Parameter estimation and analysis of BLDC motor drive for electric vehicles application

Vinay Kumar Awaar[1*], *Rajshri* Simhadri[1], *Tharuni* Jalla[1], *Mounika* Bagari[1], Siri *Aggarapu*[1], *A. Hussien* Abbas[2]

[1] Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad, Telangana, India
[2] Computer Technical Engineering Department, College of Technical Engineering, The Islamic University, Najaf, Iraq

Abstract. This paper focuses on motor parameters of the Brushless DC motor. This main goal of this work is to demonstrate that BLDC motors are the best electric motor for electric vehicles. Due to their increased efficiency and reduced maintenance requirements, brushless DC motors are used. The paper proposes a framework to analyze Brushless DC motor characteristics using Code Composer Studio software and InstaSpin BLDC GUI. The framework's features, experimental results, and potential benefits are likely discussed in the paper. Simulink is used to resemble a BLDC motor with an ideal Back-Electro Motive Force (BEMF) voltage and its control drive. Experimental results have confirmed that the BLDC motor driving model predicts BLDC motor operation properly. Additionally, the BLDC motor parameter are estimated using Field-Oriented Control (FOC) mode. Both the simulation results and the hardware results have been presented.

Keywords—BLDC motor, InstaSpin FOC, code composer studio (CCS), TMS320F28027, DRV8301, GUI.

1 Introduction

A broad range of speed and torque control is necessary in EVs. The main power supply for industrial plants is electric motors. BLDC motors are suitable for construction methods with a high power density. The most often used motors for use in electric vehicles are BLDC motors because of their high starting torque and high efficiency of 95–98%. Nowadays, brushless motors are much more apparent than brushed motors. However, a broad range of applications can be found for both [1]. Automobiles and home appliances both still frequently use brushed direct current motors. Brushed motors have a distinct commercial niche due to their ability to adjust the torque to speed ratio.

Every industry has procedures that call for a change in the standard speed, and there are numerous ways to regulate the speed of BLDC motors, including the PWM technique and

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* Corresponding author: vinaykumaar.a@gmail.com

sensor-less control [2-3]. We developed a method to operate a BLDC motor utilising duty cycle resolution and the rotor position that is determined using sensor in this research. The modelling of the three-phase inverter is designed for running the BLDC motor using MATLAB simulation, and hardware is applied.

The PWM control is the most electrically powered technology that offers a straightforward way to control analogue systems with processor digital output. The TMS320F28069 control card is used in this study to control the BLDC motor drive. Micro controllers are used by sophisticated controllers to control acceleration and speed and other characteristics.

1.1 BLDC motor for EV applications

In BLDCs, which lack brushes, the stator current is controlled by a semiconductor in order to achieve the greatest torque at a specific speed. The contrast is that torque can be produced by controlling the stator's current via semiconductor control. In this chapter, the output characteristics of a BLDC motor are compared in terms of the requirements for in-wheel motor technology in both regular and emergency situations. The best option for enhancing electric vehicles is a BLDC motor[6-8]. In addition to providing a conceptual framework, this study seeks to deliver a thorough overview of the literature and commercial practises linked to constraint analysis. In the study, the following sub-objectives are present those are PWM voltage for controlling motor speed, the motor's commutation mechanism and using back-EMF to determine the location of the rotor.In this thesis, a three-phase brushless motor powered by the DRV8301 and a control card slot will be utilised to measure the speed of a brushless DC motor. It has dynamic performance and has a low operational speed when operating in four modes. To view the performance characteristics, use INSTA BLDC. Current applications require precise movement control and continuous activity in variable speed applications, therefore, brushless DC motors are frequently used.

2 Control method for BLDC motor drive

A BLDC motor can be run using sensor or sensorless methods. In order to determine the location of the rotor, several of the sensor-less control algorithms discussed in this section employ Back-EMF and current Detecting. There a number of Control Methodologies that can be used those are Current Control Method, Velocity Control Method and Cascade Control Method.

