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Speed Control of PMBLDC Motor Using PLC

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ABSTRACT

The theme of this paper is to control the speed of the brushless Permanent magnet DC motor with the help of programmable logic controller [1]. Presently every industry becomes automated industry. To make the industry automation the equipment and machineries should be controlled automatically. In this design BLDC motor is controlled automatically through programmable logic controller. So number of machines can be controlled is increased. BLDC machines are used in applications of vital importance such as aerospace industry, tool drives, actuators and electric vehicle propulsion system. Here, the necessity for precise control speed is evident and obvious. Pot is interfaced with programmable logic controller which is used to provide the desired speed value to the programmable logic controller. When the desired speed value is given to the programmable logic controller, the programmable logic controller sends the corresponding digital signal to the drive system and controlled according to the output required.

Keywords: MBLDC, PLC, ESC, Arduino and LED.

1. INTRODUCTION

The methods of speed control of DC motors are normally simpler and less expensive than that of ac drives. Due to the commutators dc motors are not suitable for very high speed applications and require more maintenance than ac motors. Controlled rectifiers provide a variable dc output voltage from a fixed ac voltage, whereas choppers can provide a variable dc voltage from a fixed dc voltage. Due to their ability to supply a continuously variable dc voltage, controlled rectifiers and dc choppers made a revolution in modern industrial control equipment and variable-speed drives. A Programmable Logic Controller (PLC) is an industrially hardened computer-based unit that performs discrete or continuous control functions in a variety of processing plant and factory environments. Originally, it was intended as relay replacement equipment for the automotive industry. Industrial process control is one of the very important areas where the PLC is extensively used. The flexibility offered by the system to implement various control laws is great. This paper proposed speed control of dc motor system using PLC, which is used as dc to dc chopper. The proposed system gives smooth variation over a wide range of control. This system avoids the time derivatives dv/dt or di/dt of power transistors like MOSFETs or IGBTs if classical chopper is used. This system may be used in different industrial applications such as trolley buses, subway cars or battery-operated vehicle.

1.1 Motor varieties

There are multiple varieties of electric motor differentiated by structure and signal type, but are generally based on the same principle as the three-phase motor previously discussed. The different motors organized by classifying features. The primary difference between AC and DC motors is the power type applied to the armature. From this vantage, a BLDC motor actually is an AC motor. The difference between an asynchronous and a synchronous motor is whether or not the rotor runs at the same frequency as the stator. Each motor favours specific applications.

1.1.1 Brushed DC Motor

A brushed DC motor consists of a commutator and brushes that convert a DC current in an armature coil to Ac current. As current flows through the commutator through the armature windings, the electromagnetic field repels the nearby magnets with the same polarity, and causes the winging to turn to the attracting magnets of opposite polarity. As the armature turns, the commutator reverses the current in the armature coil to repel the nearby magnets, thus causing the motor to continuously turn.

1.1.2 Brushless DC (BLDC) Motor

Brushless DC motors (BLDC) have been a much focused area for numerous motor manufacturers as these motors are increasingly the preferred choice in many applications, especially in the field of motor control technology. BLDC motors are superior to brushed DC motors in many ways, such as ability to operate at high speeds, high efficiency, and better heat dissipation. They are an indispensable part of modern drive technology, most commonly employed for actuating drives, machine tools, electric propulsion, robotics, computer peripherals and also for electrical power generation. With the development of sensor less technology besides digital control, these motors become so effective in terms of total system cost, size and reliability. A brushless DC motor [8] (known as BLDC) is a permanent magnet synchronous electric motor which is driven by direct current (DC) electricity and it accomplishes electronically controlled commutation system (commutation is the process of producing rotational torque in the motor by changing phase currents through it at appropriate times) instead of a mechanically commutation system. BLDC motors are also

referred as trapezoidal permanent magnet motors [4]. Unlike conventional brushed type DC motor, wherein the brushes make the mechanical contact with commutator on the rotor so as to form an electric path between a DC electric source and rotor armature windings, BLDC motor employs electrical commutation with permanent magnet rotor and a stator with a sequence of coils. In this motor, permanent magnet (or field poles) rotates and current carrying.

