its one stage conversion, choppers are more efficient and now being used all the world for rapid transit system, in marine hoist, in trolley cars, in mine haulers an in shift trucks etc., [12]..

The circuit diagram of traditional buck converter is shown in Figure 2. It consists of constant input voltage (Vs). The buck converter is connected between the supply and the load. To maintain constant output voltage a capacitor is connected to the load. The feedback is provided by the controller connected to the output of the buck converter.

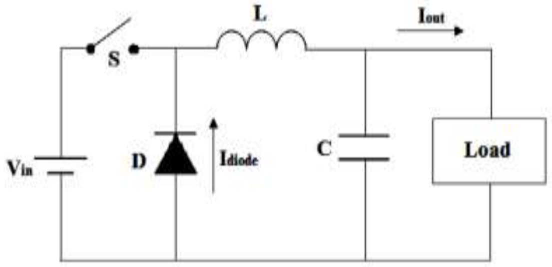

Figure2: Buck converter

The power semiconductor devices used for a chopper circuit can be force commutated thyristor, BJT, MOSFET, IGBT and GTO. These devices are generally represented by a switch. When the switch is OFF, no current will flow in the circuit. The current flows through the load when switch is ON. The power semiconductor devices have ON-state voltage drop of 0.5V to 2.5V across them. For the sake of simplicity, this voltage drop across these devices is generally neglected [13]. During period Ton, Chopper is ON and load voltage is equal to source voltage Vs. During the interval Toff, chopper is OFF, load current flows through the freewheeling diode FD. As a result, load terminals are short circuited by FD and load voltage is therefore, zero during Toff. During Ton, load current rises whereas during Toff load current decays.

IV. SEPARATELY EXCITED DC MOTOR

Separately excited DC motor has field and armature winding with separate supply voltage. Field winding supplies field flux to armature. When DC voltage is applied to motor, current is fed to the armature winding through brushes and commutator. Since rotor is placed in magnetic field and it is carrying current also. So motor will develops a back emf and a torque to balance load torque at particular speed [14], [15]. Figure 3 shows the equivalent circuit of separately Exited DC motor

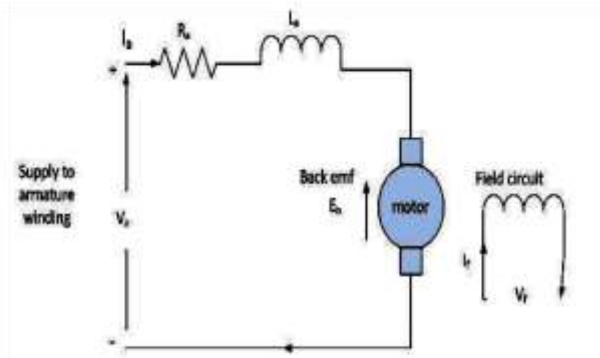

Figure 3: Equivalent circuit of separately Exited DC motor

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. Any change in the armature current has no effect on the field current. The I_f is generally much less than the I_a. In the above figure suppose V_a is the armature voltage in volt, I_a is the armature current in ampere, E_g is the motor back emf in volt, L_a is the armature inductance in Henry, R_a is the armature resistance in ohm [16].

(A)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,

$$u(t) = K_p V_i(t) + K_i \int V_i(t) \qquad (2)$$

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 [17]-[19].

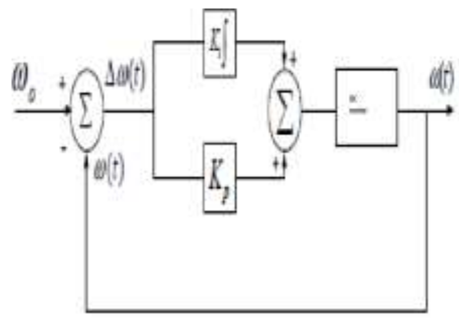

Figure 4: PI controller with DC motor (PI)

The Figure 4 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. 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 [20], [21]. 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.[22].

Table I: Comparison of gain response of three Controllers

Parameter	Speed of Response	Stability	Accuracy
increasing P	Increase	Deteriorates	Improves
increasing PI	Decrease	Deteriorates	Improves
increasing PID	Increase	Improves	No impact

TABLE II: Effects on output parameter of P, PI and PID Controller

Parameter	P Controller	PI Controller	PID Controller
Rise time	Decrease	Decrease	Minor Decrease
Overshoot	Increase	Increase	Minor Decrease
Settling time	Small change	Increase	Minor Decrease
Steady state error	Decrease	Significant change	No change
Stability	Worse	Worse	Small Better.