Current Control method is one of the fundamental control methodologies where one sensor is mounted in the line inverter input, the motor's current can be managed. A cheap resistance could be applied, if necessary[5-6].A fresh PWM duty cycle is fed at the beginning of the cycle for every current measurement. When the switch is off, there is no current flowing through the shunt resistor.

In the velocity control mode, the actual speed and intended speed difference are inputs to the pi controller. By altering the kp proportional gain and integral gain, PI can vary the duty cycle. Gain ki is regulated by PWM pulses sent to the inverter's switches. At greater speeds, the velocity control mode is stable, but the system's speed is decreased. It might turn out to be unstable.

In cascade control mode two PI controllers are tuned in Cascade Configuration using closed-loop PID Auto-tuner blocks. The device is startled by the Auto-tuner blocks, which also change the PID in accordance with the expected frequency response within the required bandwidth. Here, the feedback loop is closed, and the initial controller gains are constant, in contrast to the Open-Loop PID Auto-tuner Unit.

2.1 Proposed Method for BLDC motor drive

Permanent magnets and brushless DC (BLDC) The most widespread use of FOC, also known as basic vector control, is with DC motors[9]. When compared to other motor control techniques, FOC shows a noticeable increase in efficiency as motor speeds get close to their limits. A BLDC motor's polarity can be externally controlled using two techniques : Hall effect control and FOC. The potential of our research can be increased by using FOC (field-oriented control). This technically challenging method of controlling stepper motors and three-phase DC motors provides more efficiency and more precise position control at higher speeds.
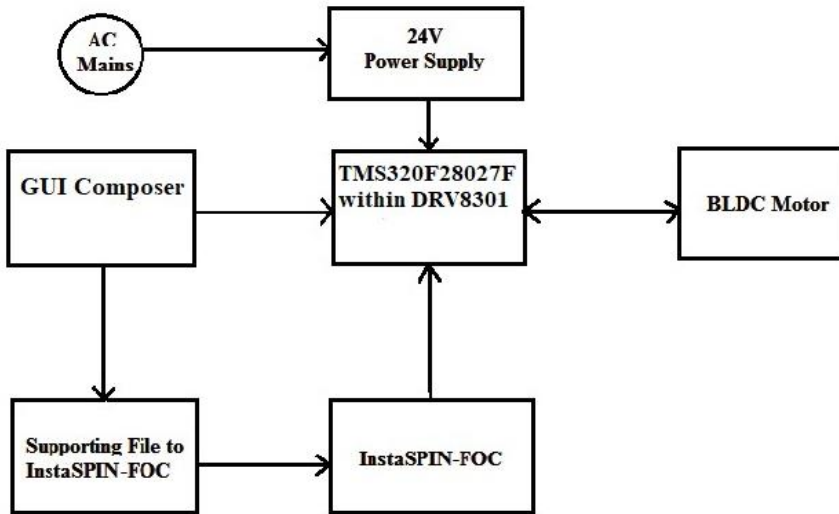
Fig 1. Block Diagram for Hardware Implementation

The BLDC hub motor's operation is depicted in the block diagram above using GUI composer. The hub motor connections were established by mounting the TMS320F28027F control card on DRV8301 ; the accompanying file for this is INSTA SPIN FOC. The motor is supplied by AC mains, which has a voltage of 24 volts.

3 Simulation Studies

The polarity of BLDC motor, this chapter includes results from a MATLAB simulations of a three-phase inverter feeding a brushless DC motor.
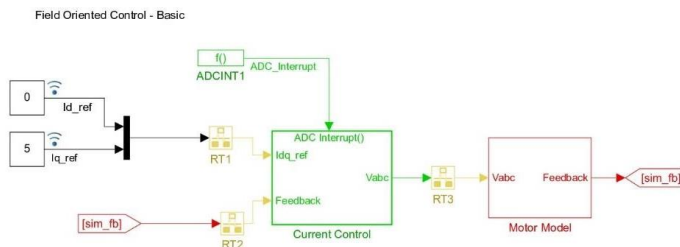
Fig2. Basic block diagram of FOC