1.1.3 AC Induction Motor (ACIM)

A sinusoidal AC current runs through the stator to create a rotating variable magnetic field that induces a current in the rotor (typically made of non-ferrous materials). This induced current circulates in the bars of the rotor to generate a magnetic field.

1.1.4 Permanent Magnet Synchronous Motor (PMSM)

The PMSM motor shares some similarities with the BLDC motor, but is driven by a sinusoidal signal to achieve lower torque ripple. The sinusoidal distribution of the multi-phase stator windings generates a sinusoidal flux density in the air gap that is different from BLDC motor's trapezoidal flux density.

1.1.5 Stepper Motor & Switched Reluctance (SR) Motor

Both stepper motors and SR motors have similar physical structures; the stator consists of concentrated winding coils while the rotor is made of soft iron laminates without coils. It has a doubly salient structure (teeth on both the rotor and stator).

1.2 Applications of BLDC Motors

Brushless DC motors (BLDC) are used for a wide variety of application requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, automation systems, health care equipments, etc. Some specific applications of BLDC motors are

- Computer hard drives and DVD/CD players
- Electric vehicles, hybrid vehicles, and electric bicycles
- Industrial robots, CNC machine tools, and simple belt driven systems
- Washing machines, compressors and dryers.

1.3 Previous Speed Control Techniques

1.3.1 Speed Control of BLDC Using PID Controller

Brushless DC motors have been used in various industrial and domestic applications. Due to overweighing merits of this motor, there is continuing trend to propose improved control schemes to enhance the performance of the motor. Torque smoothness is essential for high performance motion control applications and obtaining an accurate and ripple free instantaneous torque is of great important for BLDC motor.

1.3.2 Speed Control of BLDC Motor Using Microcontroller

In this method we control a Brushless Dc Motor using a Microcontroller. We use microcontroller of the 8051 family and a rectified-power supply. A set of IR transmitter and photodiode are connected to the microcontroller for counting the number of rotations per minute of the DC motor as a speed sensor. Opt coupler is connected to trigger the MOSFET for driving the BLDC motor which is directly interfaced to the microcontroller. A matrix keypad is interfaced to the microcontroller for controlling the speed of the motor.

1.3.3 Speed Control of BLDC Motor by Using PWM Technique

The speed control of BLDC motor can be done by using PWM pulses by the microcontroller according to the programming done. PWM is a common technique for controlling electrical power for electrical device .The average value of current and voltage fed to a load is controlled by turning on and off the switch between supply and load at a fast pace. In a similar fashion the percentage of duty cycle from keypad is received by the microcontroller and it gives wanted output to switch the motor driver so as to vary the BLDC motor speed.

1.3.4 Speed Control of BLDC Motor by Using Fuzzy PI Technique

Fuzzy controller is a logistic controller based on fuzzy logic. Fuzzy controllers depend on rules and conditions between inputs to get the output. Fuzzy controller's rules are in terms that human design if he has a well knowledge about the system that needed to be controlled. The inputs of the fuzzy controller are mapped to certain values called Fuzzy sets. Any fuzzy controller consists of three parts.

2. PROPOSED SYSTEM

2.1 Speed Control of PMBLDC Motor Using PLC Controller

The PLC has 8inputs, phototransistors, and 8 outputs, 6 relay outputs and two transistors which are used to provide clock signal or PWM. Most of the outputs are relay outputs which are not fast enough to provide fast switching and have short life span. To overcome this, a transistor output card, sink type, is attached to the PLC, so that all the output signals are taken from these transistors. The driving circuit is implemented to drive six power MOSFETs controlling the BLDCM. Only two MOSFETs are switched on at a time receiving the driving signal from the transistor outputs of the PLC. The circuit is built with six dual input NAND gates, where two CD4011BCN chip are used. The upper half utilizes three NAND gates, where one pin of each NAND gate is common to the PWM and the second pin receives 1 or 0 based on the rotor position. The output of the NAND gate of the upper half when it receives signal from the PLC in the ON and OFF state.

