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스마트 통신 플랫폼을 적용한 BLDC 모터 드라이버 개발

Development of a Driver for BLDC Motors Using Smart Communication Platform

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(Injae Lee · Barun Basnet · Junho Bang)

Abstract - This paper presents the design of a BLDC motor driver applicable to various valve control systems using smart devices. BLDC motors are relatively small in size and have better performance than other motors. They help in reducing maintenance cost, installation costs and power consumption in plant facilities. The proposed driver is specially designed for BLDC motors using Smart Communication Platform. It adds smart features in the valve control system using BLDC motors such as multi-management, control, networking and monitoring in real time with the help of smart devices.

Key Words : BLDC motor driver, Smart communication platform, Hydraulic valve, Modbus communication

1. Introduction

Motors find their applications in petrochemical, oil refining, water treatment and various plant industries. They cover approximately 13% of whole plant facility. Recent data show consistent growth in plant industries and the demand for motorized valves is expected to increase further [1].

High efficiency, high power density, high torque/inertia ratio with better control performance are some of the key features of BLDC motors. Data show their increasing use in the automobile industries, medical equipment and robot systems [2]. Existing vessel facilities also seem to use BLDC motors for propulsion purposes and many related researches are in progress [3]~[5]. However, they are still not used in fluid transfer applications. Basically, other forms of electric motors using air pressure were used for fluid transfer purposes but these days hydraulic motors are developed to replace such motors. However, they are relatively large in size and are costly as well. Therefore, small sized and high torqued BLDC motors can address these problems. In order to optimize its application in valve control systems, the development of BLDC motor drivers is necessary. Domestically produced motorized valves has a decelerating problem per manufacturer since there were no any standard as per what amount of pressure should be designated for opening and closing of the valves. And even with the uniform standard, the difference in output Revolutions Per Minute (RPM) in such actuators caused problems in case there were emergency interchange requests. Existing drivers were basically developed for typical motors and it was not suitable for installation on hydraulic valves because of the torque characteristics. So drivers for motorized valves were not much used and thus were not in the process of development.

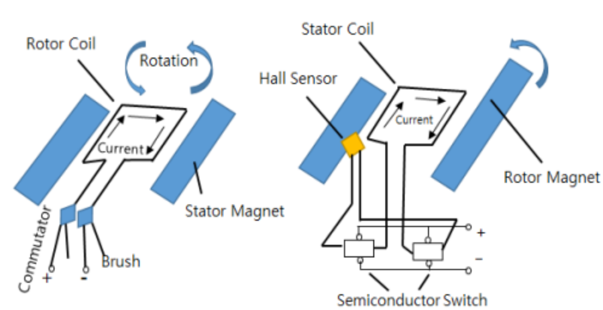

Fig. 1 Configuration of a DC motor and a BLDC motor

Fig. 1 shows a configuration of a DC motor and a BLDC motor. Fig. 2 shows existing valve control system where multiple motors are used and each is controlled by a pair of wires connected to Control Box. There are several ongoing researches in the field of engine monitoring system [6]-[7], water pressure monitoring in the field of plant industries [8], safety monitoring and guided wave device technology development [9] but very few research activities can be found in the industry relating to valve monitoring system.

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The work in this paper shows a realization of a driver for BLDC motors using Smart Communication Platform (SCP). With the use of the proposed driver easy monitoring, control and networking are possible in valve control systems using BLDC motors. In other words, the proposed driver is expected to make BLDC motors smart and thus increase their marketability.

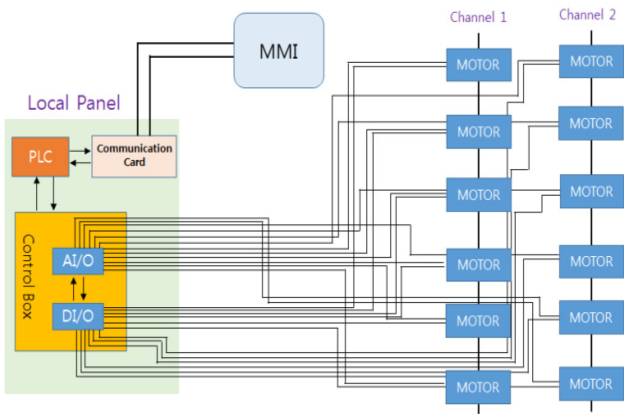

Fig. 2 Existing value control systems

2. Design of a BLDC Motor Driver using Smart Communication Platform

2.1 Modeling of a BLDC Motor Driver

Voltage equation [10] of a BLDC motor driver can be expressed as equation (1).

$$\begin{bmatrix} v_u \\ v_v \\ v_w \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} v_u \\ v_v \\ v_w \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L-M & 0 & 0 \\ 0 & L-M & 0 \\ 0 & 0 & L-M \end{bmatrix} \begin{bmatrix} i_u \\ i_v \\ i_w \end{bmatrix} + \begin{bmatrix} e_u \\ e_v \\ e_w \end{bmatrix} \quad (1)$$

