Visvesvaraya Technological University

Belagavi, Karnataka-590 018

A Project Report on

"ELECTRICALLY ASSISTED CYCLE"

Project report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering

In

Electrical & Electronics Engineering

Submitted by

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Certificate

Certified that the project work entitled "**Electrically Assisted Cycle**" carried out by Ms. AKANKSHA SHEPHALI, USN 1CR16EE006; Ms. DEEKSHA P, USN 1CR16EE020; Ms. HARSHITA KANCHAN, USN 1CR16EE028; Ms. KAVITHA ANN JIBI, USN 1CR16EE033 are bonafied students of CMR Institute of Technology, Bengaluru, in partial fulfillment of the requirements for the award of Bachelor of Engineering in Electrical & Electronics Engineering of Visvesvaraya Technological University, Belagavi during the academic year 2019-2020. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library.

The Project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

Signature of the Guide	*Signature of the HOD*	*Signature of the Principal*
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DECLARATION

I, Ms. AKANKSHA SHEPHALI (1CR16EE006), Ms. DEEKSHA P (1CR16EE020), Ms. HARSHITA KANCHAN(1CR16EE028), Ms. KAVITHA ANN JIBI (1CR16EE033), hereby declare that the Project report entitled **"Electrically Assisted Cycle"** has been carried out by me under the guidance of **Mrs. SANITHA MICHAIL C** Associate Professor, Department of Electrical & Electronics Engineering, CMR Institute of Technology, Bengaluru, in partial fulfillment of the degree of **Bachelor of Engineering in Electrical & Electronics Engineering** of Visvesvaraya Technological University, Belagaum during the academic year 2019-2020. The work done in this report is original and it has not been submitted for any other degree in any university.

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DATE: 18/05/2020

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ABSTRACT

Use of electrically assisted bicycles with a maximum speed of 25 km/h is rapidly increasing. Travel is an essential part of everyday life for most people, and the adoption of active travel represents an healthy way to increase daily physical activity. Cycling is an ideal healthy way of active travel.

Physical constraints associated with hilly terrain, poor physical fitness, lack of time and the distance to work are the drawbacks of cycling.

An electrically assisted bicycles can overcome some of the commonly reported barriers to cycle commuting. An electrically assisted bike which provide electrical assistance only when the rider is pedalling, through sensors which detect pedalling speed and force. It is through pedalling that electrically-assisted cycling may serve to increase physical activity.

Torque sensors measure how hard you are pressing on the pedals and tell the motor how much to turn on based on pedal pressure. Head up a hill and the torque sensor know you're working harder and tells the motor to chip in. The true magic happens when a torque sensor is combined with a speed and cadence sensor. This trio can give the motor controller a complete picture of how you are riding so that it can give power in just the right amount at just the right time.

An electric power-assist system may be added to almost any pedal cycle using chain drive, belt drive, hub motors or friction drive. BLDC hub motors are a common modern design.

ACKNOWLEDGEMENT

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of people, who are responsible for the completion of the Project work and who made it possible, because success is the outcome of hard work and perseverance, but steadfast of all is encouraging guidance. So, with gratitude, we acknowledge all those whose guidance and encouragement served us to motivate towards the success of the Project work.

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CONTENTS

CHAPTER 1

INTRODUCTION

An electrically assisted bike which provide electrical assistance only when the rider is pedalling, through sensors which detect pedalling speed and force. It is through pedalling that electrically-assisted cycling may serve to increase physical activity. With lower motor power and maximum speeds electrically-assisted bikes are legally classified as bicycles. An electric power-assist system may be added to almost any pedal cycle using chain drive, belt drive, hub motors or friction drive. BLDC hub motors are a common modern design. The motor is built into the wheel hub itself, while the stator is fixed solidly to the axle, and the magnets are attached to and rotating with the wheel. The bicycle wheel hub is the motor.

