International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Sensorless Speed Control of Permanent Magnet DC Motor Using PI Controller

Dhiraj Mahajan[1], S. R. Lengade[2]

[1]PG Student, Department of Electrical Engineering, AISSMS COE, Pune, India

[2]Assistant Professor, Department of Electrical Engineering, AISSMS COE, Pune, India

Abstract: ***Many brushed DC motor applications require precise speed and position control, thus requiring a sensor feedback. Commonly a separate rotary encoder is required to provide speed and positional feedback to the system with additional cost. To minimize cost of drive, we required sensorless algorithm to be implemented.This paper describes back EMF based closed loop control of DC motor for controlling the speed of motor. Output speed is continuously compared with set point based on back EMF measured and generated error signal is provided to PID controller. The resulting closed loop system gives linear relationship between back EMF and DC motor speed.***

Keywords: Brushed DC Motor, Back EMF speed measurement, Arduino microcontroller, PI algorithm

1. Introduction

Brushed DC motor is one of the oldest yet versatile electrical machine ever created. Brushed DC motor is found in almost every day-to-day machine such as ink jet printers, automated vacuum cleaners, robotic manipulators, DVD drives, electric trains, automotive power windows and battery powered hand-drill although brushless DC motors have swiftly taken over many brushed DC motor applications [1].

There are different types of control strategies have been proposed to control the speed of DC motors.In general, the Open Loop Control System, it cannot correct the variation in output automatically. In these systems the output remains constant for a constant input signal. By approximately changing input output may change to desired value and variations in external Conditions may cause the output to change [4].In closed Loop Control System, it can correct the variation in output automatically. In these systems the output remains constant for a changing input signal. The measured response of the system is compared with a desired response of the system. [4].

To acquire the precise motor speed and position control, it is necessary to include some sort of feedback mechanism in the system. Speed feedback is implemented in two ways. The first involves the use of a direct speed or position sensor which is mounted on the motor shaft. The second uses some kind of sensorless scheme [2]. There are various types of sensors used for speed/position feedback such as optical encoders, tachogenerators, hall effects, etc.

A closed loop system has to be employed for better accuracy and precision [3]. This paper describes back EMF based closed loop control of DC motor. In this method, to measure back EMF (Electro Motive Force) and it is use as a function of DC motor speed. Back EMF is the voltage produced across the DC motor during its running condition, and is linearly proportional to the speed of DC motor [3]. The calculated speed is continuously compared with set point.The error is corrected by a discrete PID controller.

The various types of control algorithm, e.g. Two mode, Three mode, fuzzy logic, etc. are used for accurate and precision speed control. PID control algorithm is one of the most effective solutions and widely used for motor speed control with high accuracy [3].

In this paper section I gives Introduction. Proposed work and system flow is given Section II. Section III gives introduction to the PID controllers and importance of the DC motor. Software design, Hardware components and its implementation is discussed in Section IV. Section V describes results of proposed system. Finally, conclusion is given in Section VI.

2. Control Scheme

A. Block diagram of a Proposed system:-

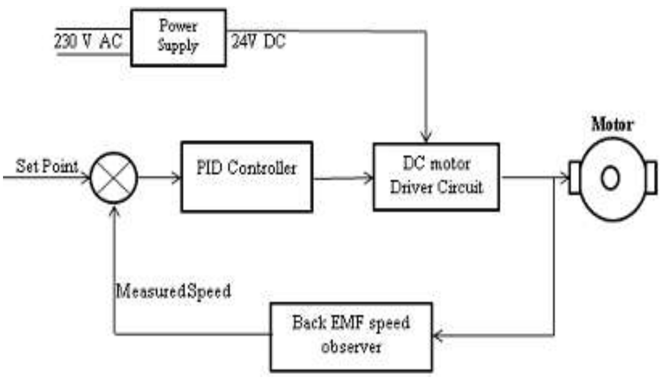


Figure 1: Block diagram of proposed system

The proposed control scheme is illustrated in Fig. 1, which includes DC motor driver, permanent magnet DC motor, Back EMF speed observer, arduinouno development board, ATmega328P microcontroller.