Here, v, i, R, and L represents Stator phase voltage, current, resistance and winding inductance respectively. The counter electromotive force by permanent magnet can be expressed as equation (2).

$$\begin{bmatrix} e_u \\ e_v \\ e_w \end{bmatrix} = w_m \lambda_m \begin{bmatrix} f_u(\theta_r) \\ f_v(\theta_r) \\ f_w(\theta_r) \end{bmatrix} \quad (2)$$

Here, e and θ_r represents counter electromotive force by permanent magnet and electrical angle respectively. The function of BLDC motor trapezoid counter power can be expressed as equation (3).

$$f(\theta_r) = \begin{cases} 6\theta_r/\pi & (0 \le \theta_r < \pi/6) \\ 1 & (\pi/6 \le \theta_r < 5\pi/6) \\ -6\theta_r/\pi & (5\pi/6 \le \theta_r < 7\pi/6) \\ 1 & (7\pi/6 \le \theta_r < 11\pi/6) \\ 6\theta_r/\pi - 12 & (11\pi/6 \le \theta_r < 2\pi) \end{cases} \quad (3)$$

Here, $f(\theta_r)$ is the function of BLDC motor trapezoid counter power where λ_m represents magnitude of flux linkage in permanent magnet in Stator winding.

The torque of 3 phase BLDC motor can be expressed as equation (4).

$$T_e = \frac{e_u i_u + e_v i_v + e_w i_w}{w_m} = 2\frac{EI}{w_m} \quad (4)$$

The load driving system equation of the motor can be expressed as equation (5).

$$J\frac{dw_m}{dt} + Bw_m = (T_e - T_L) \quad (5)$$

Here, J, B, T_L and w_m represents moment of inertia, frictional coefficient, load torque, angular velocity of the motor respectively.

2.2 Design of BLDC Motor Driver

The internal circuitry of BLDC motor driver comprises of different units which are shown in Fig. 3.

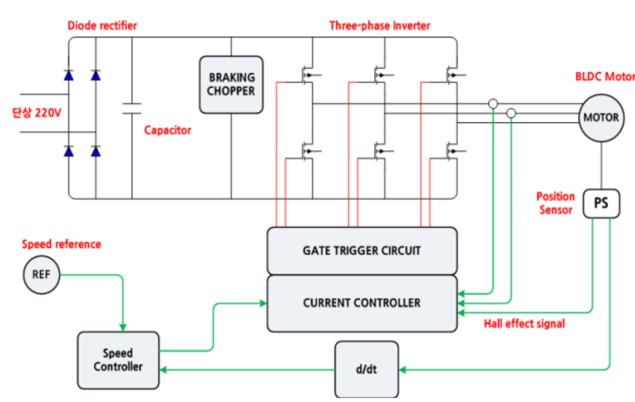

Fig. 3 Circuit configuration of the proposed BLDC motor

They are (a) constant current supplier diode rectifier circuit, (b) braking chopper which acts as switch to limit DC bus voltage, (c) position sensor to detect the position of the rotor and send delta value corresponding to the speed, (d) speed controller to control the speed by receiving PWM signals, (e) current controller and gate trigger circuit to control 3 phase inverter receiving signals from speed controller and (f) 3 phase inverter including six switches.

The system uses MC33035 Chip (manufactured by ON Semiconductor company) and SKT600-TQFP32 CPU (manufactured by Atmel company) for the speed controller, current controller and position sensor for overall motor control.

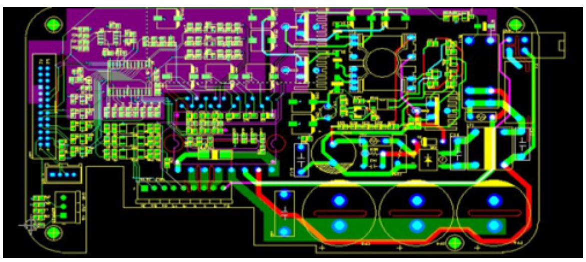

Fig. 4 Circuit configuration of the proposed BLDC motor

Fig. 5 Board of the designed BLDC motor driver

Fig. 4 shows the PCB of the designed circuit. PCB ARTWORK has been used for substrate design and testing performance of the chip and COB (Chip on Board) has been used for assisting the connection of chip board with external components. Fig. 5 shows the substrate design of the proposed BLDC motor driver.

2.3 Design of Smart Communication Platform

Arduino (Board and programming) is added to the system for facilitating communication with Programmable Logic Controller (PLC) and smart devices to monitor and manage the condition of valves. Also in order to adjust to the real industry environment, Human Machine Interface (HMI) was designed using SCADA. The status window in the HMI with touch screen function will help to monitor and control the valves. Fig. 6 shows the designed HMI screen and Fig. 7 shows the real-time monitoring and control of the system through smart devices.