CHAPTER 2

LITERATURE REVIEW

Introduction to BLDC Motor

Commutator helps in achieving unidirectional torque in a typical dc motor. Obviously, commutator and brush arrangement are eliminated in a brushless dc motor. And an integrated inverter / switching circuit is used to achieve unidirectional torque. That is why these motors are, sometimes, also referred as 'electronically commutated motors'. Electrical motors have been developed in various special types, such as stepper motors, servo motors, permanent magnet motors etc. We have a lot of choices to choose a motor that is most suitable for our application. A Brushless DC motor or BLDC motor is the type which is most suitable for applications that require high reliability, high efficiency, more torque per weight etc.

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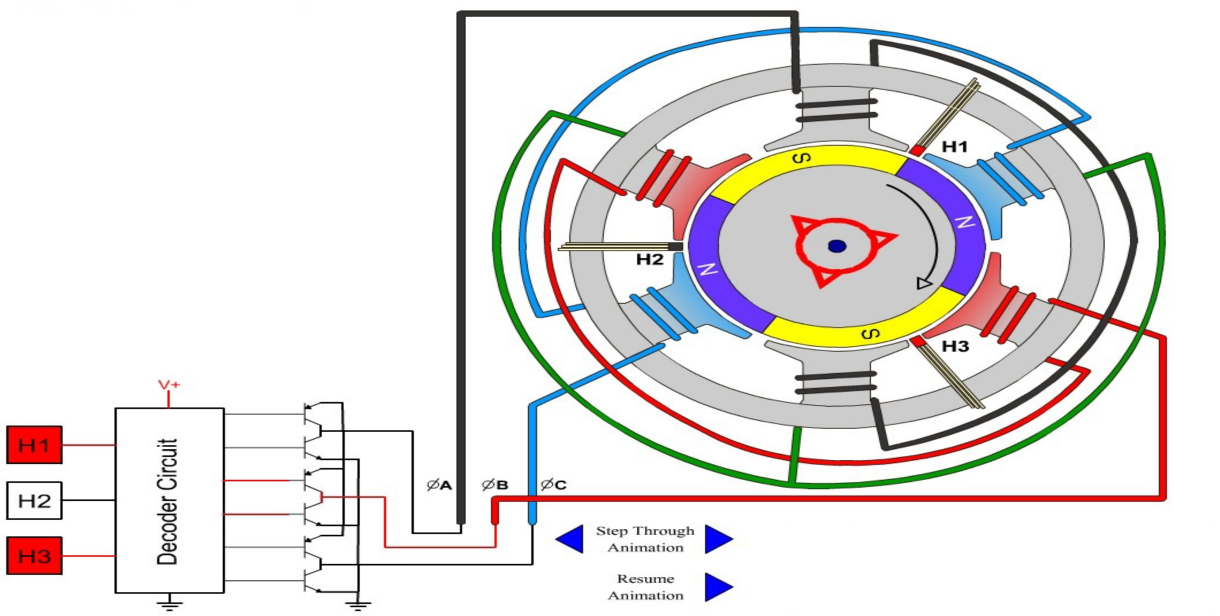
Construction of A BLDC Motor

Just like any other electric motor, a BLDC motor also has a stator and a rotor. Permanent magnets are mounted on the rotor of a BLDC motor, and stator is wound with specific number of poles. This is the basic constructional difference between a brushless motor and a typical dc motor.



Working Principles and Operation

The underlying principles for the working of a BLDC motor are the same as for a brushed DC motor; i.e., internal shaft position feedback. With a BLDC motor, it is achieved using multiple feedback sensors. The most commonly used sensors are hall sensors and optical encoders. Hall sensors work on the hall-effect principle that when a current-carrying conductor is exposed to the magnetic field, charge carriers experience a force based on the voltage developed across the two sides of the conductor. If the direction of the magnetic field is reversed, the voltage developed will reverse as well. For Hall-effect sensors used in BLDC motors, whenever rotor magnetic poles (N or S) pass near the hall sensor, they generate a HIGH or LOW level signal, which can be used to determine the position of the shaft. In a commutation system once the position of the motor is identified using feedback sensors then two of the three electrical windings are energized at a time. In figure 4 (A), the GREEN winding labeled “001” is energized as the NORTH pole and the BLUE winding labeled as “010” is energized as the SOUTH pole. Because of this excitation, the SOUTH pole of the rotor aligns with the GREEN winding and the NORTH pole aligns with the RED winding labeled “100”. In order to move the rotor, the “RED” and “BLUE” windings are energized in the direction shown in figure 4(B). This causes the RED winding to become the NORTH pole and the BLUE winding to become the SOUTH pole. This shifting of the magnetic field in the stator produces torque because of the development of repulsion (Red winding – NORTH-NORTH alignment) and attraction forces (BLUE winding – NORTH-SOUTH alignment), which moves the rotor in the clockwise direction. Motor control can be classified into following categories:

