Abstract— Brushless DC motor (BLDCM) is a high performance, low maintenance cost, adequate torque, high speed, high reliability motor and widely used in industries having several advantages over other type of motors. The reason of popularity is due to its simpler speed control with enhanced performance by the use of electronic commutation. The above mentioned characteristics and properties of BLDC motor provide a large research domain in Electrical drives. This paper presents an idea how to automate the speed control of throttle based brushless dc motor with the help of Programmable Logic Controller and monitor its real time behavior using SCADA and microcontrollers. SCADA (supervisory control and data acquisition) is a type of industrial control system (ICS). Industrial control systems are computer controlled systems that monitor and control industrial processes that exist in the physical world. A microcontroller often serves as the “brain” of a mechatronic system. Like a mini, self-contained computer, it can be programmed to interact with both the hardware of the system and the user.

Key words: Brushless DC Motor (BLDCM), Automation, Speed Control, PLC, SCADA

I. INTRODUCTION

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. The Permanent Magnet Brushless DC (BLDC) motor is the ideal choice for applications that require high power-to volume ratio, high reliability, and high efficiency[10]. BLDC motor is considered to be a high performance motor and is capable of providing large amounts of torque over a vast speed range. These characteristics can be achieved as it a dc motor having similar performance characteristics but without brushes, commutator and slip rings. A BLDC motor requires an inverter and a rotor position sensor to perform commutation process because a permanent magnet synchronous motor does not have brushes and commentators in DC motors [1]. A throttle based brushless dc motor is generally used in electric bikes but here only the performance of brushless dc drives, a single chip logic controller for controlling torque and speed uses a PLC to implement the digital logic coupled with a power controller [2].

II. PLC AS SYSTEM CONTROLLER

A PLC is a microprocessor-based control system, designed for automation processes in industrial environments. It uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as arithmetic, counting, logic, sequencing, and timing [3], [4].

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 memory (Fig. 1).

In our application, it controls through analog and digital inputs and outputs by the throttle voltage. This PLC system is of modular type composed of specific hardware building blocks (modules), which plug directly into a proprietary bus: a central processor unit (CPU), a power supply unit, input-output modules I/O, and a program terminal.

Fig. 1: Control action of a PLC.

III. MODELING OF BRUSHLESS DC MOTOR

BLDC motors are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field generated by the rotor rotates at the same frequency. BLDC motors do not experience the “slip” that is normally seen in induction motors. BLDC motors come in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motors are the most popular and widely used[9]. This application note focuses on 3-phase motors.

Fig. 2: General Scheme for speed Control of BLDC motor drive system
A brushless dc motor is defined as a permanent synchronous machine with rotor position feedback. The brushless motors are generally controlled using a three phase power semiconductor bridge. The motor requires a rotor position sensor for starting and for providing proper commutation sequence to turn on the power devices in the inverter bridge. Based on the rotor position, the power devices are commutated sequentially every 60 degrees. Instead of commutating the armature current using brushes, electronic commutation is used for this reason it is an electronic motor. This eliminates the problems associated with the brush and the commutator arrangement, for example, sparking and wearing out of the commutator brush arrangement, thereby, making a BLDC more rugged as compared to a dc motor.

IV. CONTROL STRATEGY

In this paper the speed of the brushless dc motor is controlled by varying the throttle voltage which acts as the set point for the speed controller as shown in fig. 3. A throttle based BLDCM are used in electric bike in which bike speed can vary by moving the accelerator.

On accelerating the bike throttle voltage is varied which in effect changes the set point for the speed controller. According to the error signal the controller generates signal which affects the gate pulses of the inverter. The voltage of the throttle can be controlled by varying the voltage automatically by PLC and the change in speed can be monitored in the SCADA.

