GSM Based Control Brushless DC Motor Drive System

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Abstract: - Sending written text messages are extremely popular among mobile phone users. Instant messaging allows quick transmission of short messages that allow an individual to share ideas, opinions and other relevant information. In this paper the same concept to design a system that acts a platform to receive messages is used. The designed control system which is based on the GSM technology allows control from a remote area to the desired location. The mathematical model and the design of PID speed controller for the brushless DC motor drive system are presented. The overall system is implemented and tested. The experimental results illustrate that the proposed system allows a greater degree of freedom to control and monitor the electric drive systems of a certain location is eliminated.

Key-Words: - Brushless dc motor, GSM, PID controller.

1 Introduction

Brushless Direct Current (BLDC) motors are one of the motor types which are gaining extraordinary reputation. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. As the name indicates, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors [1-3]. A few of these are [4]:

- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

In addition, the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are significant factors.

The common communication technologies used today are SMS [5], WAP, MMS, GPRS, 3-G. Nokia grants a policy for wireless communication. The machine-to-machine, mobile-to-machine and machine-to-mobile (M2M) policy comprises hardware and software to employ wireless communication. Recently, the cost of log on to public wireless data networks has been reducing while the capabilities of these networks remain to increase. Short Message Service of GSM [6] is a value-added communication service based on data packet switching offered by mobile communication company using GSM network in addition to all types of telecommunication services and bearer services based on circuit-switching. GSM has some capabilities such as two-way data transmission function, stable performance and can be interfaced with microcontroller via RS232 adaptor. GSM network provides a strong platform for remote data

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transmission and monitoring the communication between equipments and it is an important method of wireless remote monitoring system [7].

Mobile phone users are sending written text messages regularly. Instant messaging, as it is also known, allows quick broadcast of short messages that permit an individual to share ideas, opinions and other related information [8-12]. In this paper the same concept is used to design a system that acts as a platform to receive messages. In fact, these messages are commands sent to control the speed of BMDC motor drive system. The designed control system is based on the GSM technology that effectively allows control from a remote area to the desired location.

This paper is organized as follows: Section 1 presents the BLDCM mathematical model. The problem formulation of the proposed system and the design of the PID speed controller are given in section 2. The experimental setup and results of the proposed system are established in section 3and conclusions and system good merits are introduced in section 4.

2 BLDCM Mathematical Model

The mathematical model of BLDCM drive is given in [4]. During two-phase conduction, the entire dc voltage is applied to the two-phases having an impedance of:

$$Z = 2[R_s + \frac{d}{dt}(L - M)] = R_a + \frac{dL_a}{dt} \quad (1)$$

where
R_s : stator resistance per phase.
L : self inductance per phase.
M : mutual inductance per phase.

$$R_a = 2R_s \quad \text{and} \quad L_a = 2(L - M) \quad (2)$$

The stator voltage equation is given by:

$$v_s = (R_a + \frac{dL_a}{dt})i_s + e_{as} - e_{cs} \quad (3)$$

where the last two terms are back emfs in phases *a* and *c* respectively. During regular operation of the drive system, the back emfs are equal and opposite in direction therefore the back emfs are given by:

$$e_{as} = -e_{cs} = \phi_p\, \omega_m \quad (4)$$

substitute by Eq.(4) on Eq.(3) the stator voltage become:

$$v_s = (R_a + \frac{dL_a}{dt})i_s + 2\phi_p\, \omega_m \quad (5)$$

back emf constant for both phases can be written as:

$$K_b = 2\phi_p \quad (6)$$

then, the stator voltage in Eq.(5) become:

$$v_s = (R_a + \frac{dL_a}{dt})i_s + K_b\, \omega_m \quad (7)$$

The electromagnetic torque for two-phases is given by:

$$T_e = 2\phi_p\, i_s = K_b\, i_s \quad (8)$$

The electromechanical equation of the BLDCM is:

$$T_e - T_L = J\frac{d\omega_m}{dt} + B\omega_m \quad (9)$$

The load torque is proportional to the motor speed, so it can be represented by:

$$T_L = K_T\, \omega_m \quad (10)$$

Therefore, Eq.(9) can be rewritten as:

$$T_e - K_T\, \omega_m = J\frac{d\omega_m}{dt} + B\omega_m \quad (11)$$

where
R_s : stator resistance per phase.
L : self inductance per phase.
M : mutual inductance per phase.
ϕ_p : flux linkage per phase.
ω_m : rotor speed.
v_s : stator voltage.
i_s : staor current.
T_e : electromagnetic torque.
T_L : load torque.
K_T : load torque constant.
K_b : flux constant (volt/rad/sec).
B : motor friction.
J : moment of inertia of BLDCM.