🎬 Speed control 🎬 Torque control

Implementation of these control functions requires monitoring of one or more motor parameters and then taking corresponding action to achieve the required functionality. Before getting into the details of these control function implementations, it is important to understand the implementation of logic and hardware required to build up the rotation of the motor or to establish commutation.

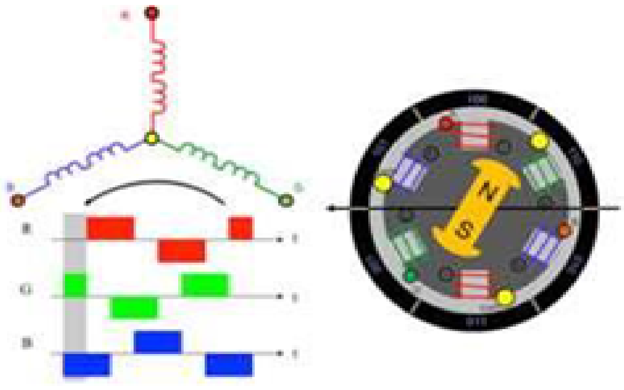


Figure 4(A): Phase 1

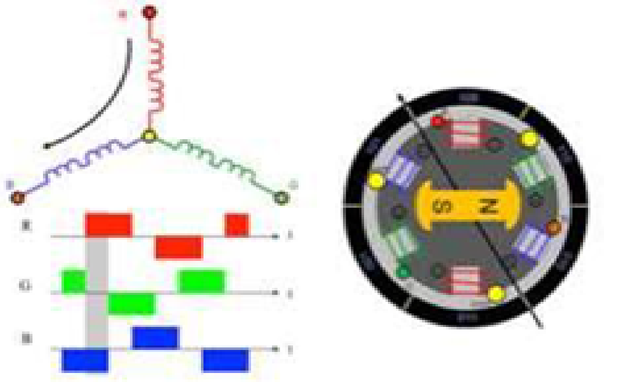


Figure 4(B): Phase 2

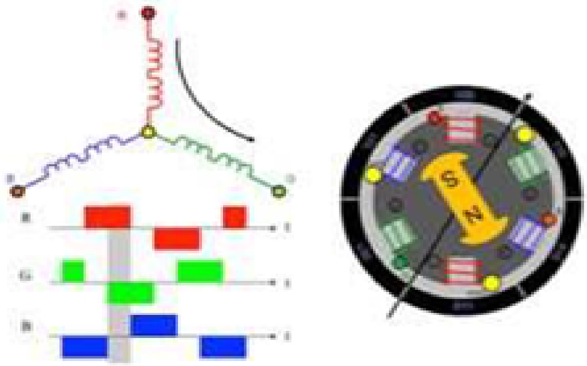


Figure 4(C): Phase 3

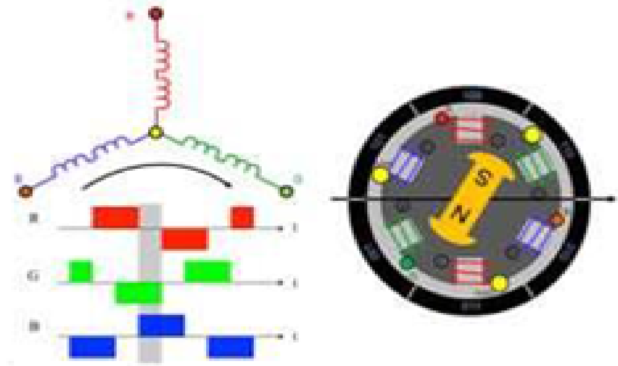


Figure 4(D): Phase 4

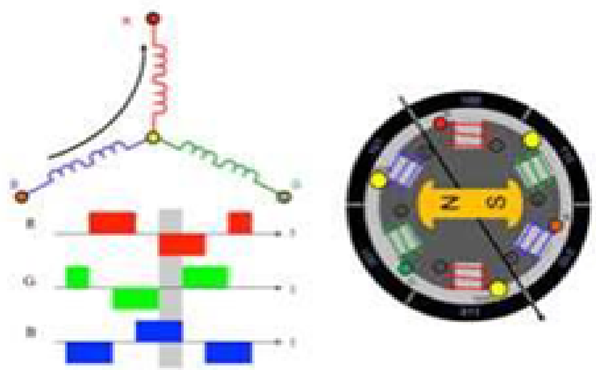


Figure 4(E): Phase 5

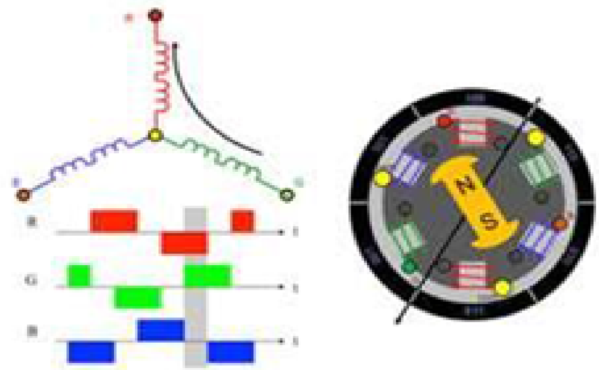


Figure 4(F): Phase 6

Commutation implementation

We know that two of the three electrical windings are energized at a time. To be able to energize the windings, external circuitry is required to be able to meet the current requirements of the motor.

A typical control circuit with a 3-phase winding connection is shown in Figure. V1, V3, V5 and V2, V4, V6 make a 3-phase voltage source inverter connected across the power supply. V1 and V4 form one bridge.

