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Intelligent Power Controller for BLDC Motor

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Abstract

Now-a-days BLDC motors are used in many applications including electric vehicles. The battery-operated vehicles are gaining popularity as people become increasingly aware of the adverse effects of fossil fuel-powered vehicles on the environment. These battery- operated vehicles are equipped with the Brushless direct current (BLDC) motor due to its high efficiency. Many researchers carried out researches to regulate the operations of BLDC motors. In this research the control of BLDC motor is analyzed. While taking into account reliability and durability, the BLDC motor fails to provide an increased fault tolerance, with decreased electromagnetic interference, acoustic noise, flux ripples, and torque ripple. Torque ripple in a BLDC motor's is mainly caused due to the variation in the interactions across the stator and rotor as well the electromagnetic fields. So, the research has come up with the solution to the torque ripple using the controllers. By using intelligent power controllers, the output performance can be improved with good power quality and efficiency.

Keywords: BLDC Motor, Speed Control, Raspberry Pi Controller.

1. Introduction

In BLDC motors the armature is stationary and permanent magnet field system is mounted on the rotating shaft. The commutation is achieved by using semiconductor switches. Thus, BLDC motor can be treated as a synchronous motor with permanent magnet rotor and is supplied current from a DC source through an inverter which is automatically synchronized. In performance, a BLDC motor in combination with auto- synchronized inverter is exactly similar

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to the conventional DC motor, with the added advantages of elimination of mechanical commutator, brushes and electromagnets. Compared with PMDC motors, BLDC motors have higher efficiency, smaller size and better cooling. Brushless DC Motors are widely used in many applications such as in home appliances, automotive and aerospace.

2. BLDC Motor

In order to transform electrical energy into mechanical energy, electrical commutation is used [3,4]. The main difference in design between brushed and brushless motors is the removal of the mechanical commutator and replacement by an electric switch circuit. BLDC motor and the brushed DC motor operates on the same principle that is when a current-carrying conductor is exposed to a magnetic field, a force is created in accordance with the Lorentz force equation. [5,6]. Whenever the stator coils are supplied by an opposing force the magnet will encounter an equivalent reaction force and move as a result. The current carrying conductor in the BLDC motor remains stationary, and the permanent magnet source transforms into an electromagnet, creating a equivalent field in the in air gap. However, the switching results in an AC voltage waveform in trapezoidal shape as the power source is DC. [7]. The rotor continues to rotate due to the force of interaction between the electro- magnet stator and the permanent magnet rotor [8,9,10]. Windings are triggered as north and south poles and switched as high and low signals, respectively. The motor rotates as the south and the north poles of the rotor in the permanent magnet is aligned with the stator poles.

The BLDC Motor model is depicted in the Fig. 2.1. In this motor, the rotor is linked to permanent magnets. The armature windings or conductors that carry current are housed in the stator. The main structural distinction between brushed and brushless motors is the removal of the mechanical commutator in favor of an electric switch circuit. When the stator coils receive power from an opposing force. The current carrying conductor in the BLDC motor is stationary, and the permanent magnet source transforms into an electromagnet, with a uniform field production across the air gap. Owing to the force of interaction amid the permanent magnet rotor as well as the electro-magnet stator, the rotor continues to rotate. The motor rotates as the south and the north poles of the rotor in the permanent magnet is aligned with the stator poles. The most common way to control a BLDC motor is to use hall sensor for the positioning system as shown in fig. 2.2.

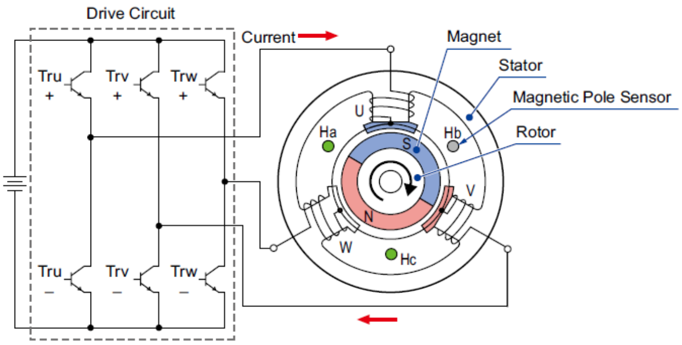

Figure 2.1. Simplified Model of a Brushless Motor [12]