2.1 Subsection

When including a subsection you must use, for its heading, small letters, 12pt, left justified, bold, Times New Roman as here.

3 Problem Formulations

The objective of this paper is to develop a user-device that allows remotely to control and monitor BLDCM drive system using a smart phone. This system will be a powerful and flexible tool that will offer this assistance at any time, and from anywhere with the constraints of the technologies being used. The proposed approach for designing this system is to employ a microcontroller-based control module that receives its instructions and command from a smart phone over the GSM network. The microcontroller then will carry out the issued commands, do the control algorithm and then communicate the status of BLDCM back to the smart phone. The overall block diagram of the proposed system is given in Fig. 1.

The designed system has two major tasks. The first task is to monitor the BLDC motor current and the temperature. The feedback signals measured from the sensors connected to the motor is feed to the microcontroller to decide if these values are within the rated accepted value or not. If it is more than the accepted value a warning signal is given and displayed by the smart phone with the present values. The processor will wait for 1 min, if it is still increasing operation shutdown warning message is given to the smart phone and wait for a decision command from the operator via the smart phone. If nothing is received by the microcontroller within a certain period of time, a shutdown signal is given to the motor for protecting it from further degradation.

The second task is to control the speed of the BLDC motor. The speed command is given by the operator via the smart phone. The microcontroller receives both the command coming from the smart phone and the feedback signal from the speed sensor. The PID controller algorithm is implemented and downloads to the microcontroller. The PID parameter is designed using Ziegler-Nichols method. The microcontroller fed the derivers of the DC-DC converter by the proper period pulses. The feedback speed signal is also monitored by the system. When the command speed is executed by the system and the BLDC motor is running by this speed a confirmation message is sent for verification to the smart phone.

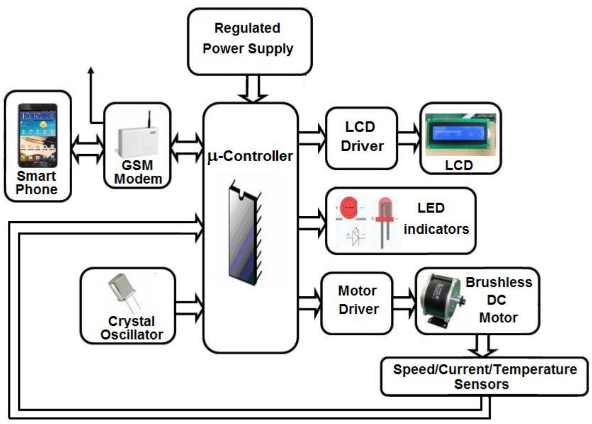

Fig. 1: The overall Block diagram of the proposed system.

3.1 Design PID Speed Control Loop

The block diagram of the speed control loop of PMBLDCM drive system is given in Fig. 2.

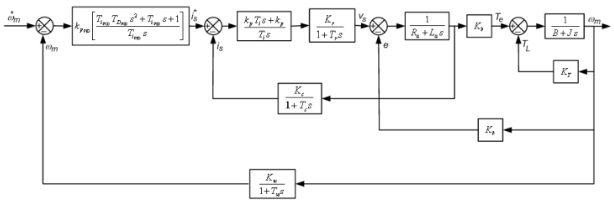

Fig. 2. Block diagram of the speed control loop for BLDCM.

The BLDCM contains three inner loops creating a complexity in the development of the model. Mason's rule is used to reduce the block diagram as shown in Fig. 3 [13-15].