This is the fundamental simulation of FOC – Field Oriented Control. where the Id ,Iq are the reference currents which are fed to the current controller through RT1 block (Rate of transmission),which indicate sampling time and the feedback is also connected to the controller system. To get output vabc there is an sub block diagram of controller system.
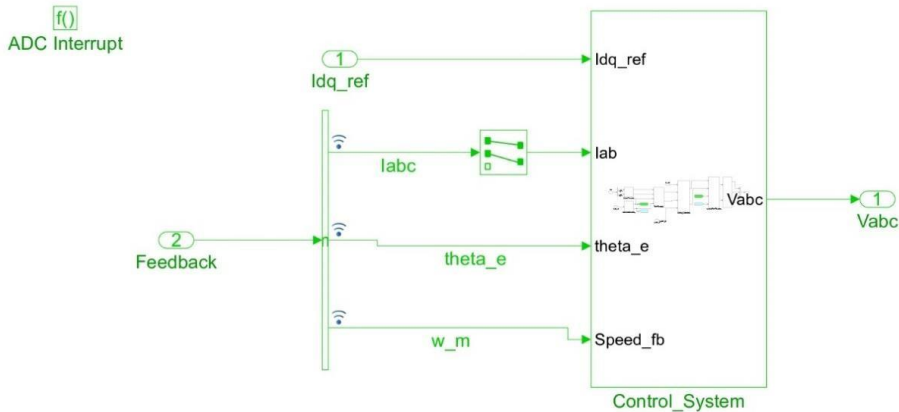

Fig 3. Control system block diagram

It is the sub block system of the current controller in which the feedback has three values mainly they are three phase currents (Iabc),theta_e(rotor position) and w_m(speed). The 3 phase currents are converted 2 phase currents by using transformations. They are mainly 2 transformations: Clarke transformation and Park transformation.
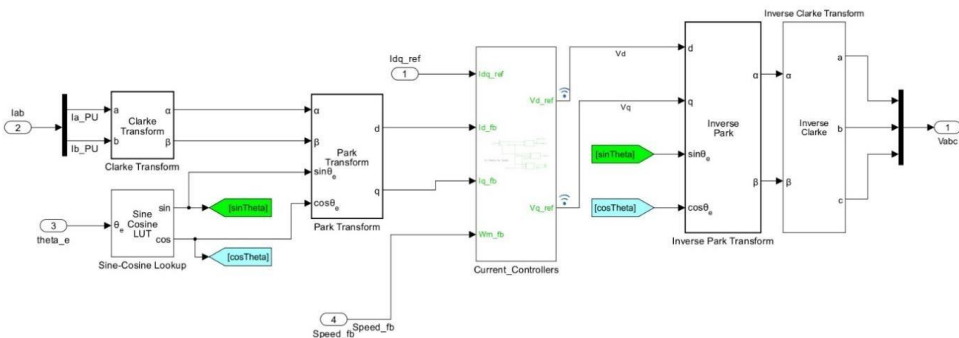

Fig 4. Current Controller Block

The FOC transformations block is made up of four different transformations (Clarke,inverse Clarke,park,and inverse park). The Clarke transformation is used to convert the current parameter to the voltage parameter, which converts the time domain components of a three-

