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Comparative Assessment for Speed Control of D.C Motor Using Buck Converter

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Abstract-— **The purpose of the paper is to manipulate the separately excited DC motor via the usage of the strength electronic IGBT (Insulate Gate Bipolar Transistor). The speed of separately excited DC motor may be manipulated by using varying the armature terminal voltage. In this way the speed may be controlled for above rated speed and under the rated speed respectively. In this model, the speed of motor up to and below the rated speed may be achieved via changing the armature voltage. The voltage of armature terminal may be precise by using IGBT or MOSFET established chopper. The IGBT chopper get the signal from controller and adjustable voltage is given to the armature of dc motor according to the specified speed. The main benefits to apply this method is that the speed varies proportionally with armature terminal voltage and varies inversely with subject terminal voltage with the help of maintaining the voltage of discipline and armature steady respectively. The PI controller is finding for isolation of delay and presents very fast manage. The version of one after the other excited DC motor is designed and the general format of DC force mechanism is obtained. By the assessment of triangular carrier signal with reference signal we get the PWM pulse for chopper switch. The simulation version is designed within the MATLAB/SIMULINK. The simulation output parameters of simulation model of DC motor such as; armature current, armature voltage, torque, speed, field current is analyzed.**

Keywords - Armature Voltage control, DC/DC Buck converter, Proportional Integral (PI) controller. PWM generator, separately excited DC motor.

I. INTRODUCTION

The development of high-performance motor drives may be very necessary for industrial application and demanding more robust and higher performance drives [1]. To meet the standards of industrial packages, a good overall performance drive system should hold load regulating response and dynamic speed command tracking. The high-performance motor drives system should have appropriate dynamic speed command tracking and load regulating reaction. DC motor drive provide quality control of speed for deacceleration and acceleration [2]. The step-down converter is delivering the high -quality performance of the DC-DC buck converter. The chopper circuit use for power semiconductor devices used for force commutated thyristor, power MOSFET, IGBT, BJT, and GTO based chopper are used. These semiconductor devices have very low switching losses because of this the general voltage drop has 0.5V to 2.5V throughout them [3]-[7]. DC motor are capable of supplying beginning and accelerating torque in Excess of 400% of rated speed [8]-[9]. Where chopper convert the fixed DC voltage to variable DC voltage. The speed of DC motor is control by use of the controlled chopper circuit. For variable speed drives separately excited and series DC motor are typically use. Two strategies for speed manipulate of DC motor are traditionally armature voltage using rheostatic method for low power DC motor , use of traditional PI controller, single phase uniform PWM AC-DC buck converter with only one switching tool used for armature voltage manipulate, the use of NARMA-L2 (Non-linear Auto-Regressive Moving Average) controller for the constant torque region.

Large experience had been received in designing trajectory controllers primarily based on self-tuning and PI manipulate. The PI controller speed manipulate has so many blessings like low value fast manage and simplified structure. In this paper in particular we address controlling of speed for DC motor the use of DC to DC chopper as power converter and PI controller [10]. Here we use pulse width modulation (PWM) signal to the converter with respect to the motor input voltage it’s one of the methods most hired to power a DC motor.

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However, the underlying hard switching strategy causes an unsatisfactory dynamic behavior.

II. BUCK CONVERTER

DC-DC buck converter also known as chopper. Buck converter is use to step down the input DC voltage to a targeted DC output voltage. The input voltage source is without delay related to a controllable solid-state tool which work as a switch. The switching device may be IGBT. We cannot use thyristor a switch for DC-DC converters because the turn OFF method of thyristor in a DC-DC circuit required any other commutation circuit. However, the power MOSFET and IGBT can be turn OFF through making use of the voltage between GATE and SOURCE terminal of a MOSFET and for IGBT voltage among GATE and COLLECTOR terminal must go to zero.
The diode is use as a second switch. The diode and switch are linked in a manner of low pass LC clear out which is mainly made for reduction of ripples of voltage and current. Here resistive load is considered. For DC-DC converter deliver voltage and load current is constant. The load may be seen as current source.