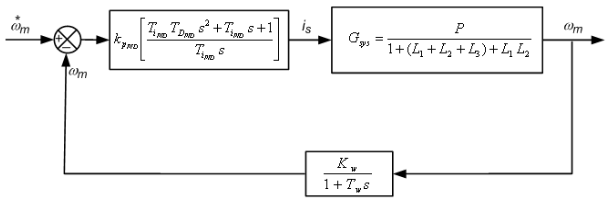

Fig. 3. Reduced block diagram of the speed control loop for BLDCM.

$$G_{sys} = \frac{\omega_m(s)}{I^*_s(s)} = \frac{P}{1+(L_1+L_2+L_3)+L_1\,L_2} \quad (12)$$

where the forward path ,loop gins are respectively given as ,

$$P = \frac{k_p\,K_r\,K_b\,(1+T_i\,s)}{T_i\,s(1+T_r\,s)(R_a+L_a\,s)(B+J\,s)} \quad (13)$$

$$L_1 = -\frac{k_p\,K_r\,K_c\,(1+T_i\,s)}{T_i\,s(1+T_r\,s)(R_a+L_a\,s)(1+T_c\,s)} \quad (14)$$

$$L_2 = -\frac{K_T}{(B+J\,s)} \quad (15)$$

$$L_3 = -\frac{K_b^2}{(R_a+L_a\,s)(B+J\,s)} \quad (16)$$

The open loop transfer function of the speed control loop is:

$$G_{speed\_openloop} = \frac{k_{P_{PID}}\,P\,K_w\,(T_{i_{PID}}\,T_{D_{PID}}\,s^2+T_{i_{PID}}\,s+1)}{T_{i_{PID}}\,s(1+(L_1+L_2+L_3)+L_1\,L_2)(1+T_w\,s)} \quad (17)$$

where,

K_w : Gain of speed transducer.

T_w : Time constant of speed transducer.
$k_{p_{PID}}, T_{i_{PID}}, T_{D_{PID}}$: Parameters of the PID controller.

The PID speed controller of the BLDCM drive system using Ziegler-Nichols PID tuning technique is designed and tested. The transfer function of PID speed controller Ziegler-Nichols is given by

$$G_{PID\_Ziegler} = 156.4\,\frac{(3.143x10^{-6}\,s^2 + 3.54x10^{-3}\,s + 1)}{3.54x10^{-3}\,s} \quad (18)$$

4 Results

The GSM system has been selected as the communication medium. The main issue to select GSM system is the worldwide recognition of the system. The GSM is wireless system. It helps the system to be used in area where wiring is impossible or for temporary/field usage. It offers high speed wireless communication. It is connected to the data adaptor RS232. Through the RS232, it can be connected to a personal computer or a microcontroller. The PMBLDCM drive, converter and transducers parameters are given in Appendix, Table 1.

The GSM modem is used as short message server (SMS) device. It can send and receive messages containing 160 characters. It supports call forwarding, call transfer, multiparty calling and security options such as call barring. In this application, the GSM modem is interfaced with the PIC18F4420 microcontroller via RS232 adaptor [10]. The modem receives a message from a mobile phone as an SMS that contains the speed command of the BLDCM. It will then transmit the information to the microcontroller via RS232 serial interface. This information is then stored in the built-in Flash memory of microcontroller. The microcontroller in-turn sends the information to the GSM modem after the BLDCM reaches the desired speed by the aid of PID controller. This information is sent as reply through an SMS to the mobile phone.

PIC18F4420 is an 8-bit microcontroller that has built-in 13 channels A/D converter module with 10-bit resolution [11]. The built-in Flash memory is used to host the embedded software algorithm that takes care of the parameters acquisition, processing, transmitting and receiving. The RS232 is utilized for the GSM modem communication to upload and download messages that contain the speed command of the BLDCM drive system.

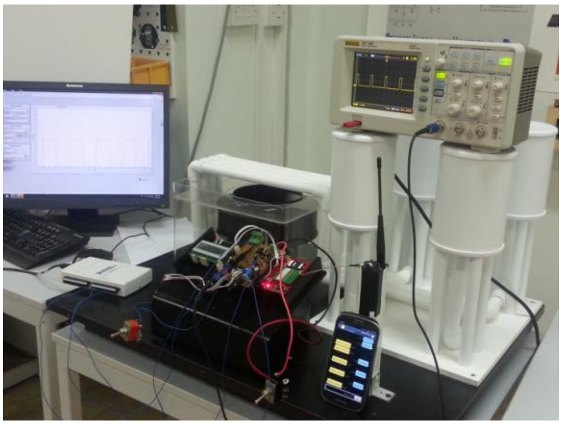

Fig.4. Experimental setup of the proposed system.