The PLC switches only two NAND gates at any moment driving the output transistors to be switched off which makes the signal to the NAND gate to be high (15V). The effect on the upper half is that the PWM signal will appear on the output on the NAND gate which is applied to the optocoupler. When the optocoupler is on the MOSFET is driven to the off state and vice versa. In the lower half, the MOSFET will be on at all times (no PWM) during the off period of the PLC transistor output. Once the rotor moves and the PLC receives the new position from the feedback sensors, the current off transistor output is activated and new one is switched off to drive a different MOSFET from the upper or

lower half based on the BLDCM sequence of operation. All resistors are selected based on the maximum current consumption of each component

3. HARDWARE IMPLEMENTATION

The main components used are:

- Permanent magnet Brushless DC Motor
- Inverter
- Arduino Board
- Electronic Speed Controller
- Programmable logic controller
- LCD Display
- DC Battery

3.1 Permanent Magnet Brushless Dc Motors (PMBLDCM)

PMBLDCM are widely used in many applications such as motors, sensors, actuators, etc. Permanent magnet motors with trapezoidal back EMF and sinusoidal back EMF have several advantages over other motor types. Most notably, they are lower maintenance due to the elimination of the mechanical commutator and they have a high-power density which makes them ideal for high-torque-to weight ratio applications. Compared to induction machines, they have lower inertia allowing for faster dynamic response to reference commands. Also, they are more efficient due to the permanent magnets which results in virtually zero rotor losses. Permanent magnet brushless dc (PMBLDC) motors [2] could become serious competitors to the induction motor for servo applications. The PMBLDC motor is becoming popular in various applications because of its high efficiency, high power factor, high torque, simple control and lower maintenance. The major disadvantage with permanent magnet motors is their higher cost and relatively higher complexity introduced by the power electronic converter used to drive them. The added complexity is evident in the development of a torque/speed regulator. The magnetization directions and intensities are analyzed using finite element analysis with a detailed magnetization procedure for ferrite bonded magnets used in inner-rotor type BLDC motors [6]. The effect of stator resistance on average-value modeling of electromechanical systems consisting of BLDC motor and 120-degree inverter systems, including commutation current has been presented. It is shown that the model becomes more accurate both in time and frequency domains for the motors with large stator resistance typically operate with small commutation angle.

3.1.1 Modelling of PMBLDC Motor

The flux distribution in the PMBLDC motor is trapezoidal and hence the d–q rotor reference frames model is not suitable. It is shrewd to derive a model of the PMBLDC motor [3] in phase variables when it is given the non-sinusoidal flux distribution. The derivation of this model is depends on the postulations that the induced currents in the rotor due to stator harmonic fields, iron and stray losses are neglected. The motor is taken to have three phases even though for any number of phases the derivation procedure is true to life. Modelling of the PMBLDC motor is done applying classical modelling equations and therefore the motor model is highly adaptable. These equations are illustrated depending upon the dynamic equivalent circuit of PMBLDC motor. The assumptions made for modelling and simulation purpose are the common star connection of stator windings; three phase balanced system and uniform air gap. The mutual inductance between the stator phase windings are uncountable when compared to the self-inductance and so neglected in designing the model.

3.2 Programmable Logic Controller (PLC)

Since technology for motion control of electric drives became available, the use of programmable logic controllers (PLCs) with power electronics in electric machines applications has been introduced in the manufacturing automation. This use offers advantages such as lower voltage drop when turn on and the ability to control motors. Many factories use PLCs in automation processes to diminish production cost and to increase quality and reliability. To obtain accurate industrial electric drive systems, it is necessary to use PLCs interfaced with power converters, personal computers, and other electric equipment. Nevertheless, this makes the equipment more sophisticated, complex, and expensive. The ratio of driving torque to the motor dimensions is very high in the BLDC motors and their speed torque curve is better than that of the brushed and induction motors. Such motors (BLDC) are therefore particularly suitable for applications where the volume available for drive installation is restricted. These advantages prompted the research into the control algorithm and control system simplification and drive fault detection. An industrial PLC was used for controlling BLDC motors [9] in a five-axis rotor position, direction and speed, reducing the number of circuit components and lowering the cost. The rotor position can be sensed by a Hall Effect sensor providing three square-waves with phase shift in 120. These signals are decoded by a combinatorial logic to provide the firing signals for 120 conduction on each of the three phases.