The turn ON and turn OFF method of strong state transfer involve pulse width Modulation (PWM). PWM may be time based totally or frequency based totally. But the one big downside with frequency primarily based PWM is very big variety of frequency is required for purchasing main manipulate of transfer to get the specified output voltage.
Another trouble with frequency primarily based PWM is the designing is complicated for LC low pass filter out and the LC clear out is needed for controlling the wider range of frequencies. So, DC-DC converter use time primarily based modulation as it's simple shape and easy in use. The time primarily based PWM use constant frequency.

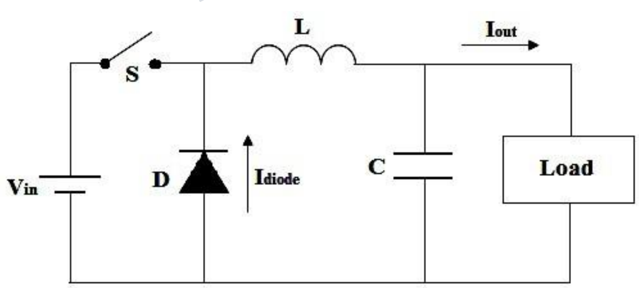

Fig.1. Buck converter

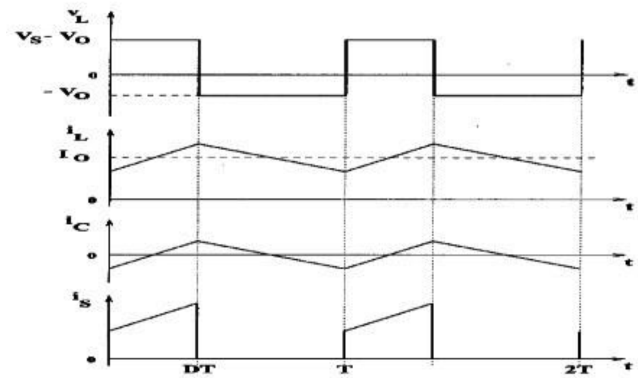

Fig.2. Output Voltage and output current waveform

In fig.2 indicate the connection among the supply voltage and voltage at output terminal, current through inductor , and current in capacitor , and the duty ratio of switch which can be derived, for instance, from the inductor voltage , for the buck converter DC output voltage , described as the multiplication of the input voltage and the duty ratio

$$V_o = V_s \; D \qquad (1)$$

From the equation (1) we can see that the voltage at output terminal is always less then to input voltage because duty ratio is always lie in between zero and one [11].
Assume that the turn ON and turn OFF time of switch is defined in term of T_{ON} for turn ON and T_{OFF} for OFF time. The time period, T, is defined as

$$T = T_{ON} + T_{OFF} \qquad (2)$$

And the frequency of switch is,

$$f_{switching} = \frac{1}{T}$$

$$D = \frac{T_{ON}}{T}$$

therefore the flux is constant for separately excited DC motor [12]. Applying Kirchhoff's voltage law (KVL) to the circuit in Fig 3, will result in armature voltage Equation (3) and the torque Equation (4).

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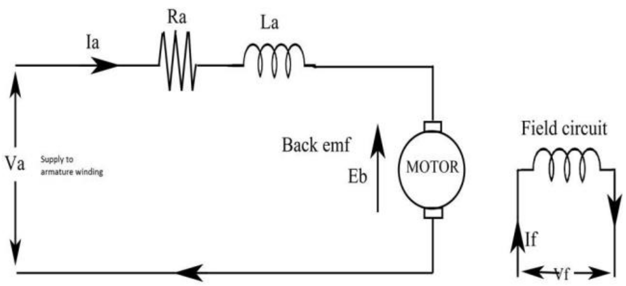

Fig 3: Equivalent circuit of separately excited dc motor

$$V_a = E_b + I_a R_a + L_a \frac{dI_a}{dt} \quad (3)$$

$$T_d = J\frac{d\omega}{dt} + T_L + B\omega \quad (4)$$

The developed Torque and back emf of the motor are written below:

$$T_d = K_a \Phi I_a \quad (5)$$

$$E_b = K_a \Phi \omega \quad (6)$$

From circuit diagram we can write

$$E_b = V_a - I_a R_a \quad (7)$$

Where
V_a = voltage across armature winding (Volts)
Ra = Resistance of armature winding (Ω),
La = armature inductance (H),
Eb = motor back emf (Volts),
I_a = current in armature (Amps),
TL= load torque(N-m),
J = Moment of Inertia (Kg/m2),
B = friction coefficient of motor,
Td= developed torque (N-m),
ω= angular velocity (rad/sec),
Φ= flux developed (Weber's),
Ka= armature constant.