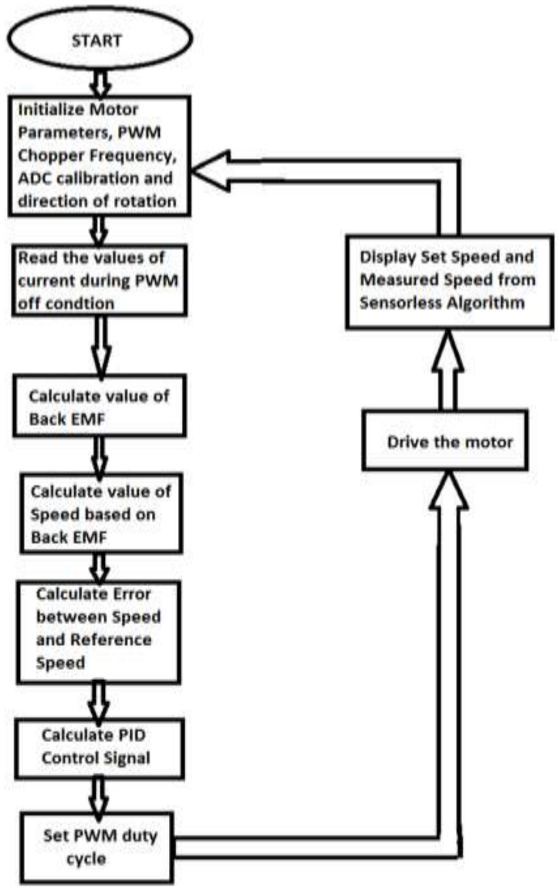
In proposed system speed of the DC motor is controlled through PID controller using back EMF measurement. The system works in the form of closed loop [4]. Process variable (speed) is measured using back EMF produced across the motor, and is fed back in terms of RPM. An error

Licensed Under Creative Commons Attribution CC BY

signal is generated based on the difference between Set Point and Feedback. This error is fed to Discrete PID controller, which will generate correction output required to achieve set point[3].

B. System flow:-

Flowchart



3. PID Controller

The combination of proportional, integral and derivative control action is called PID control action. PID controllers are commonly used to regulate the time-domain behaviour of many different types of dynamic plants [5].PID controller works in a closed-loop system as shown in figure 2.

The desired input value is represented as (R) and the actual output is represented as a (Y). The difference between desired input and actual output is represented by variable (e) called as tracking error. This error signal (e) is send to the PID controller, and the controller computes the derivative and the integral of this error signal. The signal (u) just pass the

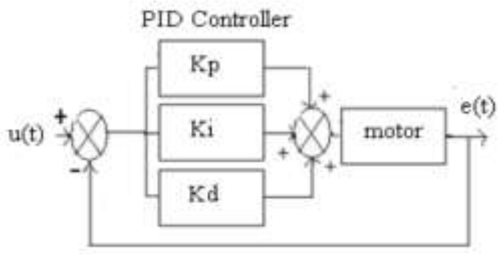


Figure 2: Blocks of PID controller

controller computes the derivative and the integral of this error signal. The signal (u) just pass the controller is now equal to the proportional gain (K**P**) times the magnitude of the error plus the integral gain (K**I**) times the integral of the error plus the derivative gain (K**D**) times the derivative of the error as given in equation (1) [5].

$$u = kpe + ki\int edt + kd\frac{de}{dt} \quad \text{---- ---- --- --- (1)}$$

Where,
K**P**= Proportional gain
K**I**= Integral gain
K**D**= Derivative gain

The input signal (u) is send to the plant (motor), and it gives the new output (Y). This new output (Y) will be sent back to the sensor again to find the new error signal (e).The controller takes this new error signal and computes its derivative and its integral again. This process will continue [6].