phase system to two components in an orthogonal stationary frame. The park creates a rotating orthogonal reference frame (dq) from the two in-frame parts. The (αβ) parameters are transformed to (dq) and sent to the current _controllers to provide quadrature and direct axis output voltage references. We use PI controllers to transform Iq, Id to vq, vd.
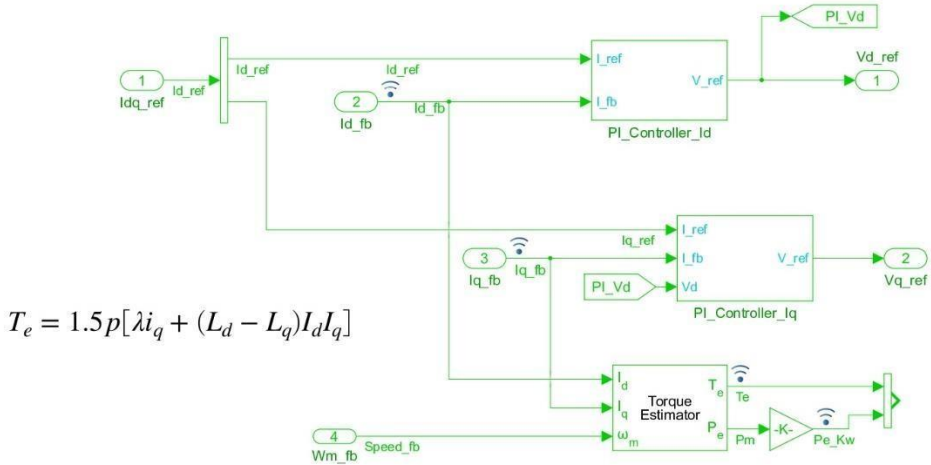

$$T_e = 1.5p[\lambda i_q + (L_d - L_q)I_d I_q]$$

Fig 5. PI Controller Block

It is a current controller sub-block system in which current parameters are converted to voltage parameters, and the error is determined using the reference and feedback to provide voltage reference. These voltage references of 1,2 are the outputs of current controllers. Using the inverse park method (converts the time-domain direct, quadrature and zero components in rotating reference frame to the components of a three- phase system in an abc reference frame).
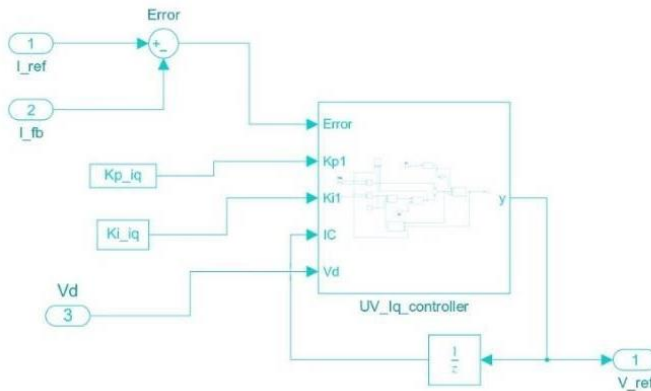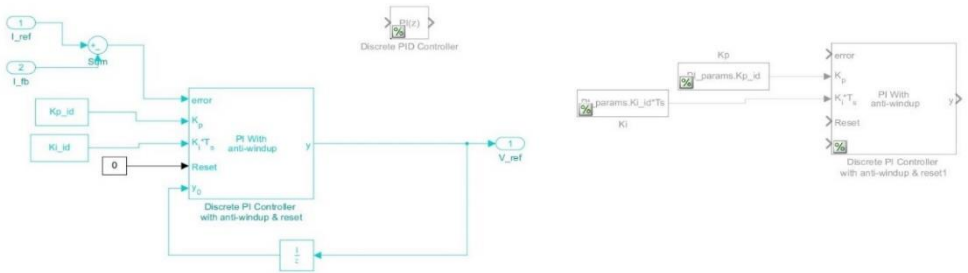

Fig 6. Quadrature Controller System

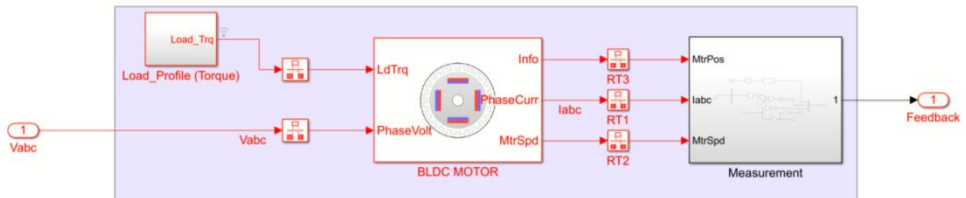**Fig 7.** Direct Controller System

Fig 8. Inverter model System

The output value of vabc of the current controller is same as of the inverter value vabc (let's assume). Now this feedback is given to the motor model.