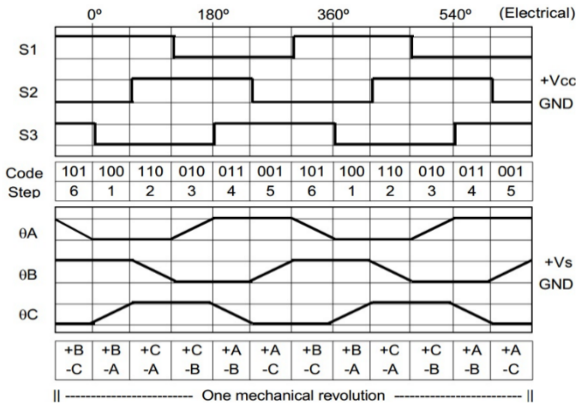

Figure 2.2. Hall Sensor Commutation Timing Diagram [12]

2.1. Classification of BLDC Motors

On the basis of rotor construction, BLDC Motors can be classified into surface mounted permanent magnet and interior type permanent magnet motors. Another classification is based on the length of the pole arc as 180-degree pole arc and 120-degree pole arc BLDC motors. According to the number of phases and pulses, BLDC motors are grouped into “1-phase-1-pulse, 1-phase-2-pulse,2-phase-2- pulse, 3-phase-3-pulse, 3-phase-6-pulse and multiphase-multipulse” BLDC motors.

$$\text{Torque equation:} \quad T = P/\omega = 2eI/\omega = 2(2rlBgNw)I/\omega$$

$$= 4rlBgNI$$

Thus, the torque equation of the BLDC motor is

$$T = k\Phi i$$

and emf equation is $E = \Phi\omega$

Where $k = 4N$ and $\Phi = rlBg$

3. Controllers

3.1. Raspberry Pi Based Control of BLDC Motor

Fig. 3.1depicts the Raspberry Pi board model 4. This board is used for the controlling of BLDC motor. The specific pin in the board is supplied with the proper signal. Quad core 6-bit Broadcom 2711, cortex A72 processor.

- Generating control signals: The Raspberry Pi can generate control signals to regulate the speed and direction of the BLDC motor. These signals are sent to a motor driver board, which amplifies them to drive the motor.
- Reading sensor data: BLDC motors often require position or speed feedback to ensure accurate control. The Raspberry Pi can read data from sensors, like encoders or hall-effect sensors, to determine the motor's position or speed.

Figure 3.1. Raspberry pi Board

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- Implementing control algorithms: The Raspberry Pi can execute control algorithms to regulate the motor's speed or position. These algorithms can be implemented in software, using languages such as Python, to perform tasks such as PID control.
- Providing user interface: The Raspberry Pi can provide a user interface, such as a web interface or a graphical user interface (GUI), to enable users to control the motor or adjust control parameters.
- Logging data: The Raspberry Pi can log data from the motor, such as speed or temperature, for further analysis or troubleshooting.
- Overall, the Raspberry Pi provides a flexible and programmable platform for controlling BLDC motors, enabling users to implement a wide range of control strategies and interfaces.

3.2. PID Controller

A PID controller controls variables associated with the process including speed, pressure, flow, and temperature in industrial control applications. The fact that PID controllers utilizes a regulated feedback mechanism loop to control variables associated with the process to make them more precise and reliable controllers. It combines all three types of control methods. It is the most commonly used type of control because it combines the benefits of each type of control. This includes a faster response time as a result of the p control action; the system will respond to a change very quickly. The system can be returned to the setpoint value thanks to the action of I control. Finally, because maintaining a constant setpoint is critical for the system, D the system accordingly. On the contrary, as mentioned previously, when used It has a slower response time when compared to the faster P-only control. As a result, the PID controller appears to be the most appropriate controller in terms of accuracy and stability. A PID controller is a common type of feedback controller used in many industrial control applications, including BLDC motor speed control. The brushless DC motor speed is proportional to the applied voltage, and the PID controller's goal is to adjust the voltage to maintain the desired speed. The PID controller receives input signals from sensors that measure and compare motor speed to desired speed. The controller adjusts the output voltage to the motor based on this error signal by varying the duty cycle of the pulse width.