Fig.5. The motor parameters read by the system after the command speed is executed.

The experimental setup of the proposed system is given in Fig. 4. In the designed system, BLDCM parameters can also be monitored and the data is send to the mobile and a LCD screen. The speed, current and temperature are the parameters are selected to be monitored in the designed system. Fig. 5. Shows the parameter selected to be monitored in the LCD screen when the command speed is executed by the microcontroller.

The layout of the hardware of the proposed system is given in Fig. 6. The overall software algorithm of designed C-program which is downloaded into the microcontroller is illustrated in Fig. 7. The on/off pulses generated

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by the microcontroller for different speed commands are illustrated in Fig. 5. The on/off pulses for 15%, 30%, 50% and 80% of the rated speed (450, 900, 1500, 2400 rpm) is given in Fig 4 (a, b, c and d) respectively. A step change of the speed commands from 0rpm to 2400rpm and back to 0rpm is given in Fig. 6. The results show the system follow the speed command precisely. The experimental results illustrate that the proposed system allows a greater degree of freedom to control and monitor the BLDCM drive systems of a certain location is eliminated.

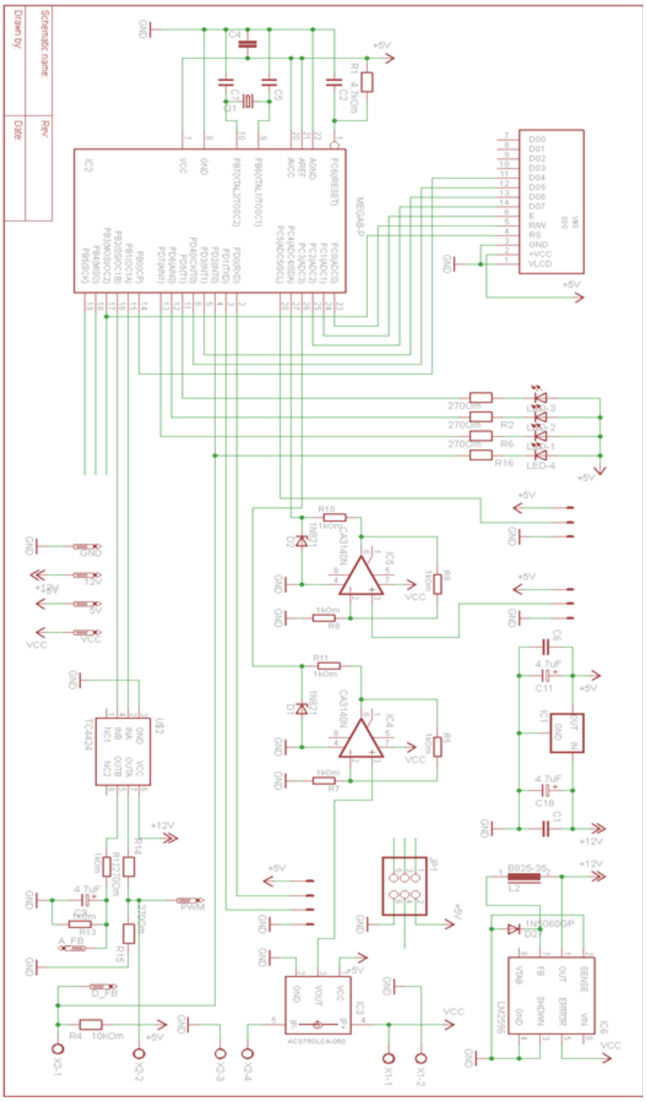

Fig. 6. The overall layout of the hardware for the proposed system.