Table 1 and 2 show the effects of coefficients and effects of changing in control parameters of the controllers. From the table, it is observed that, if decrease in rise time in the P and PI controller, the overshoot will be increase and there is no change in settling time, and also in steady state error. The PI controller gives better result than P and PID controller.

From the performance analysis, it is to be noted that, when gain is increases the speed of response is increases in P and PID controller, but in PI controller gain of response is decreases. In PI controller there is a significant change in various parameter and there is no change in steady state error which can see from Table 1 and Table 2. So, PI controller is better than P and PID controller. The P controller can stabilize only in 1st order unstable process and PID controller can be used only when dealing with higher order capacitive processes but PI controller is applicable in all stages. The comparative study of P, PI and PID Controller is carried out, in which PI controller gives good response than any other controller.

V. SIMULATION RESULTS

In Figure 5 shows the simulation model of basic buck converter. In that model the MOSFET is used as a switch for the best performance of voltage control, fast switching and low losses. Here initially given input supply voltage is 5V. In that supply voltage will be maintain the constant output voltage in load resistance. There are three buck converter parameters are monitoring by using displays. When the MOSFET switch is closed supply voltage is connected to load and the load current starts to increase. When the MOSFET switch is opened, the freewheeling diode to maintain the continuous current path in the load.

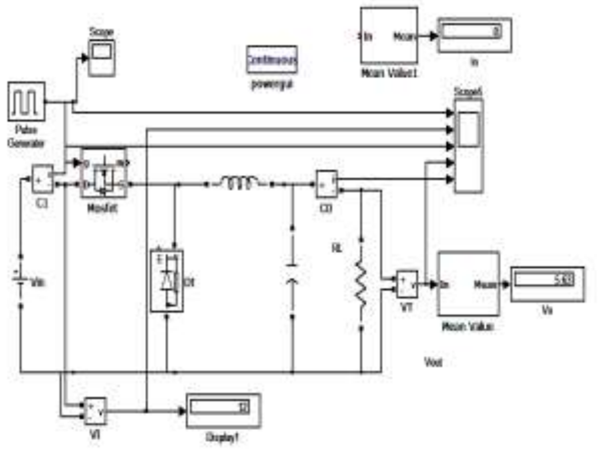

Figure 5: Simulation diagram of buck converter

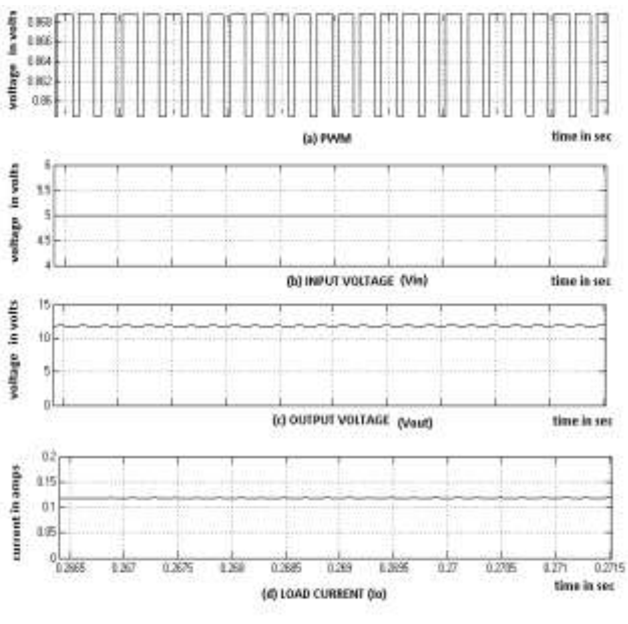

Figure 6: Simulation results of buck converter (a) PWM, (b) Input Voltage, (c) Output Voltage and (d) Load Current

The simulation circuit is necessary to get the output waveform. In input side we are giving 12V that voltage is getting in output side as 5.63V. The scope has four signals for PWM, Input voltage, output voltage, load current are shown in Figure 6(a), (b), (c) and (d).

In Figure 7 shows the simulation model of separately excited DC motor with PI controller. In that model the MOSFET is used as a switch for the best performance of voltage control, fast switching and low losses. Here initially given input supply voltage is 230V. In that supply voltage will be maintain the required output voltage to the load. In that PI controller output is act as the modulation index of the

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converter. The relational operator can be comparing the reference signal to the carrier signal. To set the maximum reference value of PI controller output is 0.6V. When the carrier signal voltage is more than reference voltage that time MOSFET go to OFF or 0 states. Otherwise the MOSFET maintain the ON or 1 state.