3.3. Speed Control of BLDC Motor using Simulink

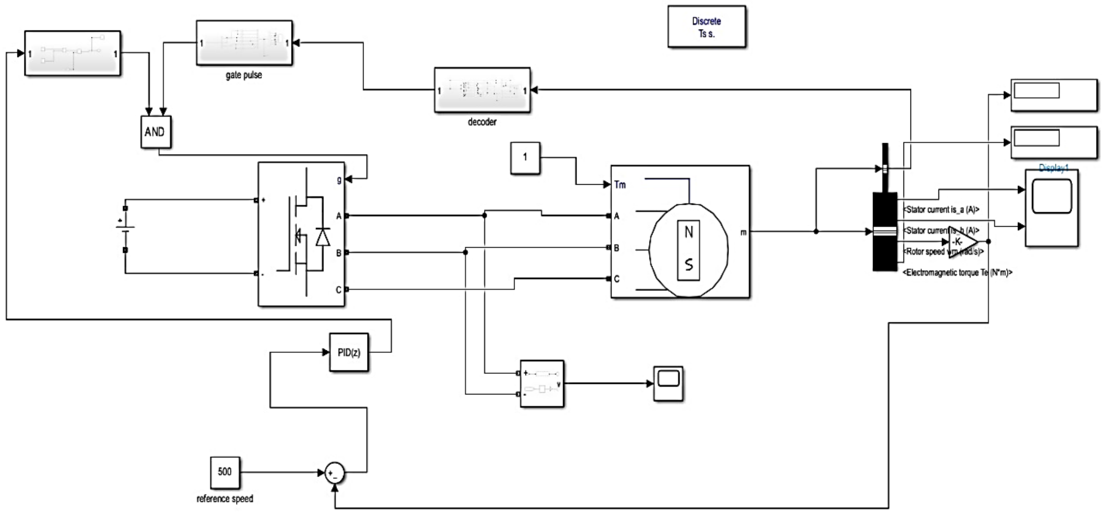

Figure 3.2. BLDC Controller Block Diagram in Simulink

The 3-phase AC supply is converted to DC supply with the rectifier, the armature and field of motor supply is taken and given to and this is controlled in closed loop. The Fig. 3.2 shows the circuit in MATLAB/ Simulink of BLDC controller block diagram. With the scope signal of the closed loop system seen below in Fig.4.1

4. Simulation Results

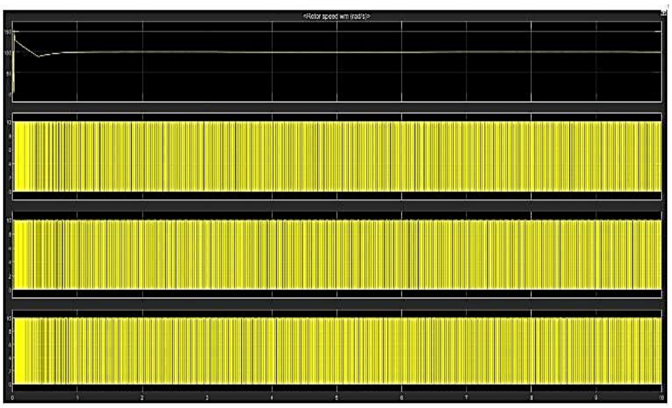

Figure 4.1. Rotor Speed and Hall Effect Sensor Digital [11]

The first channel displays the rotor speed of the motor, which gradually increases to the set value after using the PID controller. The remaining channels contain the three hall sensor signals. The Fig. 4.1 shows the rotor speed and hall effect sensor. The Fig. 4.2 shows the hall effect sensor and in the digital format. The fig. 4.3 shows trapezoidal back EMF.