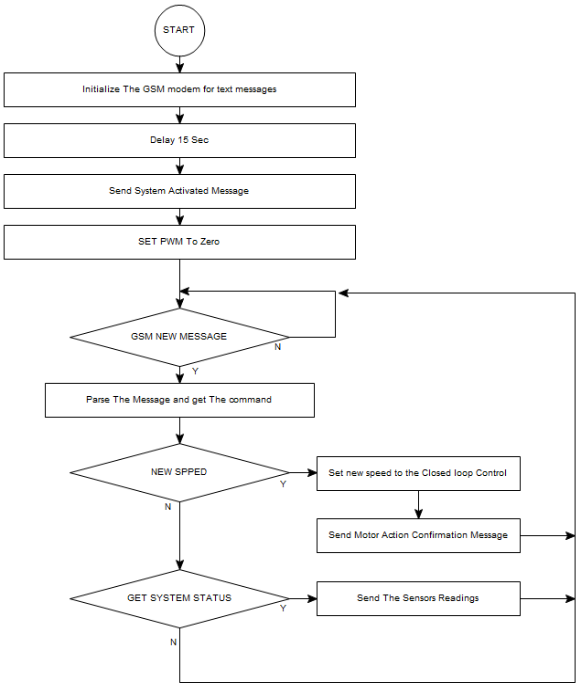

Fig.7. The overall software algorithm of the proposed system.

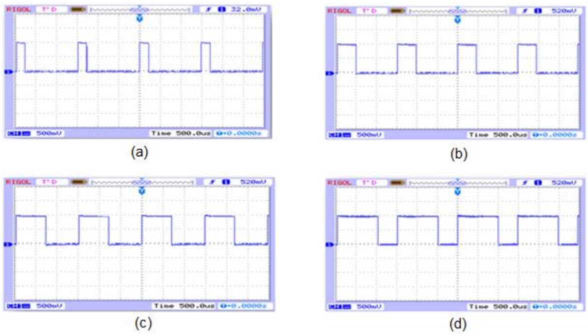

Fig. 8. On-off pulses generated from the microcontroller for different speed commands.
(a) for 15 % of the rated speed (450 rpm), (b) for 30% of the rated speed (900rpm), (c) for 50% of the rated speed (1500 rpm), and (d) for 80% rated speed (2400 rpm).

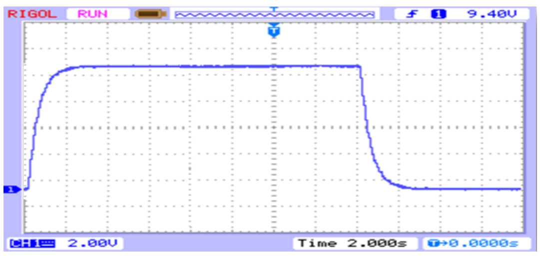

Fig. 9. Step change on the motor speed command from 0 rpm to 2400 rpm and from 2400rpm to 0 rpm at 80% load.

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5 Conclusion

A prototype for monitoring and control BLDCM drive system using GSM network. The BLDCM drive system model is given. The speed PID controller is designed. The overall derive system using the GSM network in conjunction of the RS232 serial interface adaptor and microcontroller. The GSM modem receives a message from a mobile phone as an SMS that contains the speed command of the BLDCM. It will then transmit the information to the microcontroller via RS232 serial interface. The microcontroller in-turn sends the information to the GSM modem after the BLDCM reaches the desired speed by the aid of PID controller. This information is sent as reply through an SMS to the mobile phone. The overall system is implemented and tested. The experimental results show the flexibility of this technique which allows the drive system to be monitored and controlled precisely and remotely.

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Appendix

Table 1: The PMBLDCM drive parameters (top), converter and transducers parameters (down).

Power	1.2 kW
Current	7.5 A
Voltage	160 V
Torque	3 N.m
Phase resistance (R_a)	1.9 Ω
Phase inductance (L_a)	1.24 mH
Moment of inertia (J)	0.00035 kg m^2
Motor friction (B)	0.00323 N.m/rad/sec
EMF constant (K_b)	0.358 Vs

Converter gain (K_r)	16 V/V
Converter time constant (T_r)	50 μs
Current transducer gain (K_c)	0.288 V/A
Current transducer time constant (T_c)	0.159 ms
Speed transducer gain (K_w)	0.0239 Vs
Speed transducer time constant (T_w)	1ms