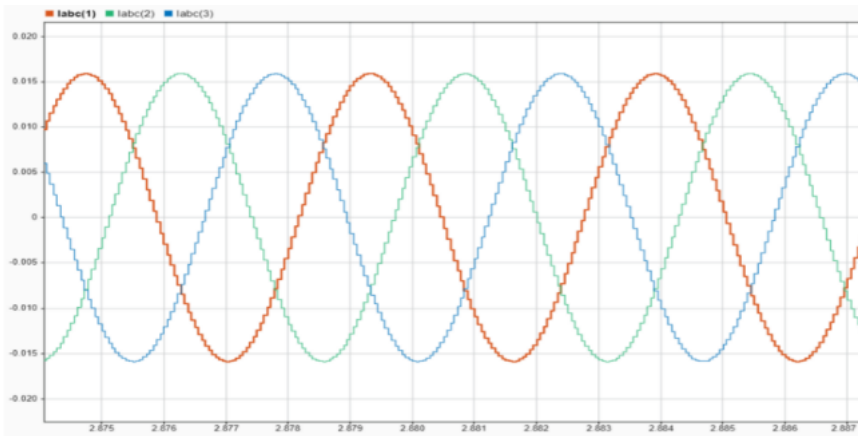**Fig 9.** Fluctuation Condition for BLDC motor

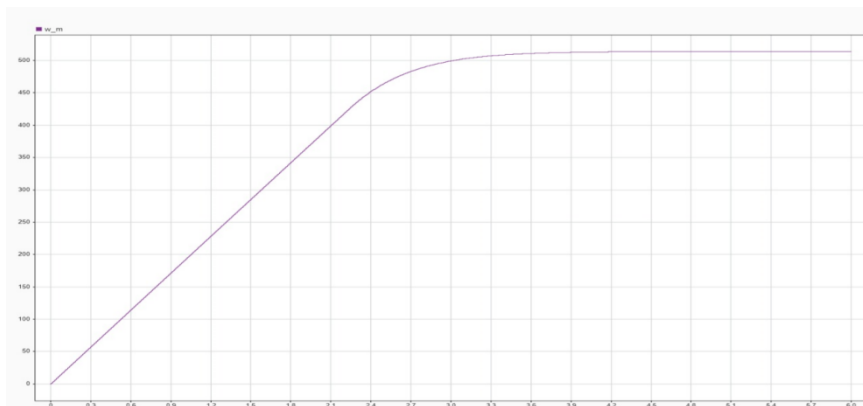**Fig 10.** Steady state condition of BLDC motor

