DESIGN OF DRIVER BRUSHLESS DIRECT CURRENT MOTOR (BLDC)

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ABSTRAK

Objektif bagi projek ini adalah untuk membina litar pemacu (kawalan) ringkas untuk Brushless DC Motor (BLDC). Pembinaan litar pemacu ini bermula dengan pembinaan suis pada litar dimana ia menjadi nadi untuk menjana isyarat output. PIC controller akan digunakan untuk meningkatkan atau menurunkan tenaga pada suis dimana gelombang keluaran bpleh didapati semasa prosesnya. Proteus (ISIS) secara amnya digunakan menganalisasi litar pemacu (kawalan) dengan melibatkan parameter litar seperti spesifikasi komponen dalam bentuk voltan dan arus yang boleh dianggarkan. Secara tidak langsung pemilihan komponen boleh dilakukan. Apabila litar kawalan telah siap dibina litar pemacu(kawalan) boleh diuji untuk menjana BLDC motor.

ABSTRACT

The purpose of this project is to develop a simple drive circuit for the Three-phase Brushless DC Motor (BLDC). The construction of this drive circuit will be began with the development of switching circuit, which is the heart of generating output signal. PIC controller will be used to energize and de-energize switches so that the required output waveform can be obtained at the load. Proteus (ISIS) is primarily used to analyze the drive circuit virtually so that the circuit parameters such as component specifications in terms of voltage and current can be predicted so that component selection can be done. Once the control circuit is already built, the drive circuit can be tested to drive the BLDC motor.

CONTENT

LIST OF TABLES

LIST OF FIGURE

LIST OF APENDIX

CHAPTER 1

INTRODUCTION

Brushless Direct Current (BLDC) motors are one of the motor type rapidly gaining popularity. BLDC motor are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC have are advantages over brushed DC motor and induction motors. Are few of they are:

- Better speed versus torque characteristics.
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

In addition, the ratio of torque delivered to the size of the motor is higher, making is useful in applications where space and weight are critical factors. Each commutation sequence has one of the windings energized to positive power (current enters into the winding), the second winding is negative (current exits the winding) and the third is in a non-energized condition. Torque is produced because of the interaction between the magnetic field generated by the stator coils and the permanent magnets. Ideally, the peak torque occurs when these two fields are at 90° to each other and falls off as the fields move together. In order to keep the motor running, the magnetic field produced by the windings should shift position, as the rotor moves to catch up with the stator field. What is known as "Six-Step Commutation" defines the sequence of energizing the windings. See the (page 53) **"Commutation Sequence"** section for detailed information and an example on six-step commutation.

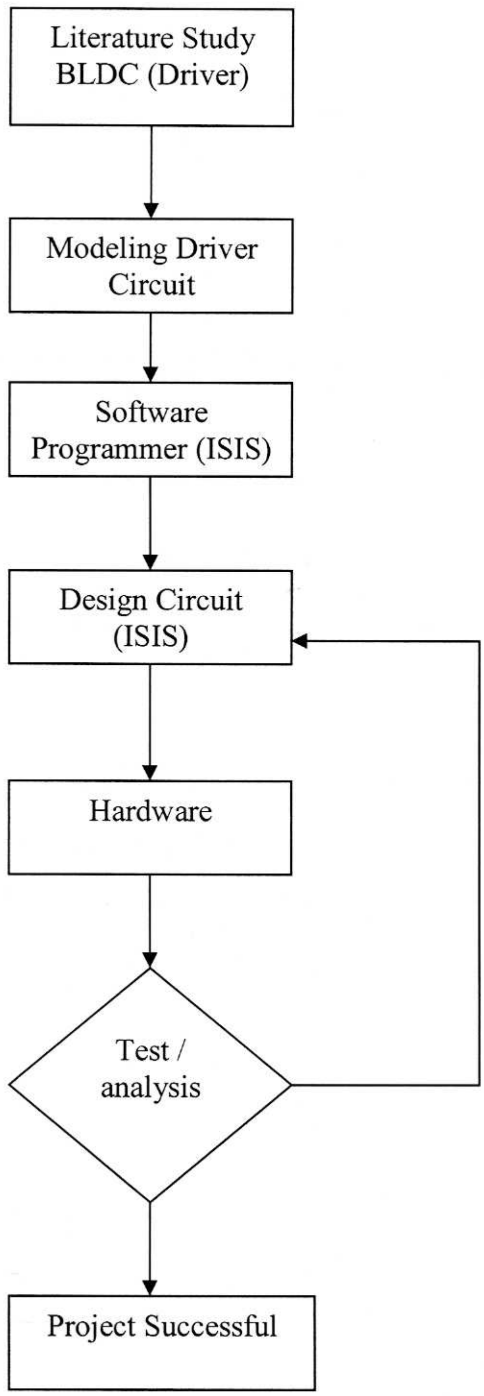

Figure 1.1: Flow Chart of Project

CHAPTER 2

THEORY ABOUT BRUSHLESS DIRECT CURRENT CIRCUIT

2.1 Typical BLDC Motor Application.

BLDC motors find applications in every segment of the market. Automotive, appliance, industrial controls, automation, aviation and so on, have applications for BLDC motors. Out of these, we can categorize the type of BLDC motor control into three major types:

- Constant load
- Varying loads
- Positioning applications

2.2 Applications With Constant Loads

These are the types of applications where a variable speed is more important than keeping the accuracy of the speed at a set speed. In addition, the acceleration and deceleration rates are not dynamically changing. In these types of applications, the load is directly coupled to the motor shaft. For example, fans, pumps and blowers come under these types of applications. These applications demand low-cost controllers, mostly operating in open-loop.