Thus, from the above Equation (6), back emf of the DC motor may be controlled via armature voltage, armature resistance and field flux. By controlling the back emf we can also manipulate the speed of DC motor [13]. For the speed control of DC motor there are three methods in which the armature voltage manage technique give a easy version of speed manage from zero to base speed. Base speed is described as the speed obtained at rated deliver voltage. Let assuming the frication to be negligible in motor (B=0) Equation (4) can be decreased to Equation (8).

$$T_d = J\frac{d\omega}{dt} + T_L \quad (8)$$

IV. GENERAL REPRESENTATION OF COMBINED MODEL FOR SPEED CONTROL OF SEPARATELY EXCITED DC MOTOR

The preferred representation of combined model for speed manipulate of separately excited DC motor as show in fig.4 has three blocks. The three blocks are DC-DC converter block, motor block and controller block. The first block is DC-DC converter (step down converter) that take input from voltage supply and then step down the voltage for the second one block consisting of separately excited DC motor. The controller block is with tachometer for measurement of speed of DC motor and after measurement this speed is evaluate with reference speed and the error signal is furnished to controller. The controller then reduces this error signal. The 240V DC deliver is given to the input side. It is in addition linked to the step-down converter section. The output of stepdown converter is given to the armature a part of the DC motor. In comparator compare the both tachometer speed and reference speed. The error signal produced through comparator is send to the PI controller. PI controller reduce the error signal and give constant signal to the PWM generator. The triangular carrier and output signal are as compared through the PWM generator of the PI controller. At closed the output of PWM pulse is given to the buck converter as a feedback.

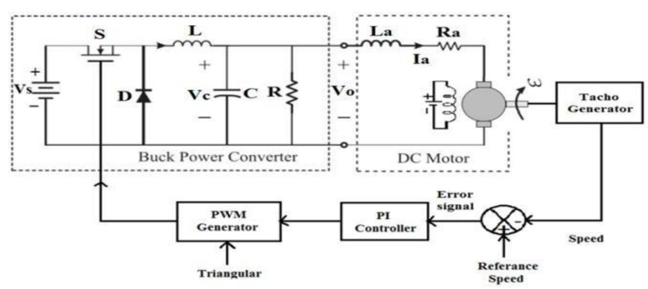

Fig.4. General representation of combined model

III. MODELLING OF SEPARATELY EXCITED DC MOTOR

The armature winding of separately excited DC motor is not depending on field winding. The field current is kept regular

V. CONTROLLERS

A. PROPORTIONAL CONTROLLER -
All controllers have individual meaning. Selection of controller is not random it's depended on system and few conditions must be satisfied. For P controller there are two condition are given below and they must be satisfied.

1. The deviation between input and output should not be large.
2. The change in deviation should not be fast.

The output of proportional controller is directly proportional to input signal (error signal). The mathematically form of proportional controller is below.

$$A(t) \propto e(t)$$

Removing the sign of proportionality of error signal, we have,

$$A(t)= K_p \times e(t)$$

Where, K_p *is proportional constant some time it is also called controller gain.*
The value of K_p should be kept greater than 1. If the value of K_p is not greater than one (>1), then it will not amplify the error signal and thus the amplified error signal cannot be found out easily.

B. PI CONTROLLER-
However, in terms of the speed of the response and overall stability of the system, it has a negative impact. PI controller is particularly use in which speed of the system is not always an important. Since the errors in future of the system is not predict by using PI controller it cannot take away the oscillations and reduce the rise time. The PI controller use bode method for the current loop. The 0-db intercept of 1/Js (1+Tis) is normally much too small. This is use due to its simple structure, because of simple structure it could be without difficult understood and apply in practice, and that many complicated manage strategies. Different value of PI gain is required for the application of large speed as compare to fixed speed application. For larger industrial equipment the range of operating speed is wider so they required different value of gain for different speed, requires in order to avoid oscillations and overshoots. Generally, tuning of proportional and integral is major problem because the cost is very high and it is time consuming for a large speed control process. The combined control scheme of a proportional and integral controller is express as below:

$$u\ (t) = K_p + Ki \qquad (9)$$

Where: u (t) is actuating signal. e (t) is error signal.   is Proportional gain constant. Ki is Integral gain constant. The Laplace transform of the actuating signal incorporating in proportional plus integral control is

$$U(s) = K_p + Ki \qquad (10)$$

C. PID CONTROLLER
The working precept behind a PID controller is that the proportional, integral and derivative terms should be individually adjusted or "turned". Based on the difference between these values a correction component is calculated and implemented to the input. For example, if an oven is cooler than required, the heat may be increased.

