JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

DC MOTOR SPEED CONTROL USING P.I CONTROLLER

SHADAB.N. SAYYAD
Department of Electrical Engineering, Government College of engineering, Aurangabad (M.S.), India
Mr. W. A. Gavhane
Assistant Professor, Department of Electrical Engineering, Government College of engineering, Aurangabad (M.S.), India

Abstract: This paper describes the methodology of speed control by understanding the control method of DC motor, definitely, armature and field resistances in addition to armature voltage control methods. The speed of the DC motor is controlled PI controller as a donor during this work. Using Matlab simulation and practical measurements, DC motor speed control is achieved during this work. The results obtained from the Matlab simulation circuit appeared approximately similar that obtained by practical connection. In this activity, we will design and implement a speed controller for a simple DC motor. In particular, we will choose and tune the gains of a PI controller based on the effect of the gains on the system's closed-loop poles while accounting for the inherent uncertainty in our model. We are going to design the controller to realize the desired level of transient response and can examine very well the steady-state error produced by the resulting control system, including within the presence of a continuing disturbance.

***IndexTerms* - Armature control DC Motor DC motor control Field control PI controller.**

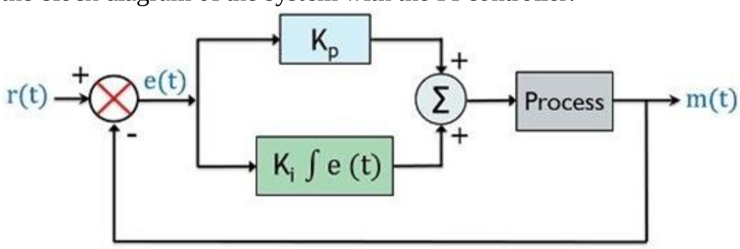
I. INTRODUCTION

The development of technologies affects the demands of industries at the present time. Thus, automatic control has played a vital role in the advance of engineering and science. In today's industries, control of DC motors is a common practice. Therefore, the implementation of a DC motor controller is required. There are many types of controllers that can be used to implement elegant and effective output. One of them is by using a PI controller. PI stands for Proportional and Integral Controllers which are designed to eliminate the need for continuous operator attention thus providing automatic control to the system. Cruise control in a car and a house thermostat are common examples of how controllers are used to automatically adjust some variable to hold the measurement (or process variable) at the set-point. This project focuses on implementing a PI controller to control the speed of a dc motor. The first part concerns the simulation using MATLAB Simulink where the dc motor is modeled and the PI controller is tuned using Ziegler-Nichols rules and software tuning. The second part is implementing the simulation. Graphical User Interface (GUI) development and hardware interfacing. As the result, the PI controller is capable to control the speed of the dc motor following the result of the simulation.

In the proportional-integral controller, the control action of both is proportional and similar because the integral controller is employed. This mix of two different controllers produces a more efficient controller which eliminates the disadvantages related to all of them. During this case, the control signal shows proportionality with both the error signal and like integral of the error signal. Mathematical representation of proportional plus integral controller is given as:

$$m(t) = K_p\, e(t) + K_i \int e(t)$$

The figure below represents the block diagram of the system with the PI controller:



1. Proportional Controller:

Proportional controllers are referred to as the type of controllers in which the output signal shows proportionality with the error signal. It is given as

$$m(t) \propto e(t)$$
$$m(t) = K_p\, e(t)$$

2. Integral Controller:

Integral controllers are the type of controllers where the output is proportional to the integral of the error signal. This is given as

$$m(t) \propto \int e(t)$$

$$m(t) = K_i \int e(t)$$

It is to be noted here that one can use integral controllers separately without combining them with proportional controllers. However, generally proportional plus integral controllers are used combined to overcome the disadvantage of integral controllers. a significant disadvantage which is related to the integral controller is that these are quite unstable. the rationale behind this can be that integral controllers show somewhat slow responses toward the produced error. However, the foremost advantage concerning the proportional controller is that these are designed in a way by which steady-state error gets reduced significantly thereby making the system more stable.

This is the reason the two are combinedly used to produce a type of controller which provides highly stable results.

Proportional Integral Controller:

Till now we have discussed what proportional and integral controller is individual. So, let us now understand how the two are combined. So, in this, the control signal is formed by merging the error and integral of the error signal.