Characteristics of P, I, and D controllers:-

- A proportional controller (K**P**) reduces the rise time but it will never eliminate the steady-state error.
- An integral control (K**I**) eliminates the steady-state error, but it makes the transient response worse.
- A derivative control (K**D**) increases stability of the system, by reducing the overshoot, and it improves the transient response of the system [4].

CL RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
Kp	Decrease	Increase	Small change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small change	Decrease	Decrease	Small change

The given table shows the effects of each of controllers K**P**, K**I**, and K**D** on a closed-loop system

$$G(s) = K_P\left(1+\frac{1+T_I T_D S^2}{T_I S}\right) = K_P\left(1+\frac{1}{T_I s}+T_D s\right) \quad \text{...... (1)}$$

The above equation shows the transfer function of PID controller.

If no derivative action, we have gives the transfer function of PI Controller is shown in below equation.

$$G_c(s) = \frac{U(s)}{E(s)} = K_p + \frac{K_i}{s}$$
$$= K_p\left(1+\frac{1}{T_i s}\right)$$
$$= K_p\frac{T_i s+1}{T_i s} \quad \text{.......... (2)}$$

4. System Development

a) Software description

The Arduino Software (IDE) is an open source compiler. In this software we can write code and upload it to the board. It

Licensed Under Creative Commons Attribution CC BY

runs on Mac OS X, Linux and Windows. It is based on processing and other open-source software and environment is written in Java. Arduino compiler accepts C and C++ many of the libraries are written in C++.The Arduino environment performs some small transformations on the code to make sure that the code is correct then it gets passed to a compiler, which turns the code into machine language.Itcontains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus.

b) Hardware Description

Components	Specification
PMDC motor	• Rated voltage:-24 volt • Rated speed:- 6000 rpm • Rated current:- 5 amp
Chopper fed motor Driver Circuit(L298N)	• Thyristor based driver circuit • Drive voltage:- 5V-35V • Current range:-3amp
Microcontroller (Ardunio uno)	• Atmega 328P- 8 bit AVR family • Inputs voltage limits:- 5-20 volt
LCD display	• 16*2 display • Operating voltage:- 4.7-5.3 volt
Current sensor(ACS712)	• Supply voltage:- 8 volt • Output current sink:- 10 amp

5. Results and Discussion

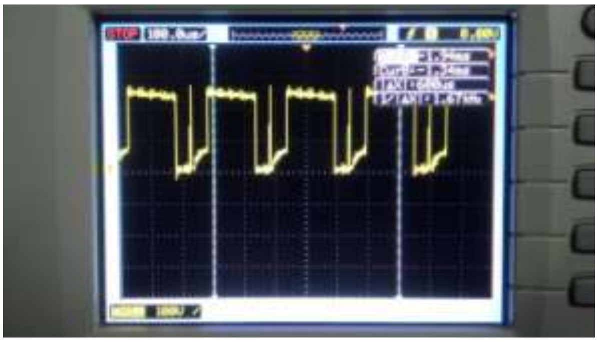


Figure 1: Driver output voltage waveform

Figure 1 shows the output voltage waveform of H-bridge dual motor driver. The switching frequency of driver is set to 1.67Khz

Figure 2: Supply voltage

Figure 2 shows the input supply voltage of motor which is set to 24V DC.

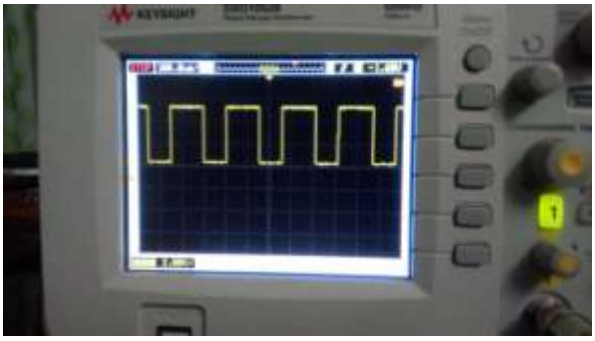


Figure 3: PWM pulse

Figure 3 shows the pulse width modulation waveform. The duty cycle 75%. The total time period of PWM pulse is 100µsec. The ON period is 75µsec and OFF period is 25µsec