2.3 Applications With Varying Loads

These are the types of applications where the load on the motor varies over a speed range. These applications may demand a high-speed control accuracy and good dynamic responses. In home appliances, washers, dryers and compressors are good examples. In automotive, fuel pump control, electronic steering control, engine control and electric vehicle control are good examples of these. In aerospace, there are a number of applications, like centrifuges, pumps, robotic arm controls, gyroscope controls and so on. These applications may use speed feedback devices and may run in semi-closed loop or in total closed loop. These applications use advanced control algorithms, thus complicating the controller. Also, this increases the price of the complete system.

2.4 Positioning Applications

Most of the industrial and automation types of application come under this category. The applications in this category have some kind of power transmission, which could be mechanical gears or timer belts, or a simple belt driven system. In these applications, the dynamic response of speed and torque are important. Also, these applications may have frequent reversal of rotation direction. A typical cycle will have an accelerating phase, a constant speed phase and a deceleration and positioning phase. The load on the motor may vary during all of these phases, causing the controller to be complex. These systems mostly operate in closed loop. There could be three control loops functioning simultaneously: Torque Control Loop, Speed Control Loop and Position Control Loop. Optical encoder or synchronous resolves are used for measuring the actual speed of the motor. In some cases, the same sensors are used to get relative position information. Otherwise, separate position sensors may be used to get absolute positions. Computer Numeric Controlled (CNC) machines are a good example of this. Process controls, machinery controls and conveyer controls have plenty of applications in this category.

4.5 Contraction and Operating Principle:

BLDC motor are type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field generated by the rotor rotate at the same frequency. BLDC motors do not experience the slip that is normally seen in induction motors.

BLDC motor come in single-phase, 2-phase and 3-phase configuration. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motor are the most popular and widely used. This application Project Sarjana Muda focus on 3-phase motor (BLDC).

2.7 Stator

The stator of a BLDC motor consists of stacked steel laminations with windings placed in the slot that are axially cut along the inner periphery. Traditionally, the stator resembles that of an induction motor; however, the winding are distributed in a different manner. Most BLDC motors have three stator winding connected in star fashion. Each of these winding are constructed with numerous coil interconnected to form a winding. One or more coil are placed in the slots and they are interconnected to make a winding. Each of these windings are distributed over the stator periphery to form an even numbers of poles.

There are two type of stator winding variants: trapezoidal and sinusoidal motors. This differentiation of coil in the stator winding to give the different type of back Electromotive Force (EMF). As their names indicated, the trapezoidal motor gives a back in trapezoidal fashion and the sinusoidal motor's back EMF is sinusoidal, as shown in figure 2.0 and figure 2.1

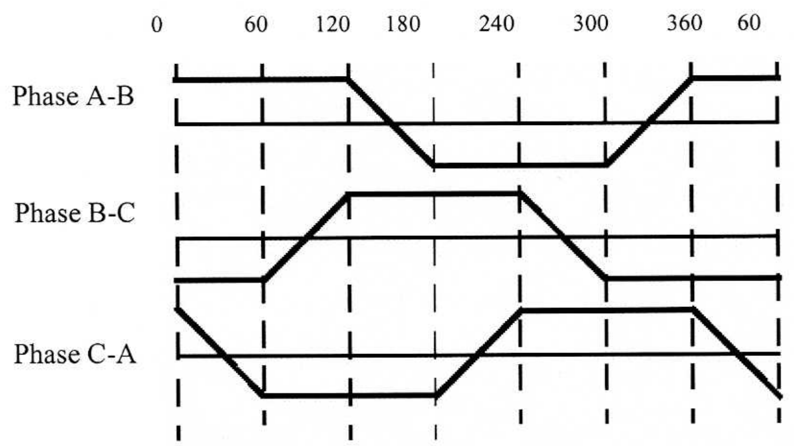

Figure 2.0 :Trapezoidal Back Emf.