This is given as:

$$m(t) \propto e(t) + \int e(t)$$

In order to have the transfer function of the controller, we need to consider the Laplace transform of the above equation, so it is given as

$$M(s) = K_p E(s) + K_i \frac{E(s)}{s}$$

Taking the common term i.e., E(s) out, we will get

$$M(s) = E(s) \left[K_p + \frac{K_i}{s} \right]$$

It is to be noted here that the error signal will act as input that will cause variation in the output of the controller.

Thus on transposing E(s) to the LHS, we will get

$$\frac{M(s)}{E(s)} = K_p + \frac{K_i}{s}$$

On further simplification, we will get

$$\frac{M(s)}{E(s)} = K_p \left[1 + \frac{K_i}{K_p s} \right]$$

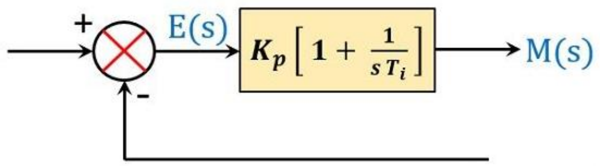
Thus it can be written as:

$$\frac{M(s)}{E(s)} = K_p \left[1 + \frac{1}{T_i s} \right]$$

This equation represents the gain of the PI controller.

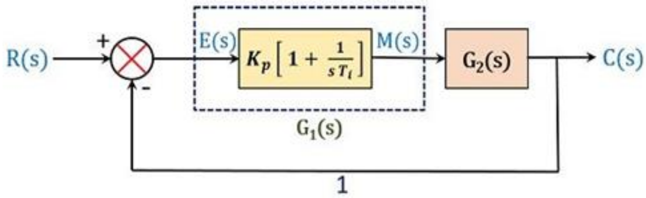
: Ti = Kp / Ki

So, the block diagram of a PI controller is given as:



Effects of PI Controller:

To understand the effect of PI controller, consider the PI controller with unity negative feedback given below:



Suppose the gain of the controller is given as G1(s) whose value we have recently evaluated as:

$$K_p \left[1 + \frac{1}{T_i s} \right]$$

And let the open-loop gain of the system be G2(s), given as

But the overall loop gain of the system will be

$$\frac{\omega_n^2}{s(s+2\zeta\omega_n)}$$

So, on substituting,

$$G(s) = K_p\left[\frac{1+T_i s}{T_i s}\right].\frac{\omega_n^2}{s^2+2\zeta\omega_n s}$$

We know that the gain of the closed-loop system or overall controller is given as:

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$$

Since we have already considered the unity feedback system.
Therefore, H(s) = 1

Thus the gain will be given as,

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)}$$

On substituting the values we will get,

$$\frac{C(s)}{R(s)} = \frac{K_p\left[\frac{1+\ T_i s}{T_i s}\right].\frac{\omega_n^2}{s^2+2\zeta\omega_n s}}{1+K_p\left[\frac{1+\ T_i s}{T_i s}\right].\frac{\omega_n^2}{s^2+2\zeta\omega_n s}}$$

$$\frac{C(s)}{R(s)} = \frac{K_p(1+\ T_i s)\omega_n^2}{T_i s\,(s^2+2\zeta\omega_n s)+\ K_p(1+\ T_i s)\omega_n^2}$$

$$\frac{C(s)}{R(s)} = \frac{K_p(1+\ T_i s)\omega_n^2}{T_i s^3+2\zeta\omega_n s^2 T_i+\ K_p\omega_n^2+K_p\omega_n^2\,T_i s}$$

Taking Ti out from the denominator, we will get

$$\frac{C(s)}{R(s)} = \frac{K_p}{T_i}\frac{(1+\ T_i s)\omega_n^2}{s^3+2\zeta\omega_n s^2+\frac{K_p\omega_n^2}{T_i}+K_p\omega_n^2\,s}$$

Since we know
Ti = Kp / Ki
So substituting Kp/Ti as Ki in above equation we will get

$$\frac{C(s)}{R(s)} = K_i\frac{(1+\ T_i s)\omega_n^2}{s^3+2\zeta\omega_n s^2+\frac{K_p\omega_n^2}{T_i}+K_p\omega_n^2\,s}$$

We have already discussed that PI controllers are designed to decrease steady-state error. And in order to cause a reduction in steady-state error, the type number must be increased. It is to be noted here that the type number of the controller is defined by the presence of in the transfer function. The above equation clearly indicates that the power of 's' is showing a significant increase in the transfer function. This implies the rise in the type number which resultantly causes a reduction in steady-state error.

