Permanent magnet DC motor control by using arduino and motor drive module BTS7960

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Abstract. This study proposes a control system for permanent magnet DC (PMDC) motor. PMDC drive control system has two critical parameters: control and monitoring. Control system includes rotation speed control and direction of rotation of motor using motor drive module BTS7960. The PWM signal has a fixed frequency of waves with varying duty cycles (between 0% and 100%), so the motor rotation can be regulated gradually using a potentiometer already programmed on the Arduino Uno board. The motor rotation direction setting uses the H-bridge circuit method using a 3-way switch to set the direction of forward-reverse rotation of the motor. The monitoring system includes measurements of rotational speed, current, and voltage. Motor rotation speed can be adjusted from the armature voltage settings through the duty cycle PWM setting so that the motor speed can be increased or decreased by the desired duty cycle. From the unload PMDC motor test results it has also been shown that the torque of the motor is relatively constant when there is a change in speed from low rpm to high rpm or vice versa.

1. Introduction

Permanent magnet DC motors (PMDC) have been widely used in industries as mechanical drivers. They are also applied in transport vehicles, biomedical equipmentand household appliances. These type of motors have several advantages,i.e.good speed regulation, simple starting system, low cost,small physical size, high efficiency and they do not need high current and no excitation at the start. The torque of these motor is relatively constant at any speed after reaching their nominal speed [1]. Besides these advantages, there are some disadvantages of these motors, i.e. the flux density generated in the air gap is so limited and such as having the limitation of field flux density generated in the air gap, and due to the armature reactions,the demagnetizing effects are generated in the motor. This condition causes the motor inoperative[2].

The speed of the PMDC can be controlled in the range below and above its nominal speed. The most common method to control the speed of the PMDCis by varying the input voltage to the motor. Studies have been done to investigate the speed control methods of these PMDC such as the AC-DC power supply control using single phase matrix converter (SPMC) [3], the speed control based on the uncertain disturbances [4], automatic sensorless speed control based on PMDC characteristics compensation [5], and low rotation speed setting performance was investigated to maintain the stability of the PMDC torque [6]. Arduino and LabView have been applied to control the speed of the PMDC [7]. It used a L298motor driver to control the speed of the PMDC. The input voltage to the motor is regulated by changing the duty cycle of the pulse width modulation (PWM) signal to the

motor. The LINX package is used as an interface between LabView and Arduino. As several devices are involved in controlling the speed of the motor, these make the control system of this method complicated. The design can be simplified by eliminating the LabView in the design. Therefore, in this paper a simple method is proposed to control the speed of PMDC motor by using Arduino as a microcontroller and a BTS7960 module as a motor driver.

2. Methods of PMDC speed control
DC motor speed control can be achieved by adjusting the armature voltage or using electronic power components to acquire voltage drops on the armature. The relation of speed and voltage can be described from the equivalent circuit of PMDC motor,whereas the equivalent PMDC is similar to DC shunt motor with the exception that the field is given by a permanent magnet as shown in figure 1[1].
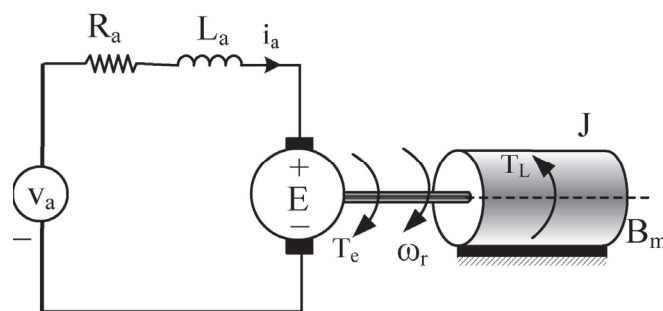

Figure 1. Equivalent circuit of PMDC motor.