60 120 180 240 320 360 60

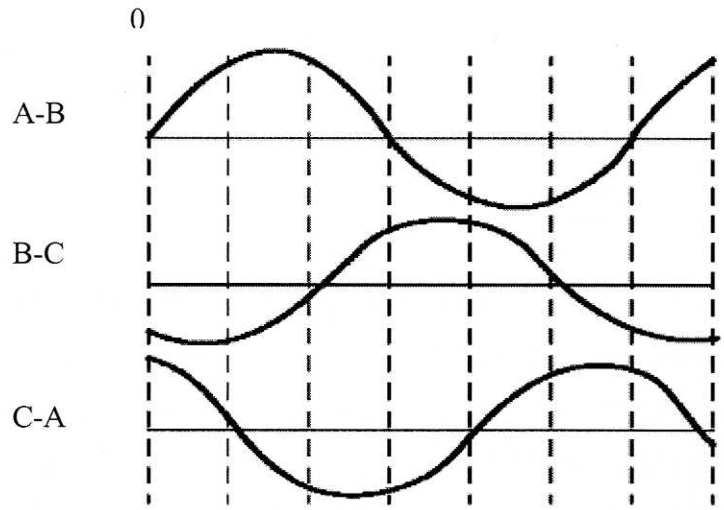

Figure 2.1: Sinusoidal Back Emf.

In addition to the back EMF, the phase current also has trapezoidal and sinusoidal variations in the respective types of motor. This makes the torque output by sinusoidal motor smoother than that of a trapezoidal motor. However, this come with an extra cost, as the sinusoidal motors take extra winding interconnection because of the coils distribution on the stator periphery, thereby increasing the copper intake by the stator windings.

Depending upon the control power supply capability, the motor with the correct voltage rating of the stator can be chosen. Forty-eight volt, or less voltage rated motor are used in automotive, robotics, small arm movements and so on. Motors with 100 volt, or higher rating, are used in appliances, automation and in industrial applications.

2.7 Rotor

The rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles.

Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Ferrite magnets are traditionally used to make permanent magnets. As the technology advances, rare earth alloy magnets are gaining popularity. The ferrite magnets are less expensive but they have the disadvantage of low flux density for give volume. In contrast, the alloy material high magnet density per volume and enables the rotor to compress further for the same torque. Also, there alloy magnets improve the size-to-weigh ratio and give higher torque for the same size motor using ferrite magnets.

Neodymium (Nd), Samarium cobalt (SmCo) and the alloy of Neodymium, ferrate and Boron (NdFeB) are some examples of rare earth alloy magnets. Continuous research is going on to improve the flux density to compress the rotor further.

2.8 Hall sensors

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. To rotate the BLDC motor, the stator windings should be energized in a sequence. Is it important to know the rotor position in order to understand which winding will be energizing sequence. Rotor position is sensed using Hall effect sensors embedded into the stator. Most BLDC motors have three hall sensors embedded into the stator on the non-driving end of the motor.

Whenever the rotor magnetic poles pass near the hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Figure 3 shows a transverse section of a BLDC motor with a rotor that has alternate N and S permanent magnets. Hall sensors are embedded into the stationary part of the motor. Embedding the Hall sensors into the stator is a complex process because any misalignment in these Hall sensors, with respect to the rotor magnets, will generate an error in determination of the rotor position. To simplify the process of mounting the Hall sensors onto the stator, some motors may have the Hall sensor magnets on the rotor, in addition to the main rotor magnets. These are a scaled down replica version of the rotor. Therefore, whenever the rotor rotates, the Hall sensor magnets give the same effect as the main magnets. The Hall sensors are normally mounted on a PC board and fixed to the enclosure cap on the non-driving end. This enables users to adjust the complete assembly of Hall sensors, to align with the rotor magnets, in order to achieve the best performance.

Based on the physical position of the Hall sensors, there are two versions of output. The Hall sensors may be at 60° or 120° phase shift to each other. Based on this, the motor manufacturer defines the commutation sequence, which should be followed when controlling the motor.

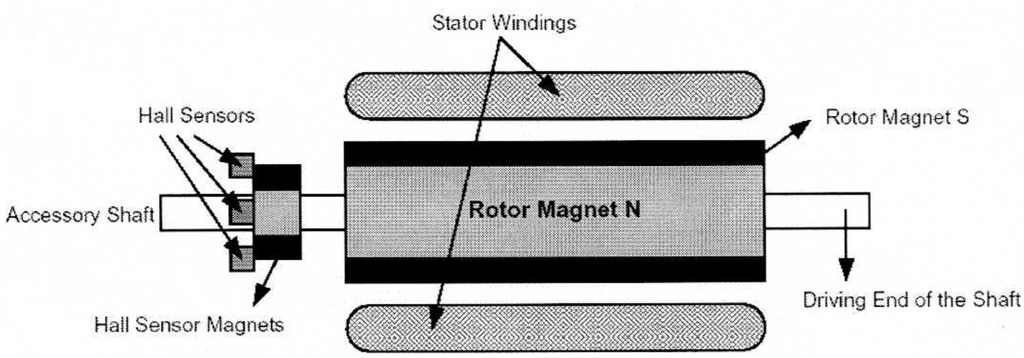

Figure 2.2: BLDC Motor Transverse Section

2.9 Comparing BLDC Motors to other Motor Type.