When the PI controller is not present in the control system then there will be the absence of 's' in the numerator which will cause the absence of zeros in the transfer function. So, we can say by introducing PI controllers in a control system, the steady-state error of the system gets extremely reduced without affecting the stability of the system.

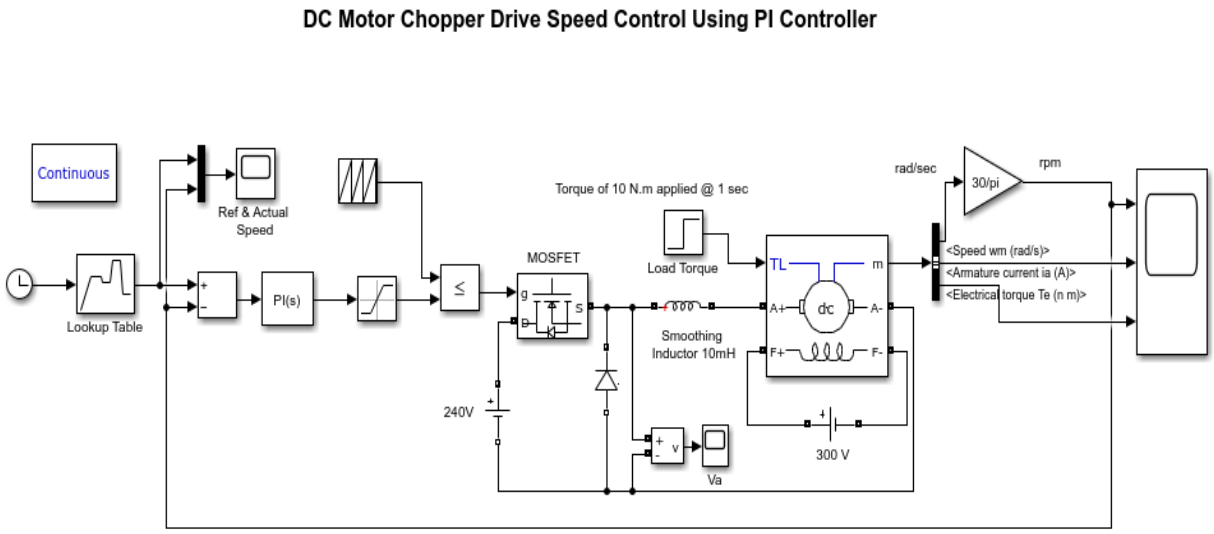


Fig.1: Simulation model of DC Motor.

II. RESULTS AND DISCUSSION

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. Those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or Fortran.

DC Motor Chopper Drive Speed Control using PI Controller simulation model:

In this 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 240V (5HP, 1750 RPM). In this setup, the supply voltage will be maintaining the required output voltage to the load. In that, the PI controller output is acting as the modulation index of the converter. The relational operator can be differentiating the reference signal from the carrier signal. To set the maximum reference value of PI controller output is 0.6V. When the carrier signal voltage is more than the reference voltage that time MOSFET goes to OFF or 0 states. Otherwise, the MOSFET maintains the ON or 1 state. The bias voltage is also used in this model. The bias voltage is a low DC voltage, typically somewhere between 1.5 and 9.5V DC, used to power electronic circuitry located inside a condenser (or capacitor) type microphone's capsule. The bias voltage is necessary when the error feedback from the output of the DC motor is zero so that the input from the PI controller never reaches to zero. This provides the stable operation of the control system but there is a small steady-state error. An array to-step signal converter is also used in this simulation model. It is placed in series with the output of the PI controller. The converted step signal is then compared with the bias and the result is fed to a MOSFET When the carrier signal voltage is more than the reference voltage, that time MOSFET goes to OFF or 0 states. Otherwise, the MOSFET maintains the ON or 1 state. The output of this MOSFET is connected to the cathode terminal of a diode. This ensures the unidirectional flow of current. Another branch of the MOSFET output is also connected to a smoothing inductor (10 mH). It is a static electromagnet unit intended to reduce higher harmonics (ripples) in the rectified current by their inductance. The ripples should be in the range of up to 10% of DC's current value. The smoothing inductor is usually connected in series with a rectifier, so that the load current flows through it, in full. Please note that only the variable component of the current is limited, therefore, the electrical loss in the unit is minimal. The steel core allows for reducing the magnetic loss and creates a significant inductance with small dimensions.