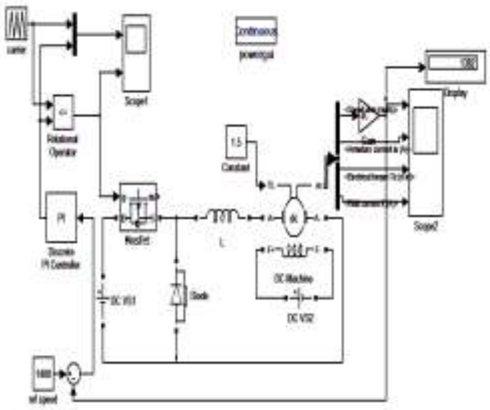

Figure 7: Simulation results of separately excited DC motor (a) Speed, (b) Armature Current, (c) Electrical Torque and (d) Field Current

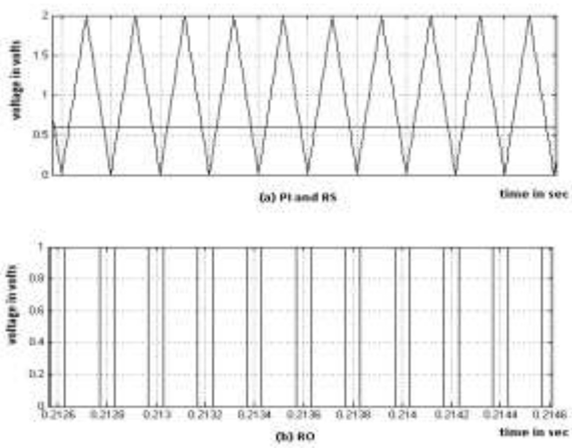

Figure 8: PWM Generation (a) PI and Triangular multicarrier and (b) PWM Pulses

The simulation circuit is necessary to get the output waveform. For the PWM generation, there are two signals given to the relational operator one from PI controller output signal and other from triangular carrier signal and the relational operator output is PWM signal, that signal is given to the switch. The Figure 8 shows the PI controller output and triangular multi carrier signal. The Figure 9(a), (b), (c) and (d) show the Speed, Armature Current, Electrical Torque, Filed Current of the separately excited DC motor.

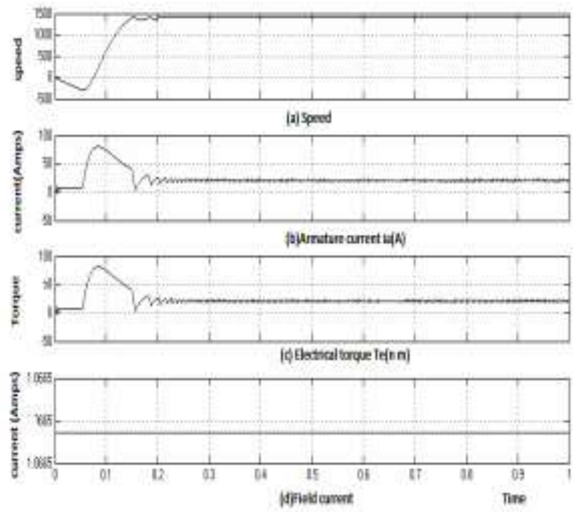

Figure 9: Simulation results of separately excited DC motor (a) Speed, (b) Armature Current, (c) Electrical Torque and (d) Field Current

VI. CONCLUSION

The speed of a DC motor has been successfully controlled by using Chopper as a converter and Proportional-Integral type controller as a speed and current controller based on the closed loop model of DC motor. 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. The MATLAB/SIMULINK model shows good results under below the rated speed during simulation. The simulation output creates the constant armature voltage and constant field current that time speed and torque of DC motor also produced constant output. Here using buck converters the switching losses will be reduced and motor efficiency are reach approximately more than 95%.

REFERENCES

[1].Varun rohit vadapalli, Hemanath Kumar Kella,T.Ravi Sekhar,Y.David Samson, N.Avinash, "Speed Control of dc Motor using Chopper", International journal of Electrical and, Electronics Research, vol.3, no.1, pp.289-285, 2015.

[2]. J. C. Basilio and S. R. Matos, Design of PI and PID Controllers with Transient Performance Specification, Vol .45, No.4, pp,364-370 2002.

[3].R.Nagarajan and M,Saravanan. "Performance Analysis of a Novel Reduced Switch Cascaded Multilevel Inverter," Journal of Power Electronics, Vol.14, No.1, pp.48-60. 2014.

[4].Dr.R.Nagarajan, S.Sathishkumar, K.Balasubramani, C.Boobalan, S.Naveen, N.Sridhar, "Chopper Fed Speed Control DC motor using PI controller", IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE),Vol.11,no.3, Pp.65-69, 2016.