VI. SIMULATION MODELLING AND RESULT ANALYSIS

The simulation modelling is done in MATLAB2014. The simulated model is used for Comparative Assessment for speed control of DC motor using buck converter. The switching device is use in simulation is IGBT due to good performance of speed control and low losses high switching frequency. Here rating of separately excited DC motor is 5HP, 240V, 1750 rpm and additionally 300V DC supply are given to the field. Constant load of 20Kg is used at load terminal. The reference signal to the carrier signal is compare by relational operator. Switch IGBT should be off when reference voltage is less than carrier signal voltage otherwise the IGBT will maintain ON.
The simulation model for separately excited DC motor with discrete P controller is shown in fig.6. As shown in fig.7 the speed of DC motor is above the rated speed more than 1600rpm. It is observed that only discrete P controller not able to control the speed. So discrete PI controlled is added in simulation model as shown in fig.8.

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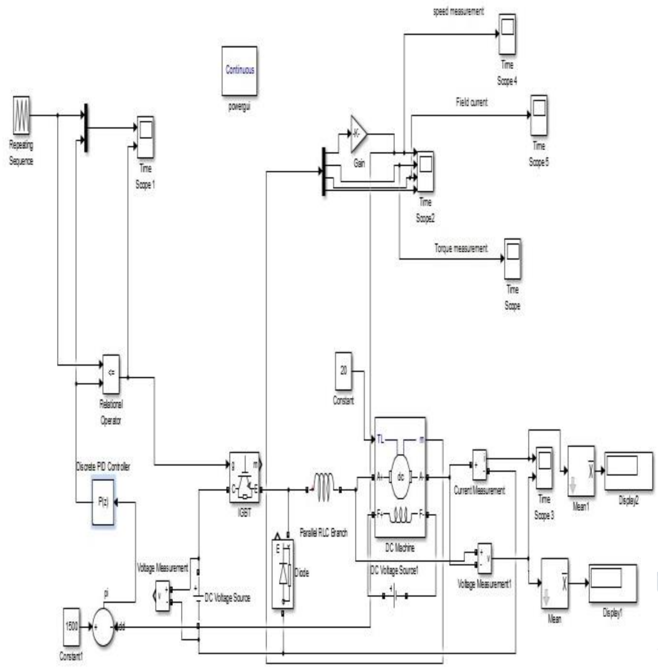

Fig 6. Simulation model of separately excited DC Motor using step down converter and P controller.

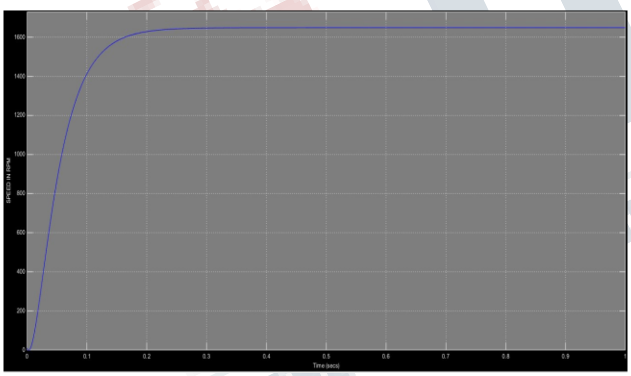

Fig. 7. Simulation output of D.C motor Speed (RPM) Using P Controller

The speed of DC motor as shown in fig.9 is between 1500rpm to 1600rpm. The speed is not equal to reference value but better then discrete P controller.
To get the preferred speed that is 1500 rpm PID controller is connected in simulation model. Fig.10 show the simulation version for speed control of DC motor with PID controller. Fig.11 display that the speed of DC motor is equal to reference speed. The variation of developed torque, armature current and field current the use of P, PI and PID are show in Fig.12, Fig.13, and Fig.14, respectively.