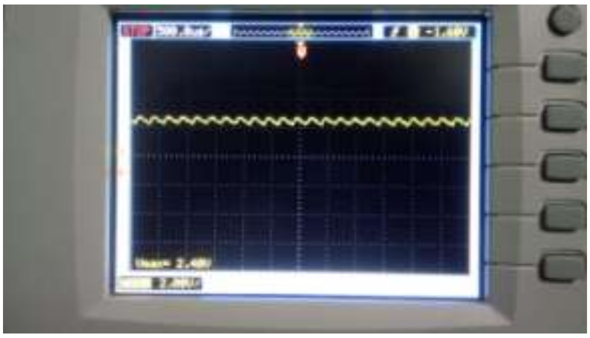


Figure 4: Input current to motor

Figure 4 shows the input current of motor in terms of voltage. At no load the input current is 1.40 A. If load increases simultaneously motor current also increased.

Figure 5: Speed curve of the motor

As we load the motor, it will regain its reference speed due PI action. The fig 5 shows the respected speed curve which explains the output characteristics shows the critically damped characteristics

6. Conclusion

Closed loop speed control using sensorless speed measurement with back EMF technique is successfully done. The system is design and implemented using ardunio IDE software tools. The several experiments of speed control with no load and load were successfully performed. This system has less expensive than other sensored based system. However, this type speed control mechanism can have a wide range of applications such as lab diagnostics, surgical precision etc.

Licensed Under Creative Commons Attribution CC BY

References

[1] Brendan Khoo, MuralindranMariappan and Ismail Saad, "A Sensorless Speed Estimation for Brushed DC Motor at Start-up"International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 6, June 2016.
[2] E. Afjei,A. NadianGhomsheh, and A. Karami,"Sensorless Speed/Position Control of Brushed DC Motor"1-4244-0891-1/07/ã IEEE 2007.
[3] SauymaKamdar, HarsidhBrahmbhatt, Tigmanshu Patel, Manish Thakker, "Sensorless speed control of high speed brushed DC Motor by model Identification and Validation",5th Nirma University International Conference on Engineering (NUiCONE), 978-1-4799-9991-0/15/ ©2015 IEEE
[4] RomharshalTalele,"PID Controller based DC Motor Speed Control",International Journal on Recent and Innovation Trends in Computing and Communication, ISSN: 2321-8169,Vol. 5 Issue. 9.
[5] Aditya P. Singh, UditNarayan,"Speed Control of DC Motor using Pid Controller Based on Matlab", International Conference in Applied Sciences with Engineering Applications, ISSN 2222-1727 (Paper), Vol.4, No.6, 2013.
[6] ThirupathiAllam, MatlaRaju, S.SundeepKumar,"Design of PID controller for DC Motor Speed Control Using Arduino Microcontroller", International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 09 | Sep-2016.
[7] S. A. Deraz,"Genetic Tuned PID Controller Based Speed Control of DC Motor Drive", International Journal of Engineering Trends and Technology (IJETT) – Volume 17 Number 2 – Nov 2014.
[8] Saurabh Dubey1, Dr. S.K. Srivastava, "A PID Controlled RealTime Analysis of DC Motor", International Journal ofInnovative Research in Computer and CommunicationEngineering, Vol. 1, Issue 8, October 2013.
[9] Seiko Epson Corp., "Brushless dc Motor Without Position Sensor andits Controller," E.P. Patent 0 553 354 B1, 1993
[10] Safina Al Nisa, Lini Mathew, S Chatterji ,"Comparative Analysis of Speed Control of DC Motor Using AI Technique", International Journal of Engineering Research and Applications, Vol. 3, Issue 3, May-Jun 2013, pp.1137-1146.

Licensed Under Creative Commons Attribution CC BY