V. HARDWARE DESCRIPTION

The control system is implemented and tested for a brushless dc motor which is a part of electric bike in which power supply is given by chargeable battery of 54 volts. The throttle output voltage is provided by the analog output of the PLC. When voltage from the PLC is varied, the speed varies accordingly which can be seen either in SCADA at the central unit and an LCD is programmed and connected to display the speed.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of poles</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Voltage Constant ±5% (V/Krpm)</td>
<td>136.1357</td>
</tr>
<tr>
<td>3</td>
<td>Torque Constant ±5%(Nm/A)</td>
<td>1.3</td>
</tr>
<tr>
<td>4</td>
<td>Stall Current (A)</td>
<td>2.46</td>
</tr>
<tr>
<td>5</td>
<td>Peak Torque (Nm)</td>
<td>9.60</td>
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<tr>
<td>6</td>
<td>Peak Current (A)</td>
<td>7.4</td>
</tr>
<tr>
<td>7</td>
<td>Max. Current (A)</td>
<td>8.6</td>
</tr>
<tr>
<td>8</td>
<td>Resistance/ Phase(Ω)</td>
<td>10.91</td>
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<tr>
<td>9</td>
<td>Inductance/ Phase (mH)</td>
<td>30.01</td>
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<tr>
<td>10</td>
<td>Insulation Class</td>
<td>F</td>
</tr>
<tr>
<td>11</td>
<td>Moment of Inertia (Kgcm²)</td>
<td>2.9</td>
</tr>
<tr>
<td>12</td>
<td>Mechanical Time Constant(ms)</td>
<td>1.4/1.8</td>
</tr>
</tbody>
</table>

Table 1: PMBLDC Motor specification
Brushless DC Motor using PLC

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Speed Control of Brushless DC Motor

Discrete output module (DOM);
Discrete input module (DIM);
Analog outputs module (AOM);
Analog inputs module (AIM);
Power supply.

<table>
<thead>
<tr>
<th>I/O</th>
<th>Available</th>
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</thead>
<tbody>
<tr>
<td>Discrete Inputs (%I)</td>
<td>32</td>
</tr>
<tr>
<td>Discrete Outputs (%Q)</td>
<td>16</td>
</tr>
<tr>
<td>Analog Inputs (%AI)</td>
<td>8</td>
</tr>
<tr>
<td>Analog Outputs (%AQ)</td>
<td>8</td>
</tr>
<tr>
<td>Register Memory (%M)</td>
<td>540</td>
</tr>
</tbody>
</table>

Table 2: PLC Configuration

A corresponding SCADA system is also designed to monitor and vary the voltage automatically so that by varying slider the motor speed can vary. An interfaced is made in such a way that by varying the switch position in the screen in which animated slider is shown in fig. 6, voltage at the output of analog module can vary. The varying speed is displayed in SCADA.

![Automation of Brushless DC Motor](image)

Fig. 6: SCADA Screen for speed control of BLDCM

The analog voltage generated by the analog module is monitored with the help of a microcontroller. Code is generated to display corresponding digital value for speed of the motor in liquid crystal display.

![Connection Diagram of ADC and LCD for BLDC drive system](image)

Fig. 7: Connection Diagram of ADC and LCD for BLDC drive system

VI. SOFTWARE DESCRIPTION

PLC’s programming is based on the logic demands of input devices and the programs implemented are predominantly logical rather than numerical computational algorithms[8]. Most of the programmed operations work on a straightforward two-state “on or off” basis and these alternate possibilities correspond to “true or false” (logical form) and “1 or 0” (binary form), respectively. Thus, PLCs offer a flexible programmable alternative to electrical circuit relay-based control systems built using analog devices.

The programming method used is the ladder diagram method. The PLC system provides a design environment in the form of software tools running on a host computer terminal which allows ladder diagrams to be developed, verified, tested, and diagnosed. First, the high-level program is written in ladder diagrams, [6], [7]. Then, the ladder diagram is converted into binary instruction codes so that they can be stored in random-access memory (RAM) or erasable programmable read-only memory (EPROM). Each successive instruction is decoded and executed by the CPU. The function of the CPU is to control the operation of memory and I/O devices and to process data according to the program. Each input and output connection point on a PLC has an address used to identify the I/O bit.

![Flowchart of the main program](image)

Fig. 8: Flowchart of the main program

Here plc is used as a driver for the motor which provides set point for the required speed of the motor. Analog module used here is 1766 IF2OF2 of Allen Bradley PLC. In here one analog input and one analog output is used. Output is connected to the throttle and input to the tacho generator which works as a feedback to the plc. In real time system this speed is displayed in the dial present in the SCADA monitor.

VII. RESULTS AND DISCUSSION

Fig. (9-12) Show the performance of the Hall sensor-based commutation of PMBDC motor drive with conventional speed controller and current controller using PLC and SCADA. The motor is running at the reference speed of 500 rpm with constant load torque. Speed, torque, current and Back-emf wave form are shown below for speed control of Brushless DC motor and which is monitored and control by PLC and SCADA. The performance variable such as speed, voltage can be varied with the help of SCADA screen which is shown in fig.6 and corresponding speed and digital equivalent voltage to that speed is monitored in LCD arrangement which is shown in fig.7.
ACKNOWLEDGEMENT

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REFERENCES