3.3 Electronic speed controller (ESC)

ESC has extreme low output resistance, super current endurance, totally meet electric current specs. Possess temperature protect circuit function. Possess over-volts, lower volts protection function. Possess delicate touch feeling, superior speed linear. When switch on power, ESC won't be started no matter throttle rocker at which positions, safe and reliable. When input volts lower than setted value, ESC will reduce or shut down the output automatically, protecting battery effectively. When input volts higher than rated volts, it emit warning tone, and stop working, self-protecting effectively. When the temperature is over 100 Celsius degree, the ESC will reduce the output power, protecting ESC effectively.

3.4 Arduino Board

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing. from everyday objects to complex scientific instruments. A

worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike

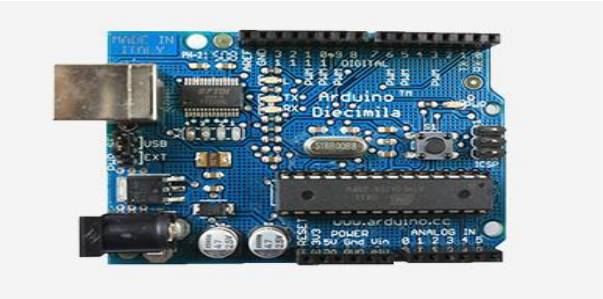

Fig 1: Arudino board

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IOT applications, wearable and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

4. WORKING

In these the supply is taken from DC battery to the electronic speed controller. The electronic speed controller consists of 3-wires, one wire is from arduino board connected to the electronic speed controller. Then the three wires from electronic speed controller are connected to PMBLDC motor. The potentiometer is connected to the arduino board, and to vary the potentiometer so that it speed of the PMBLDC motor is controlled. It uses a programmable memory for the internal storage of user-orientated instructions for implementing specific functions such as arithmetic, counting, logic, sequencing, and timing. A PLC can be programmed to sense, activate, and control industrial equipment and, therefore, incorporates a number of I/O points, which allow electrical signals to be interfaced. Input devices and output devices of the process are connected to the PLC and the control program is entered into the PLC**.**

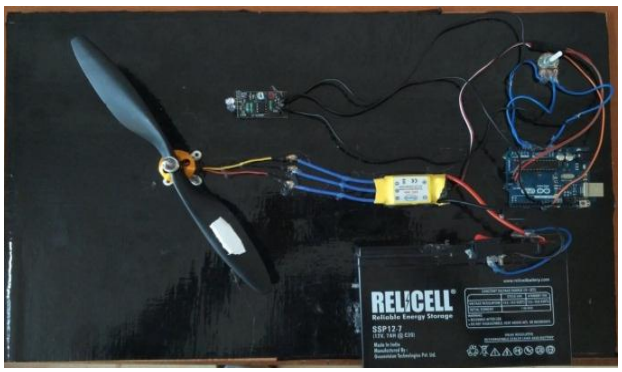

Fig.4: Speed control of PMBLDC motor using PLC

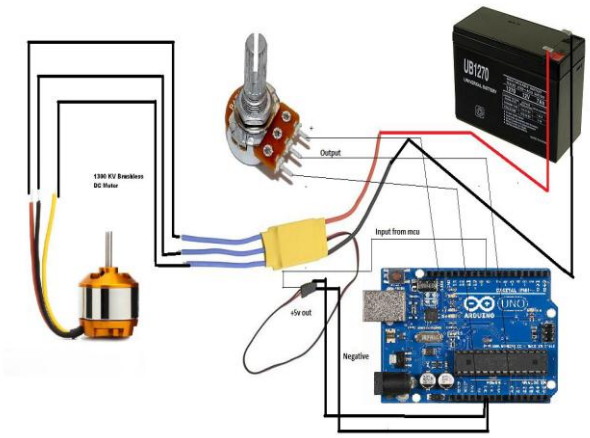

Fig 2: Schematic Diagram

In the block diagram the variable pot is connected to the microcontroller and then PLC is connected to the PMBLDC motor and one of the terminals from PLC is connected to the electronic speed controller and then speed controller is connected to PMBLDC motor. Here pop act as a load, then the temperature sensor is connected to PLC to get the temperature of the motor.