As seen in figure 1 above, the dynamic equivalent equation of PMDC motor can be described as below [1]:

$$V_a = R_a . i_a \ + \ L_a \frac{di_a}{dt} + E \tag{1}$$

$$E \ = k_v \omega_m \tag{2}$$

$$T_e = k_T . i_a \ = J \frac{\omega_m}{dt} \ + B_m . \omega_r + T_L \tag{3}$$

$$T_L = K_n . \omega_m{}^2 \tag{4}$$

Equation (2) above has described the characteristics of speed versus PMDC motor voltages as shown in figure 2 [2].
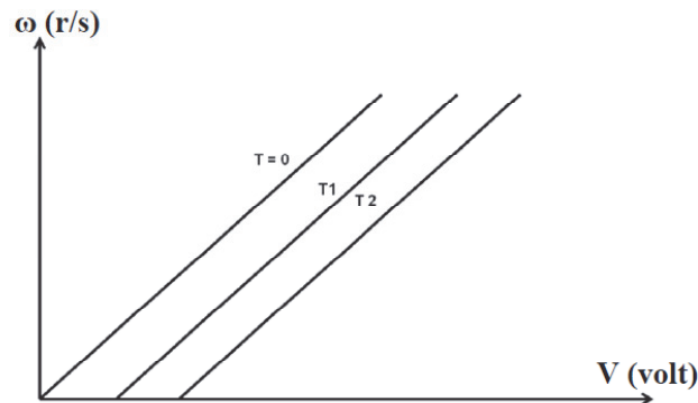
Figure 2. Speed vs voltage characteristics

It is also described in [2] the characteristic of torque versus speed of PMDC motor at varying armature voltages under steady-state conditions as shown in figure. 3.
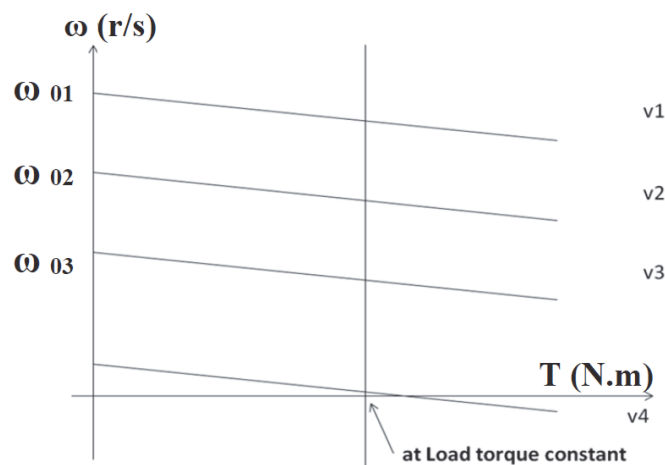

Figure 3. Torque vs speed characteristics.

Pulse Wave Modulation (PWM) is a method used to regulate motor rotation speed by adjusting the percentage of high pulse width to the period of a square signal in the form of the periodic voltage applied to the motor as a power source[2], [8], [9]. A recent article in [7] described the using of PWM technique in Arduino board to adjust PMDC motor rotation speed. The direction of PMDC motor rotation (forward - reverse) can be adjusted by varying RPWM (Right PWM) and LPWM (Left PWM) to change switching mode in H-bridge motor drive module.

3. Proposed System
The block diagram of PMDC control system proposed in this articleis shown in figure 4.The system using power supply 24 volt DC as a voltage source on PMDC motor type MY1016 (350 Watt). The motor itself has a speed rate of 2750 RPM and a torque rate of 1.2 N.m in current rate of 19.2 A.The potentiometer is used as a regulator to set a setpoint value in Arduino board in which the one who adjuststhe speed of PMDC motor.The 3-way switch is used as forward or reverseguidance of DC motor rotation, and also be as a function to switch off the PMDC motor. Arduino will then compared the setpoint by using the magnitude of the voltage obtained from the potentiometer, and the result value is then processed to produce the desired data. Furthermore, Arduino will instruct the motor drive module BTS7960 to rotate the motor to the right or left with desired motor rotation speed by the input