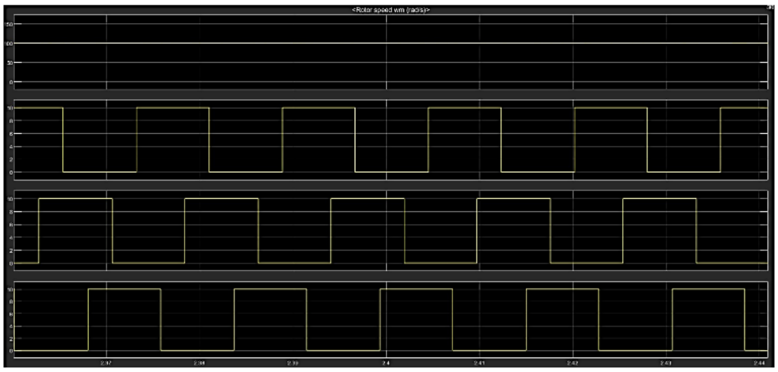

Figure 4.2 Hall effect Sensor Signal [11]

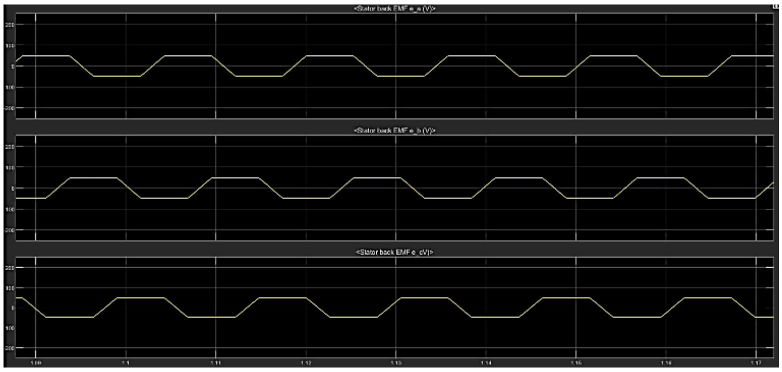

Figure 4.3 Trapezoidal Back EMF [11]

5. Hardware Components

Intelligent power Module, BLDC Motor, Hall sensor Interface cord, Raspberry Pi controller (RP2040), Auto transformer, DSO, Latches, Connecting wires.

5.1. Hardware Setup

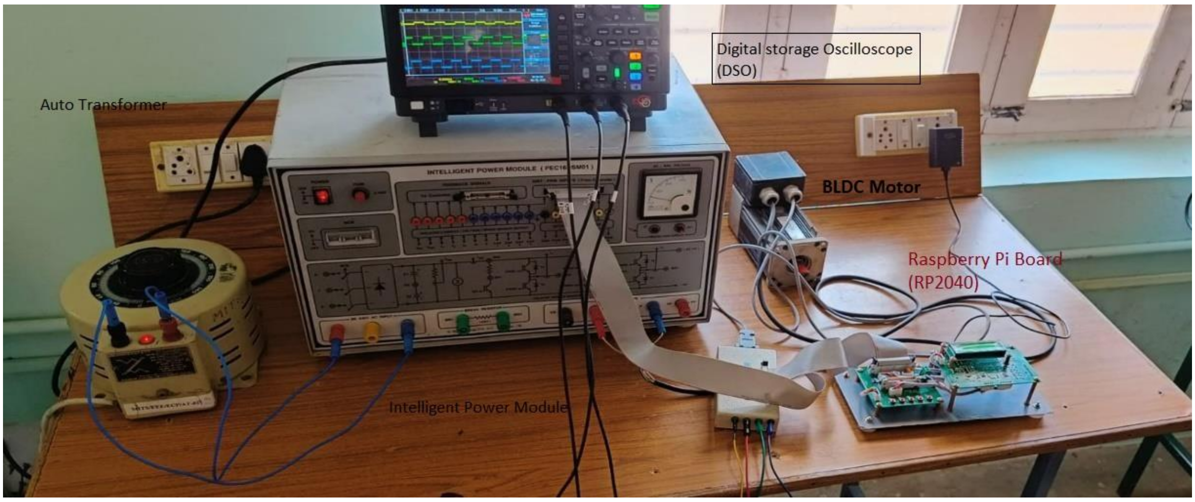

Figure 5.1 BLDC Motor with Raspberry Pi Controller (Speed Control)