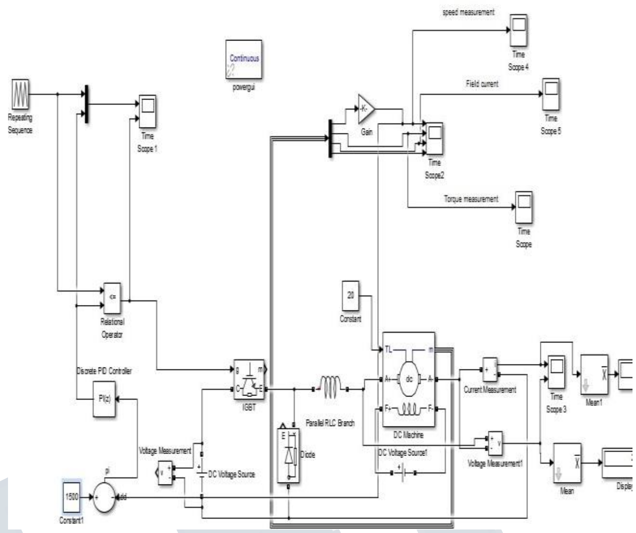

Fig 8. Simulation model of separately excited DC Motor using step down converter and PI controller.

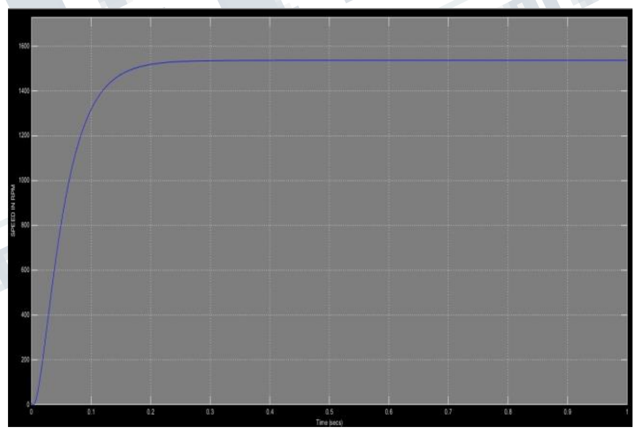

Fig. 9. Simulation output of D.C motor Speed (RPM) Using PI controller

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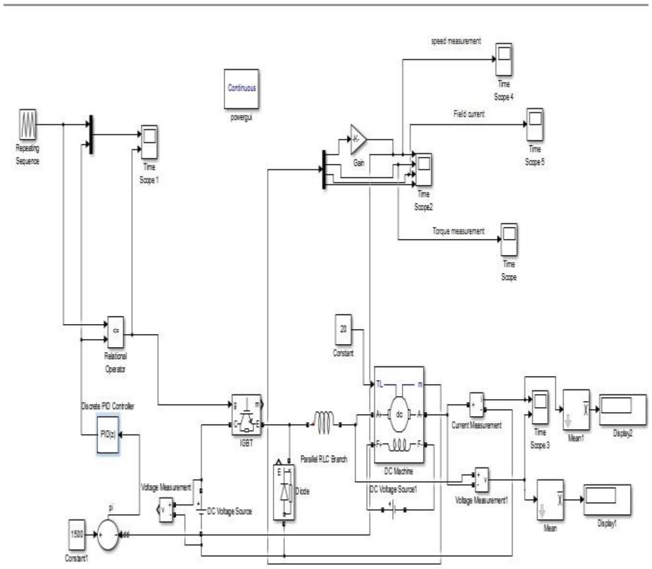

Fig 10. Simulation model of separately excited DC Motor using step down converter and PID controller.

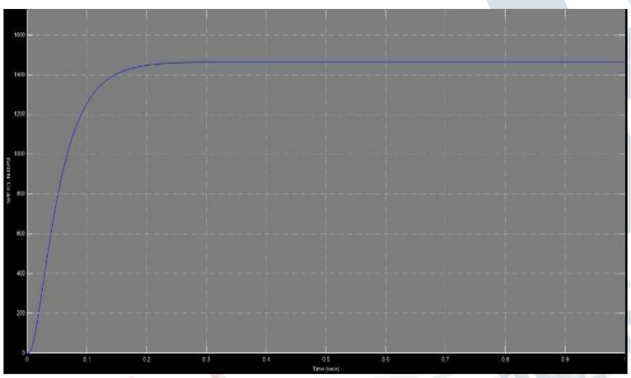

Fig. 11. Simulation output of D.C motor Speed (RPM) Using PID Controller.