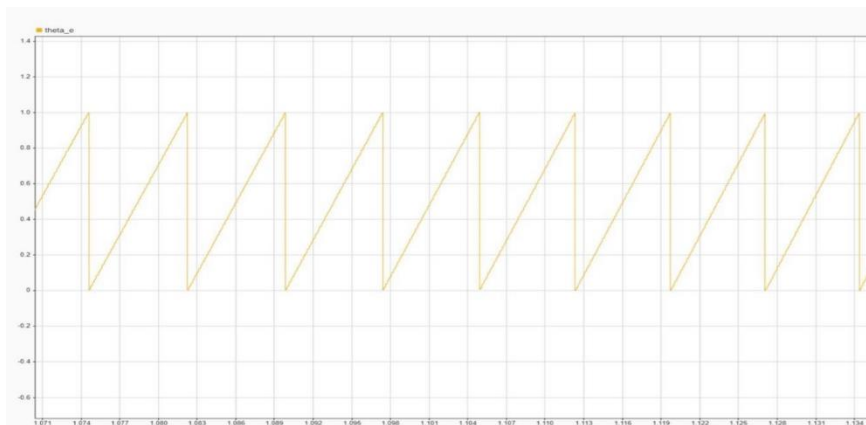
Fig 11. Speed of the BLDC motor

Fig 12. Theta(Position) rotor position of BLDC motor

We are assuming Iq reference to be 5.0, due to initial oscillations there is a transient state observed in 2.4 ms and once stability is attained, we observe the speed to be marginalized.
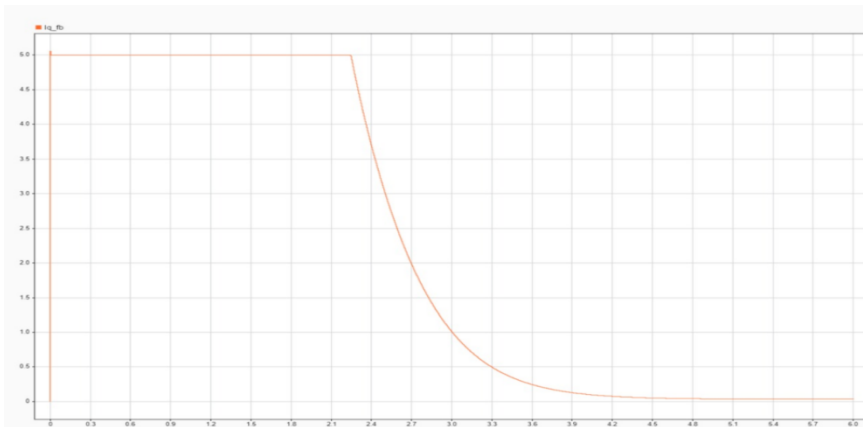
Fig 13. Iq_fd (quadrature current feedback) of BLDC motor

While Iq reference is considered to be 5.0, we observed that with increasing the speed Iq feedback is drastically decreasing.

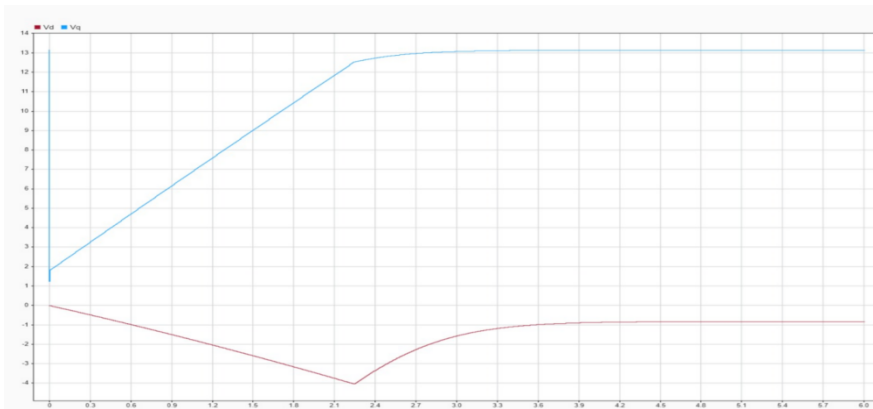

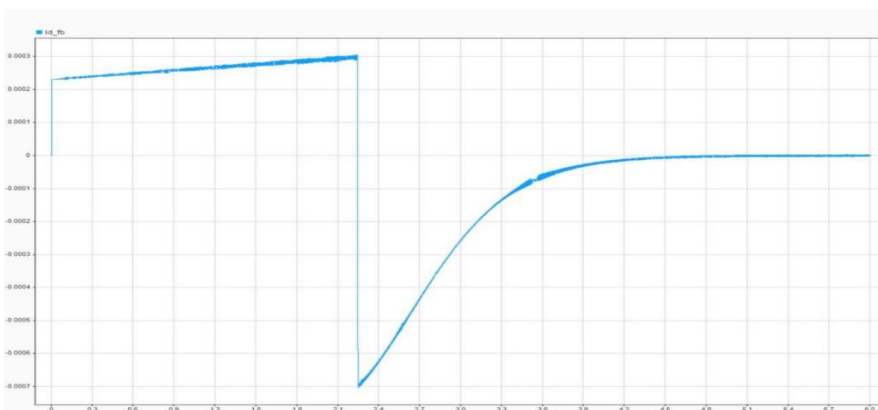**Fig 14.** Vd_Vq (direct,quadrature voltage)of BLDC motor

Fig 15. Id_fd (direct current feedback) of BLDC motor

From fig 13, 14 graphs we observe that, there is a sudden drop this is this is due to back EMF.