The is the complete hardware setup of the proposed is depicted in Fig.5.1. In this case, we're using an auto transformer to provide AC power to the Intelligent Power Module. The Intelligent Power Module contains six IGBT switches that provide gate pulse signals to rotate the motor. Intelligent Power Module provides the BLDC motor input. The Raspberry Pi controller receives power, and its PWM signals are connected to the sensor interface cord via latches. Through latches, the sensor interface cord is also linked to the PWM signal block in the Intelligent Power Module. Digital storage oscilloscope (DSO) is used to measure and monitor the waveforms of the signals with respect to amplitude and time.

Raspberry Pi is utilized to regulate the BLDC motor's speed using the open loop control method. When the modulation index in the Raspberry Pi controller, is decreased the speed of the motor decreases automatically, as shown on the Raspberry Pi display. As a result, the hall sensor signals are visible in DSO.

5.2 Hardware Results

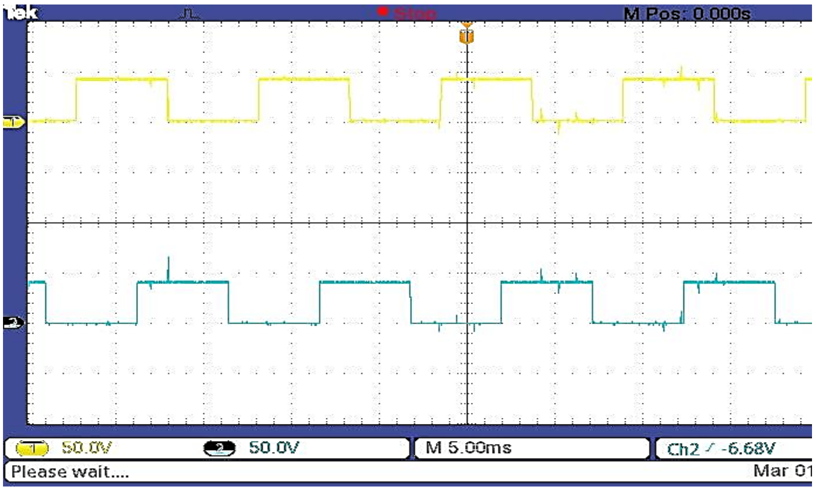

Figure 5.2. Hall Sensor Signals (signal-a, signal-b)

Fig. 5.2 shows the signals of hall-sensor that monitors the rotor position in a signal.