Fig. 6 HMI drawing of designed system

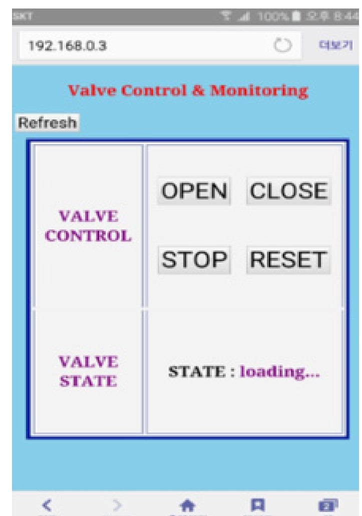

Fig. 7 Real time monitoring and control using smart devices

2.4 Design of a Motor Driver Control System using Smart Communication Platform

This sub-chapter focuses on realization of a motor driver control system using SCP as mentioned in previous chapters. Here the communication configuration can be divided into inner and outer type.

Fig. 8 shows the inner communication configuration of the proposed system. Here, Arduino and PLC, PLC and motor driver have used RS485 communication protocol whereas PLC and HMI have used RS232 protocol.

Fig. 9 shows the entire configuration of the proposed system using BLDC motor drivers supported by SCP. Here, for outer communication configuration, Modbus protocol system is used where a single wire is sufficient for communication with one channel. Fig. 10 shows the designed prototype of the proposed system.

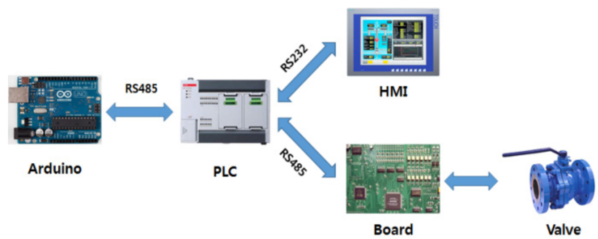

Fig. 8 Communication configuration of proposed system

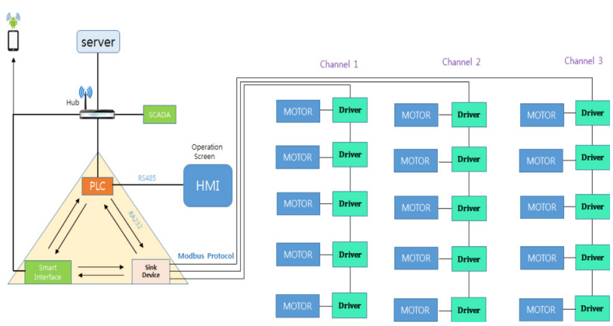

Fig. 9 Proposed BLDC motor driver system using Smart Communication Platform

Fig. 10 Prototype of the proposed system

The specifications of the designed BLDC motor driver is shown in the Table 1.

Table 1 Specifications for BLDC motor driver for 600 W

Function	Specification
Rated working controller(V)	36
Matching with controller	36V current limit 19A controller
No-load speed(rpm)	3700±100%
No-load current	≤2.0A
Max.Output power(W)	620
Max.efficiency point rotating torque(N.m)	1.75
Max.rotating torgue(N.m)	3.0
Efficiency	≥83%
Life time(hour)	300H

Several test of the designed prototype were conducted according to different modes, communication protocols (RS-232, RS-485), smart device compatibility and analog/digital in-output. Table 2 represents the comparison and contrast of the designed system with existing systems.

Table 2 Comparison of the designed system with existing systems

Category	Existing Systems	Proposed System
Station Control	Possible	Possible
HMI Control	Partly possible	Possible
Smart Device Control	Not Possible	Possible (Real Time Monitoring)
Communication Function	Each motor required multiple input output wires	Largely minimize wires (Use of RS-232, RS-485 and Modbus protocol)

3. Conclusion

In this paper, we have designed a BLDC motor driver as an important improvement in existing hydraulic motorized valve control systems and provided a real-time monitoring of multiple motors using Smart Communication Platform model. A real prototype was made and several performance tests such as communication response, digital/analog signal processing, mode selection etc were carried out to check its reliability.

The main improvement of the designed system is the omission of a large amount of wire. The designed BLDC motor driver just needs a single cable per channel for communication and feedback This will reduce the physical size and complexity of the system and thus make easy for any repair and maintenance. In addition to that, the use of SCP facilitates 24 hours real time remote monitoring and control of the system through smart devices. This will help in acquiring data from a system whenever needed. The proposed BLDC motor driver is therefore expected to be used in various large vessels, unmanned water treatment facilities and petrochemical industries where effective valve control systems are necessary.

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