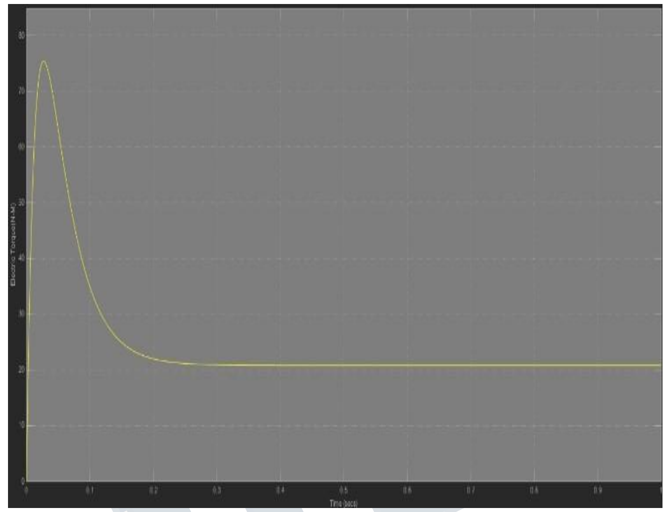

Fig. 12. Simulation output of D.C motor Torque(N-M) Using P &PI &PID Controller.

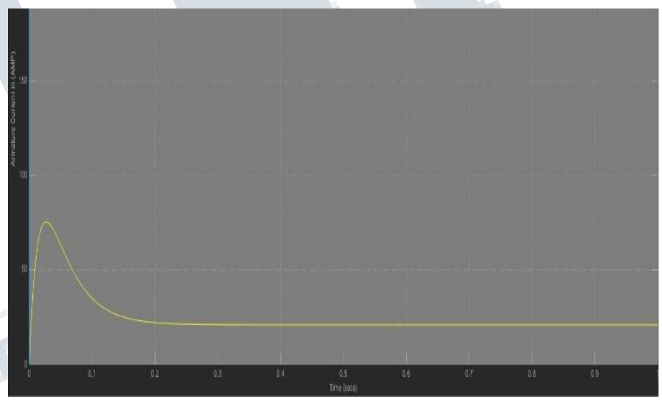

Fig.13. Simulation output of D.C motor Armature current in (AMP) Using P &PI &PID Controller

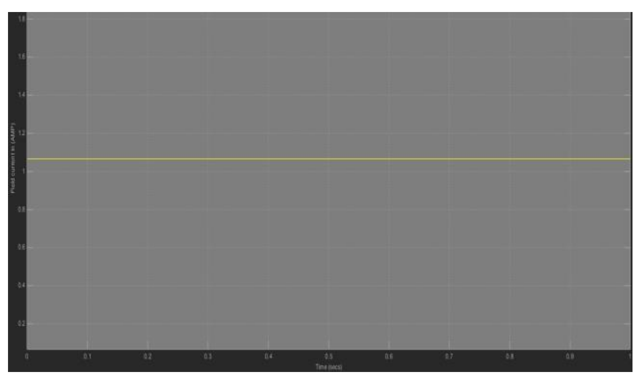

Fig.14. Simulation output of D.C motor Field current in (AMP) Using P &PI &PID Controller

VII. CONCLUSION

Simulation model is designed for speed control of separately excited DC motor using buck converter and P, PI & PID controller circuits. When using P controller alone the speed is more than reference speed. When using PI controller alone the DC motor speed is nearly equal to reference speed. In both the cases the speed is not controlled up to the desired value. To get the desired output we combine the P controller, I controller and D controller. It is analyzed that using PID controller the output speed is equal to the reference speed that is 1500rpm. The Buck converter is used to step down the DC input voltage as the it causes low losses. The simulation output shows the constant armature voltage and constant field current and torque with time for DC motor using PID controller. The value of dc motor torque is lie between 70 to 80 N-M for P,PI &PID controller. Similarly, the armature current of DC motor is near about 70 AMP. And the value of field current is near about 1.05AMP.

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