4. Hardware Implementation

The parameters derived from the simulation study are displayed below. In order to determine the parameters, we used a GUI programme for the motor.

Table 1 BLDC Motor model parameters

Number of pole pairs, P	4
Stator resistance per phase, Rs	0.1 ohm
Stator self-inductance per phase, Ls	Le-4 H
Stator mutual inductance, Ms	Le-5 H
Maximum permanent magnet flux linkage, psim	0.0175 Wb
Rotor inertia, Jm	0.0005 kg-m^2
Sample time for inner control loop Tsc	le-4 s
Maximum DC link voltage Vdc	48 V

Table 2 Proportional and Integrator for Voltage and Speed Controller

Kpw	0.1	Proportional gain for speed controller
Kiw	15	Integrator gain for speed controller
Kpv	0.1	Proportional gain for voltage controller
Kiv	0.5	Integrator gain for voltage controller

4.1 Testing of BLDC Hub motor

 The experiment was performed under three test conditions ; under no load, 50% load and 100% load conditions, and the following is the analysis.

The three BLDC phases are connected to DRV8301, which is also supplied by 24 volts of power. The load was applied using a spring balance and pulleys. The BLDC hub motor is connected to INSTASPIN using DRV8301 and TMS320F28027F. A tachometer was used to measure currents, and INSTASPIN was the software used. The hub motor was tested under different load condtions.

Fig 16. Testing of BLDC Hub Motor

4.1.1 Under no load condition

The BLDC motor is provided an external supply of 24 dc source as there is no load. The system is enabled by the InstaSpin software, which after some time identifies the motor and allows it to rotate freely. In order to understand why speed is inversely related to armature current, it is important to take note of the phase currents as the speed steadily increases.

Table 3 Speed vs Phase Currents under no load conditions

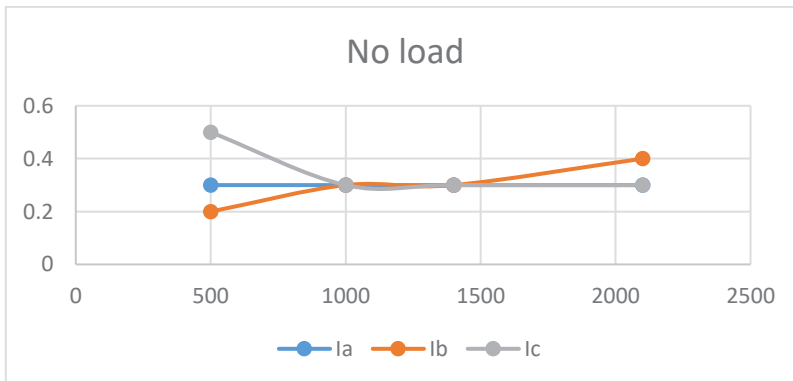| Speed (rpm)	Ia (A)	Ib (A)	Ic (A)
500	0.3	0.2	0.5
1000	0.3	0.3	0.3
1400	0.3	0.3	0.3

Fig 17. Speed vs Phase Currents under No load conditions

4.1.2 Under 50% load condition

When there is a 0.5 kg load, the rated current is 7.5A. As speed increases, load decreases and armature current similarly declines at constant voltage. The motor runs in free motion for all the various speed conditions so that when a given load is added to the motor, it draws more current.