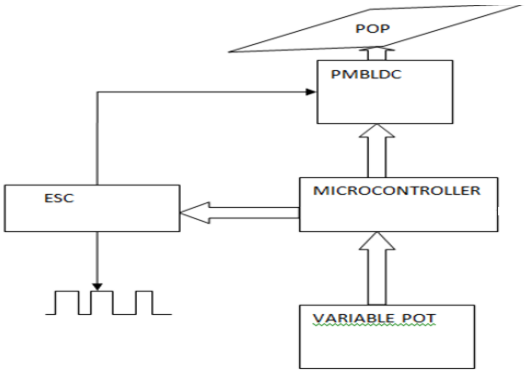

Fig 3: Block diagram of speed control of PMBLDC

5. RESULT

The electrical motors are known as the work horses of the modern industries. The synchronous motors, induction motors are extensively used in almost every process industry and domestic applications. A DC motor is the one with good speed-torque characteristics and high efficiency. Their use had been under the dark side due to domination of AC power generation and distribution. In the wake of creating autonomous devices, which are intelligent enough to sense and respond to their environments the electronic control has become prominent. A PMBLDC motor is a highly efficient motor with less maintenance requirements and suitability to apply in most of the scenarios.

It has to be electronically commuted and can be operated even under remote control that is it can be controlled manually. As PLC is believed to rule the future of intelligent devices and is really important to make life smarter and better. We can use PLC even in synchronizing energy sources.

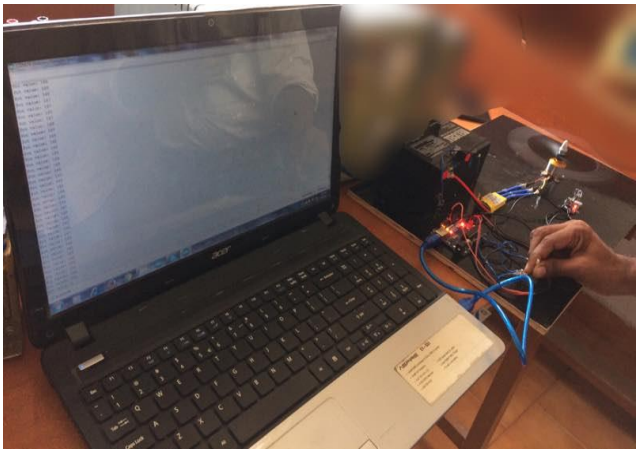

Fig.5: speed control of PMBLDC motor using PLC working model

Thus, we conclude this has a good scope in future due to the analysis of very basic ideas that make it worthy, also since the PMBLDC and PLC are few of the most decorated words in the arena of electrical technology. We can observe the output pot values in the display unit connected.

POT VALUE	SPEED IN RPM
1024	27000
450	11865
320	8437
180	4746

Tabular form: 1

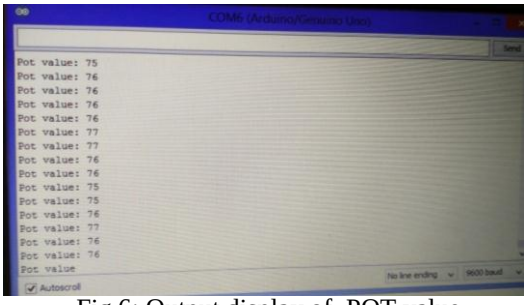

Fig.6: Output display of POT value

6. CONCLUSION

BLDC motors have replaced other motors in applications ranging from air conditioners to remote controlled drives providing advantages in terms of efficiency, reliability and performance. The cost of BLDC motors has been decreasing drastically over last 10 years causing their adapting rate to spike, a strong need for the development of "improved control and their performance enhancement" becomes essential and this is motivation for the present work.

The role of the speed controllers governs the performance of any electric motor drive to a considerable extent. The recent enhancements in controllers have paved the way for realizing the desired excellence in electrical utilities besides serving to improve these line current distortions. The advancements in hardware technology offer a wide scope for extending the horizon of applicability of newer controllers in existing/improved drive topologies.

(i) It will be interesting to explore performance of the proposed controllers and algorithms for permanent magnet synchronous motor (PMSM).
(ii) Space Vector based pulse width modulation method may be exercised instead of traditional pulse width modulation.

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