Observations

Case 1: In this case the values of the proportional tuning constant and the integral tuning constant are set to 0.001 and 0.02 respectively. We can see from the MATLAB graph above:

1. Comparison of Gain with Armature current:
   Current becomes stable when there is a steady rise in the gain. When the gain is fairly constant, the current graph reflects this with some instability. We also observe that the armature current becomes stable when the gain is constant. However, when there is a drop in gain, the current becomes zero.

2. Comparison of Gain with Electrical torque:
   The behavior of electrical torque with respect to gain is identical to that of the armature current.

3. Voltage smooth and stable operation can be evaluated.

Table No.1:

Block	Parameters
MOSFET	
FET Resistance	0.1
Internal diode	0.001
Snubber resistance	1e5
Inductor	Smoothing Inductor 10mH
DC Machine	
Model	5HP 240v 1750 RPM
Input	Mechanical Torque
PI Controller	
P	0.001
I	0.02
Zero Crossing	True

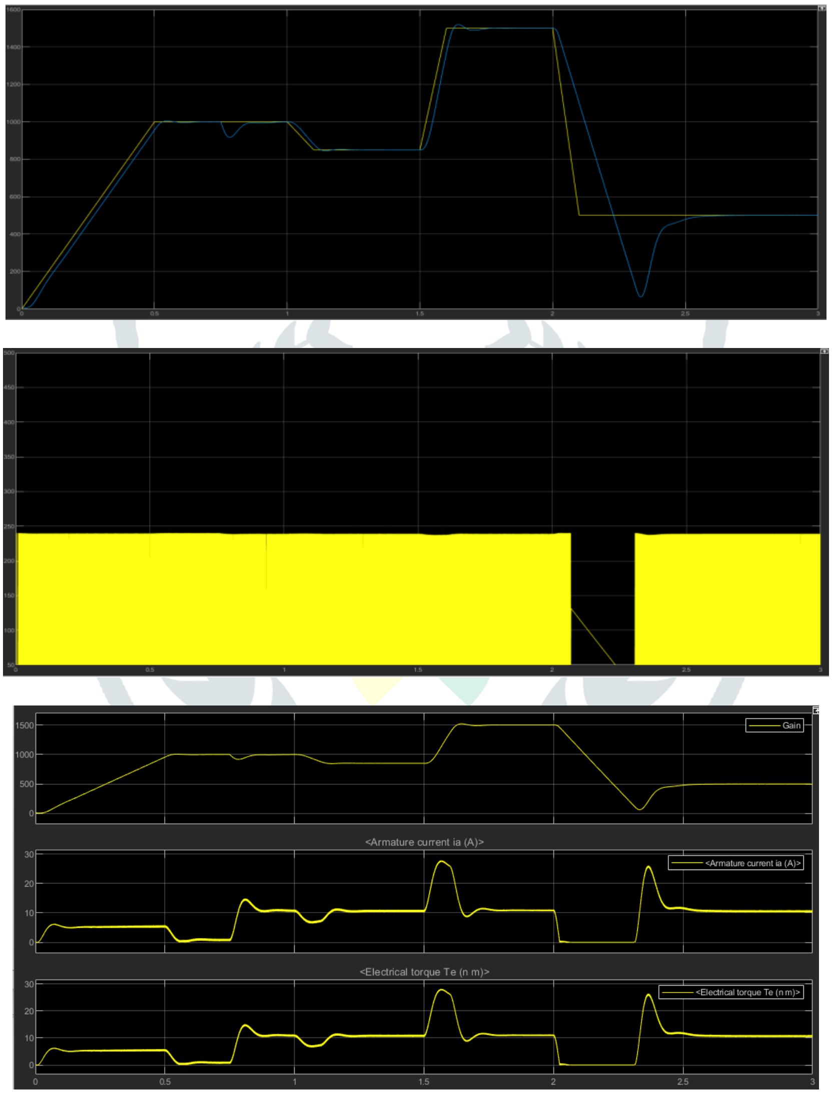


Figure 2: proportional tuning constant and the integral tuning constant are set to 0.001 and 0.02 respectively

Here the freewheeling diode is to maintain a continuous current path in the armature. The discrete PI controller gain is chosen by the trial and error method. In that PI controller output acts as the modulation index of the 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 0.9V. When the carrier signal voltage is more than the reference voltage that time IGBT goes to OFF or 0 state. Otherwise, the IGBT maintains the ON or 1 state. Fig. shows the PWM Pulse generation for the converter. The outputs of the simulation results are shown in.