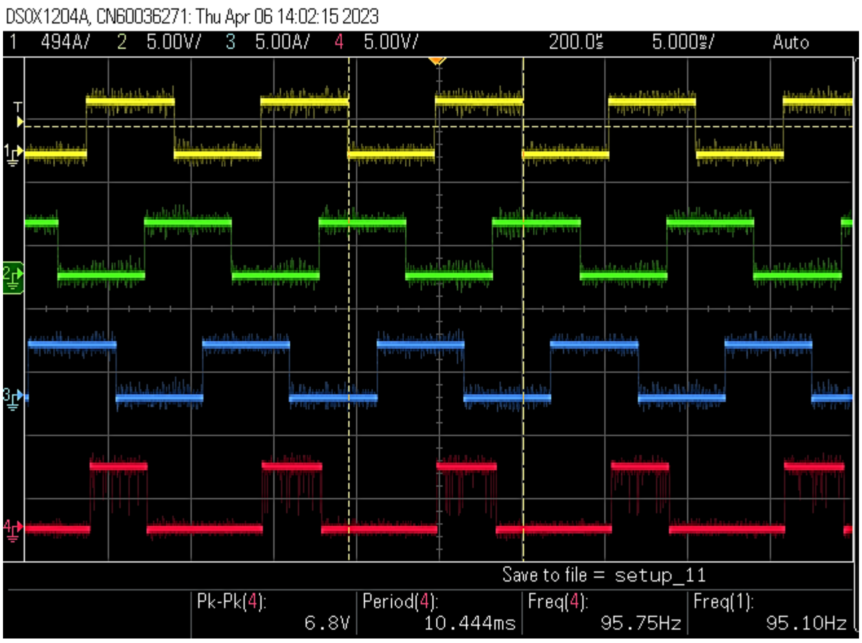

Figure 5.3. Hall sensor signals

The Fig .5.3 shows the hall sensor signals used in controlling the BLDC motors by determining the rotor position. The processor used as the control system gather s the information of the rotor position to and regulates the motor by applying a proper voltage pattern.

6. Results & Discussion

The tabulation in the table 6.1 below shows the hardware results obtained for the different AC and DC voltages at the hall sensor voltage of 50

Table 6.1. Hardware Results

S.NO	**AC supply (Volt)**	**DC supply (Volt)**	**Hall sensor voltage (Volt)**	**Duty cycle (%)**	**Speed (rpm)**
1	40	30	50	0.4	0377
2	100	105	50	0.42	1414
3	125	150	50	0.42	1928
4	150	180	50	0.42	2371
5	175	210	50	0.40	2955
6	200	255	50	0.40	3491
7	225	285	50	0.40	3973
8	234	300	50	0.40	4110
9	250	310	50	0.40	4600

Table 6.2. Dutycycle vs Speed

S.No	Duty cycle	Speed in RPM
1	0.40	4110
2	0.34	3913
3	0.28	3371
4	0.22	2726
5	0.17	2105
6	0.10	1140
7	0.05	443

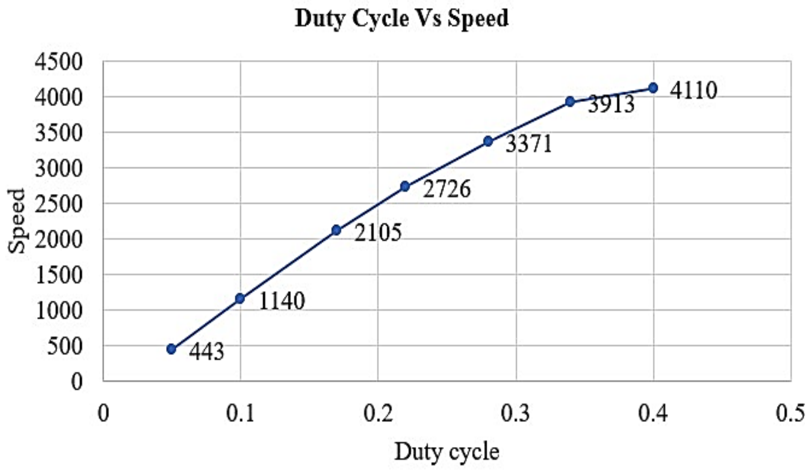

Figure 6.1. Graph for Duty Cycle vs Speed

Hall sensor signals are visible in the Fig. 5.2 which shows the rotor position. Hall sensor with five channel digital storage oscilloscope (DSO). Keysight DSOX1204A has 04 channel and it is observed in Fig. 5.3 as in different color indicating the hall effect sensor signals which is fixed in motor. The tabular column 6.1 shows the hardware results. When AC voltage is increased the DC voltage also increased with respect to speed is increased as duty cycle is changed. A separate tabular column is depicted in Table 6.2 as duty cycle is decreased the speed is also decreased. The pictorial representation is shown in Fig. 6.1 as shown.

7. Conclusion

This research depicts the speed regulation scheme of a BLDC motor. The BLDC motor's speed is gradually increased to the set value of 100 rad/sec using a PID Controller. To operate efficiently and effectively, BLDC motors require precise speed control. A PID controller aids in this by constantly adjusting the motor's input voltage according to the variation in the actual and the desired speed of the motor. The BLDC motor's speed can be controlled with high accuracy, stability, and responsiveness using a PID controller, making it suitable for applications such as robotics, automation, and electric vehicles.

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