Table 4 Speed vs Phase Currents under 50% load conditions

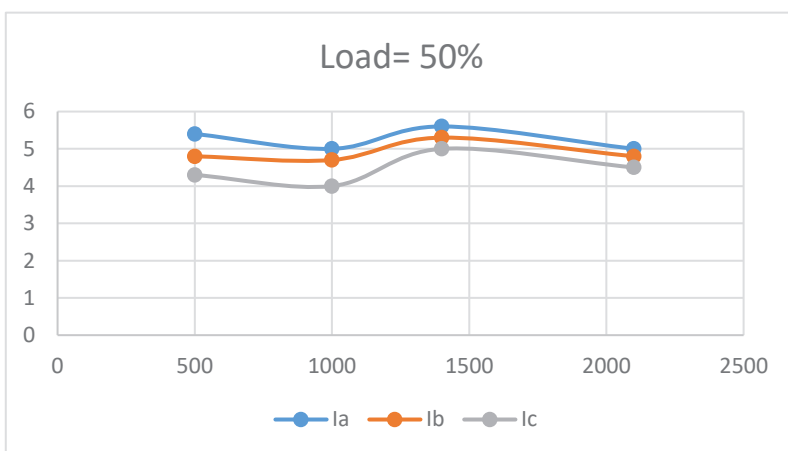| Speed	Ia	Ib	Ic
500	5	5.4	5.8
1000	4.8	5	5.2
1400	*5.2*	5	6

Fig 18. Graph of Speed vs Phase Currents under 50% load conditions

4.1.3 Under 75% load condition

Under full load condition when speed is about 1400 rpm such that motor draws more current because as more load is given to the motor then we need more torque. To slow down or motor up the speed we need to raise or lower the voltage. As load increases then torque required to drive the load increase which in turn it draws motor current.

Table 5 Speed vs Phase Currents under 75% load conditions

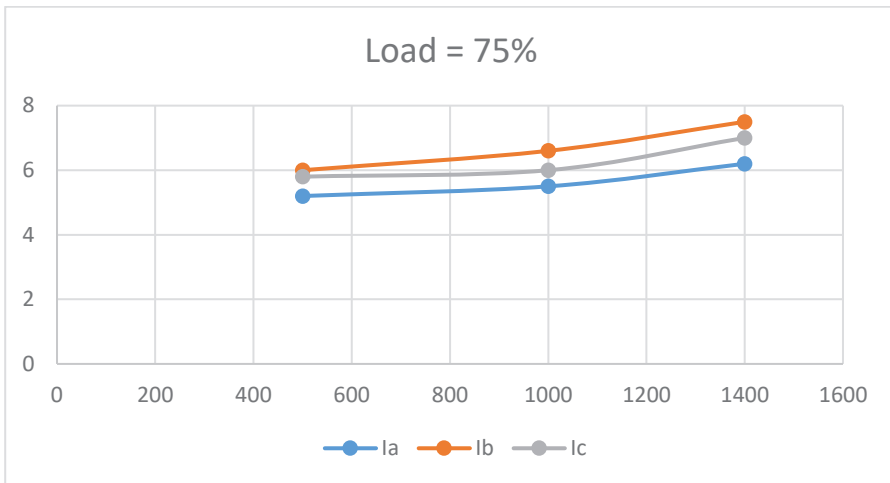| Speed	Ia	Ib	Ic
500	5.2	6	5.8
1000	5.5	6.6	6
1400	6.2	7.5	7

Fig 19. Graph of Speed vs Phase Currents under 75% load conditions

4 Conclusion

The framework's attributes, experimental results, and potential benefits are covered in the paper. The back-Electro Motive Force (BEMF) voltage and control drive of an ideal BLDC motor are simulated using Simulink. The BLDC motor driving model's performance has been validated by experimental findings to be correct. The features of BLDC motors can also be seen in Field-Oriented Control (FOC) mode. It has been done to estimate the parameters and to determine the simulation's findings, and these results have been applied to various load circumstances and speed ranges. With a rise in load, the speed progressively decreases and current demand increases.

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