[5].Jaafer Sadiq Jaafer, Mohammed Chessab Mahdi, "Speed control of Separately Excited DC Motor Using Chopper", Vol.11, No.1,Pp.26-35, 2013.

[6].K Smriti Rao, Ravi Mishra, "Comparative Study of P, PI, PID Control For Speed control of VSI-fed induction Motor", IJEDR,Vol.2, no. 2, Pp. 2740-2744, 2014.

[7]. R.Nagarajan and M, Saravanan, "Comparison of PWM Control Techniques for Cascaded Multilevel Inverter" International Review of Automatic control, Vol.5 No.6, pp. 815-828. 2012.

[8].I.Kavita, Dr.S.Selvaperumal, P.Nedumal Pugazhenthi, A.MohamedRajithkhan, R.Jagatheesan, "Performance Investigation of PI controller based chopper fed DC drives" International Journal of Science and Research, vol. 573, no.pp.19-25, 2014.

[9].AtulKumar Dewangan, Durga Sharma, Shikha Mishra, "PID controller Based Chopper fed DC motor drive using fuzzsy logic", International JournaL of Engineering Research and Application,Vol.2, no.3, Pp.1073-1081, 2012.

[10]. Sagar Sattigeri, Meghana Patil, Sumangala Huded &Mallappa Malashetti, ”Speed control of dc motor using Chopper”, Internation journal on resent technologies in Mechanical and Electrical Engineering, Vol.3, no.5, Pp.25-28, 2016.
[11]. Sugandhra Pal Singh, Deepak Kumar Singh, Harish Kumar,Rheesabh Dwivedi, ”Design and parametric variation of PI Controller for buck converter for constant voltage Application”, International journal of Engineering trends and Technologies,Vol.13,No.4, Pp.169-174, 2014.
[12]. Shridhar Kulkarni, Anurag Kokate, Pallavi Kembale Prajakta Bhore, ”Speed Control of separately excited dc motor using Power electronic converter”, International journal of Innovations Engineering Research And Technologies,Vol.2, no.4, Pp.2364-3692, 2015.
[13]. R.Nagarajan and M,Saravanan “Staircase Multicarrier SPWM Technique for Nine Level Cascaded Inverter,” Proceedings of the International Conference on Power, Energy and Control, IEEE Press,pp-668-675. 2013.
[14]. Moleykutty George, ”Speed control of separately Excited dc motor”, American journal of applied sciences, Vol.5,issue.3, Pp.227-239, 2008..
[15] S. Tharani, P. Palpandian, N. Gowthaman, ”Speed control of separately Excised dc motor using Optimization technique”, international journal of innovative Research in Computer and Communication Enginnering, Vol.2, issue.2, Pp.3924-3934, 2014.
[16] Miss. Pranoti Khanke, Assi. Prof. Sangeeta Jain, ”Speed Control of Separately Excited DC motor using Various Conventional Controller”, International journal of Engineering Research and Application, Vol.5, Issuse.4, Pp.67-72, 2015.
[17] Nazanin afrasiabi, Mohammadreza hairi yazdi, “DC Motor Control Using Chopper” Gobal Journal Of Science,Engineering and Technology, Issue 8, Pp.67-73, 2013
[18] Rishabh Abhinav, Jaya Masand, Piyush Vidyarthi, Gunja Kumari, Neha Gupta,” Separately Excited DC Motor by Using Four Quadrant Chopper” International Journal Engineering Research,Vol.4, Issue 1, Pp.1-3,2013
[19] Waleed I. Hameed and Khearia A. Mohamad,”Speed Control Of Separatly Excited DC Motor Using fazzy Neural Model Reference Controller”, vol.2, no.4, Pp.27-39, 2012
[20] Kaustubh S.Deshmukh, ”Speed Control of Separately Excited DC Motor Using Chopper”, International Research Journal Of Engineering and Technology, Vol.04, no.01, Pp.799-803, 2017
[21]. Saman Javed, Sumit Jha, Hasan Sajid, Vishu Kumar,”Speed Control Of Separatly Excited DC Motor Using Chopper”,International Journal Of Scientific Research and Management Studies,Vol.3, no.1, Pp-80-87, 2013
[22]. R.Nagarajan [1], R.Yuvaraj[2], V.Hemalatha[3], S.Logapriya[4], A.Mekala[5], S.Priyanga[6]"Implementation of PV - Based Boost Converter Using PI Controller with PSO Algorithm"International Journal Of Engineering And Computer Science (IJECS), https://www.ijecs.in, Volume 6 Issue 3, March 2017, 20477-20484, DOI: 10.18535/ijecs/v6i3.14

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