of potentiometer. In the monitoring system, there are several sensors that will monitor the parameters of the motor system such as current, voltage, and a rotational speed of the motor.Sensors will then transmit Analog to Digital(ADC) signals to Arduino to display on the LCD.
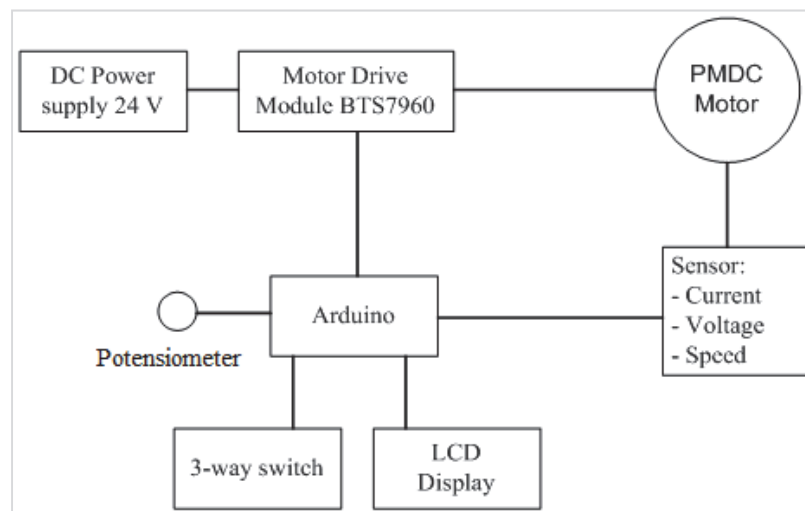

Figure 4. Proposed System.

4. Result and analysis

4.1 Direction of PMDC motor rotation

The result of PMDC motor rotation direction testing is shown in table 1. PMDC motor will rotate forward when it is given logic value 1 to RPWM and 0 to LPWM,and will rotate counterclockwise direction when given logic value otherwise (0 to RPWM and 1 to LPWM). The motor is turned off in any set logic value other than above mentioned (1 to RPWM and 1 to LPWM, 0 to RPWM and 0 to LPWM). Thus it can be concluded that the test control of DC motor rotation direction can run well on the system.

Table 1. Results of motor rotation PMDC direction control test.

Output Logic		Direction
RPWM	LPWM	
0	0	Off
1	0	Clockwise*(forward)*
0	1	Anti-Clockwise*(reverse)*
1	1	Off

4.2 Speed of PMDC motor

The speed test is performed by fluctuating the value of PWM duty cycle from 0–100%. The test is used to acknowledge the relationship between PWM value and average voltage associated with the speed of the PMDC motor.The motor rotation speed is set gradually from the minimum to maximum speed by adjusting the duty cycle value using a potentiometer as a determinant of the signal setpoint value. The results of PMDC motor speed testing is shown in figure 5.
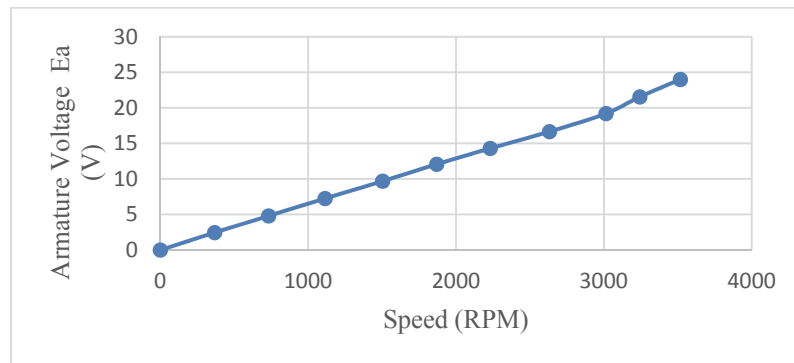
Figure 5. Speed versus voltage.

4.3 Unload torque PMDC motor
The results of unload test are in the formed of armature voltage, armature current, armature speed and torque of PMDC motor as shown in table 2.

Table 2. PMDC testing of the un-load motor.