Case 2: In this case, the values of the proportional tuning constant and the integral tuning constant are set to 0.005 and 0.07 respectively. We can see from the MATLAB graph below:

1. Comparison of Gain with Armature current:

The behavior of armature current with respect to gain in case 2 is similar to that of case 1. The difference here is that whenever there is rise or fall in gain, we observe destabilizing ripples in the armature current.

2. Comparison of Gain with Electrical torque:

   The behavior of electrical torque with respect to gain is identical to that of the armature current.

3. Voltage is unstable and found many ripples over voltage changes and torque over EMF changes**.**

Table No.2:

Block	Parameters
MOSFET	
FET Resistance	0.1
Internal diode	0.001
Snubber resistance	1e5
Inductor	Smoothing Inductor 10mH
DC Machine	
Model	5HP 240v 1750 RPM
Input	Mechanical Torque
PI Controller	
P	0.005
I	0.07
Zero Crossing	True

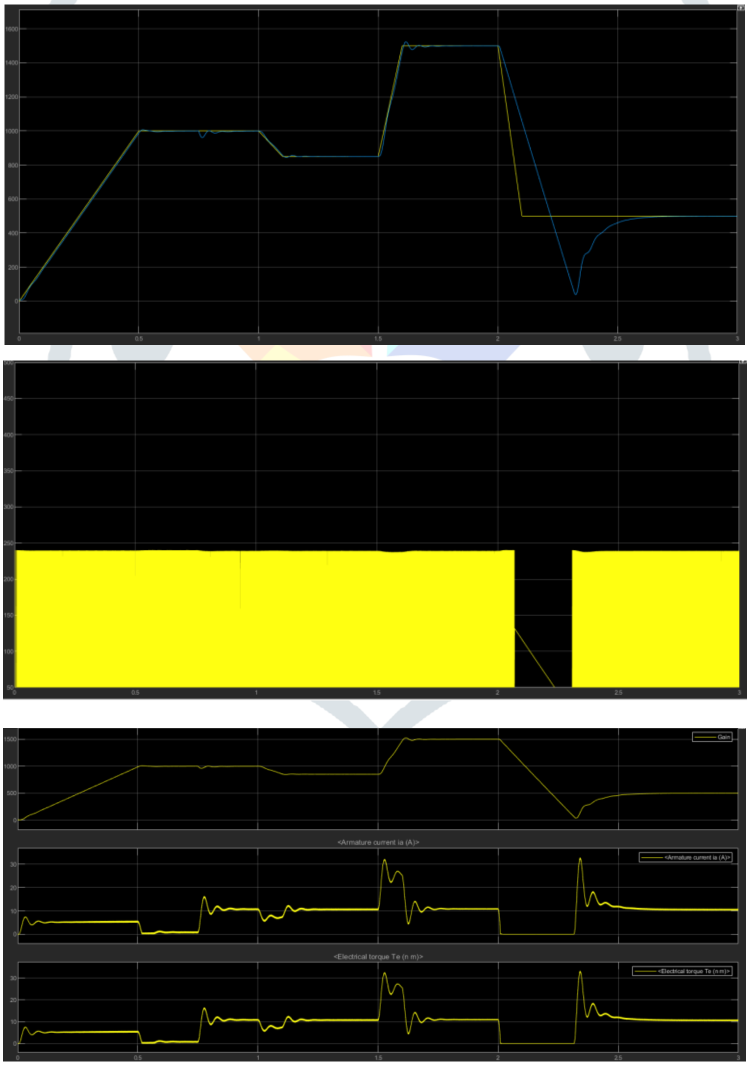


Figure 5: In this case the values of the proportional tuning constant and the integral tuning constant are set to 0.005 and 0.07 respectively.

The other terminal of this smoothing inductor is fed to the DC chopper. The output is taken in three forms i.e. rotation speed (rad/sec), current (armature current Ia) and torque (Electrical torque Te in N-m). The rotation speed output of the chopper is in radians per second. We need this in RPM to give feedback to the PI controller. Hence we use a 30/pi converter for this purpose.

CONCLUSION:

The analysis of the output of a DC motor chopper drive using PI controller in the form of three parameters i.e. Gain, Armature current and Electrical torque with respect to the values of proportional tuning constant and integral tuning constant of the PI controller reveals that the if these tuning constants are above a certain threshold, then armature current and electrical torque undergo unstable ripples at regular intervals (whenever there is a change in the gain).

- Hence, voltage is unstable and found many ripples over voltage changes and torque over EMF changes.
- However, if the threshold is not overshot then voltage is smooth and stable operation can be evaluated.

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.Mohamed Rajithkhan, 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