No.	Armature VoltageEa (Volt)	Armatur CurrentIa(Ampere)	Speed (RPM)	Torque (Nm)
1.	0	0	0	0
2.	2.45	1.98	374	0.126286
3.	4.8	1.973	732	0.123609
4.	7.25	1.823	1114	0.113352
5.	9.69	1.761	1503	0.108472
6.	12.07	1.736	1869	0.107112
7.	14.3	1.734	2231	0.106188
8.	16.66	1.732	2632	0.104744
9.	19.2	1.724	3014	0.104927
10.	21.55	1.724	3243	0.10939
11.	24.05	1.724	3517	0.11824

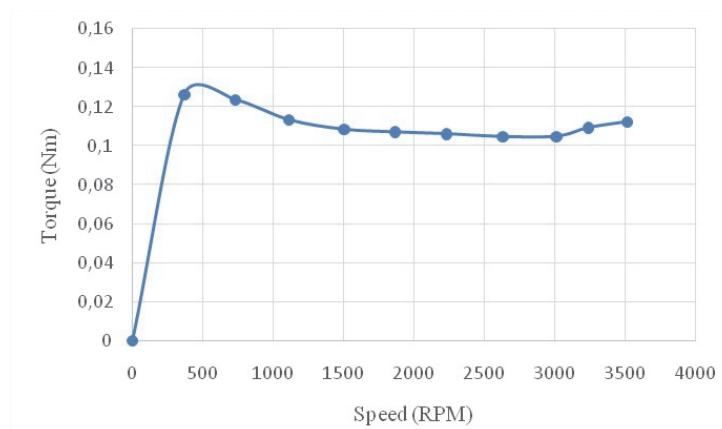As derived from table 2,the relation between torque and motor speed is shown in figure 6.

Figure 6. The relation between torque and speed of PMDC motor underunload conditions.

It is clearly shown that when the armature voltage E_a is varied, the current is relatively constant but motor speed changes dynamically following the change of armature voltage.As also shown in figure 6, it can be concluded that when a speed change occurs between 500 rpm to 3500 rpm the PMDC torque motor is relatively constant.

5. Conclusion

Based on the results obtained from several tests performed in this research, the direction of motor rotation can be performed using RPWM technique for the forward direction and LPWM for the reverse direction. Motor rotation speed can be adjusted from the armature voltage settings through the PWM duty cycle arrangement so that the motor speed can be increased or decreased by the desired duty cycle.The result of PMDC motor testing on un-load condition also shows that torque motor is relatively constant when the speed change from low rpm to high rpm or vice versa.

References

[1] Mahghani M and Afjei E 2017 Carrier-based with unipolar switching technique current control of PMDC motors in electric vehicle applications*Iranian Conference onElectrical Engineering (ICEE)* 1060

[2] Tarnini M Y 2014 Microcontroller based PMDC motor control for driving 0.5 KW scooter*Power Electronics and Motion Control Conference and Exposition (PEMC), 16th International*1204

[3] Idris A, Baharom R, Hamzah, N R and Hamzah M K 2013 Controlled AC-DC converter fed permanent magnet DC motor using single-phase matrix converter *Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International* 764

[4]   Chu H, Tao W, Gao B, Liu Q and Chen H 2016 Speed control of the permanent-magnet DC motor subjected to uncertainty and disturbance*Control Conference (CCC), 35th Chinese* 4664

[5] Saurav K and Potluri R 2013 Sensorless speed control of a permanent magnet dc motor by compensating the plant nonlinearities*Industrial Electronics (ISIE) International Symposium* 1

[6] Chu H, GaoB, Gu W and Chen H *2017* Low-Speed Control for Permanent-Magnet DC Torque Motor Using Observer-Based Nonlinear Triple-Step Controller*IEEE Transactions on Industrial Electronics* **64** 3286

[7] Angalaeswari S, KumarA, Kumar D and Bhadoriya S 2016 Speed control of permanent magnet (PM) DC motor using Arduino and LabVIEW*Computational Intelligence and Computing Research (ICCIC), IEEE International Conference* 1

[8] Li Q, Huang H and Yin B 2008The study of PWM methods in permanent magnet brushless DC motor speed control system Electrical Machines and Systems*ICEMS International Conference* 3897

[9] Yurkevich V D and Stepanov N A 2014 PWM speed control of DC motor based on singular perturbation technique*Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 6th International Congress on* 434