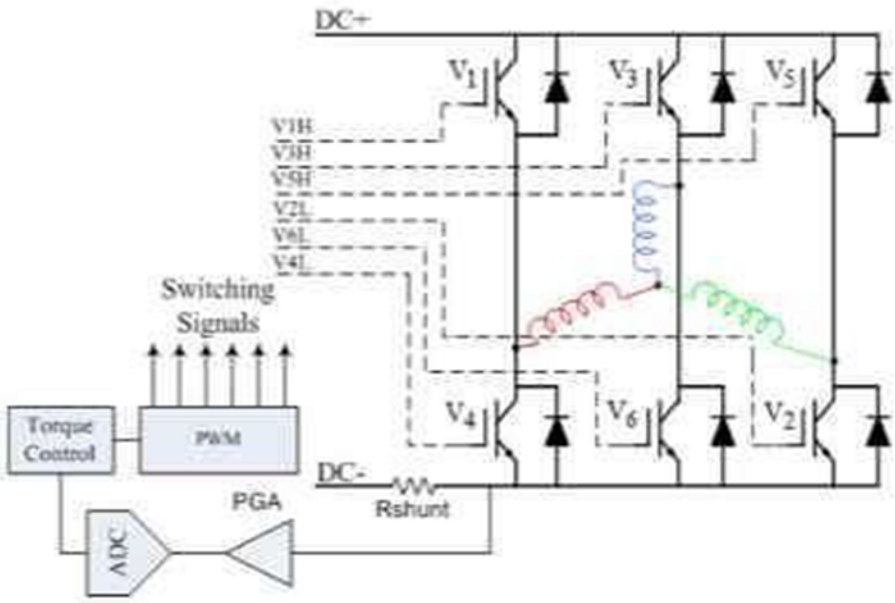


Figure 6: Torque control

V1 is high side, which is connected to the high voltage DC source while V4 is low side, which is connected to ground. By adjusting the high-side and low side of the power device (via signals V1H, V3H, V5H and V2L, V4L, v6L), the current flow through the stator winding can be controlled. For example, if current has to flow in to the RED winding and flow out from the BLUE winding, turning on V1 and V6 while keeping the other signals will cause the current to flow in the required direction, as shown in Figure 2 (A). Next, by switching ON V5 and V6 and turning all other signals OFF, the current can be switched to flow in from the GREEN winding and out from the BLUE winding, shown in Figure 2 (B).

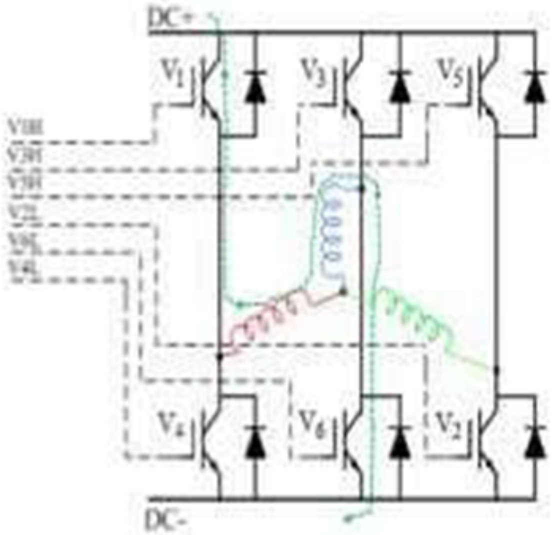


Figure 2 (A) – V1 and V6 ON; remaining all OFF

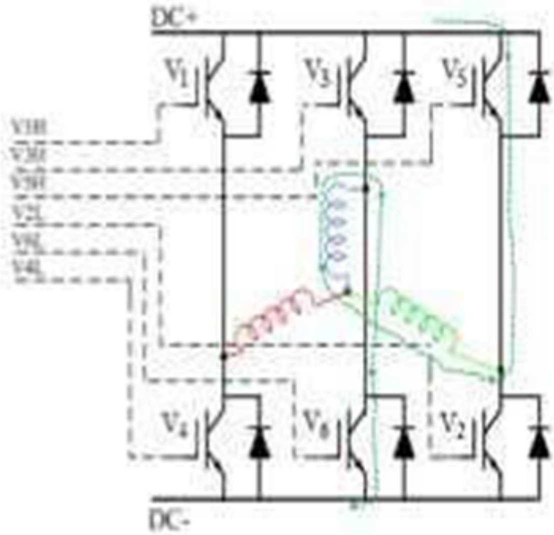


Figure 2 (B) – V5 and V6 ON; remaining all OFF

Following the same procedure, the 6-step driving sequence for a BLDC motor can be generated. The below table provides the switching sequence for power circuitry based on a Hall sensor output.

Table 1: Switching sequence

Hall C	Hall B	Hall A	Green	Red	Blue	Sector No.	MOSFET - ON
0	0	1	DC+	NC	DC-	0	V5, V6
0	1	1	DC+	DC-	NC	1	V4, V5
0	1	0	NC	DC-	DC+	2	V3, V4
1	1	0	DC-	NC	DC+	3	V2, V3
1	0	0	DC-	DC+	NC	4	V1, V2
1	0	1	NC	DC+	DC-	5	V1, V6

To build up the rotation, the motor should be periodically switched from one phase to another as shown below.

→ 0 → 1 → 2 → 3 → 4 → 5 →

This Figure shows the excitation waveform, including phase current, phase voltage, Hall sensor, and sector value. The top half of the figure shows the 3-phase winding excitation current and voltage in which black lines are phase current, while green, red, and blue lines are the phase voltage. As the phase current is trapezoidal, we call 6-step BLDC control trapezoidal control.

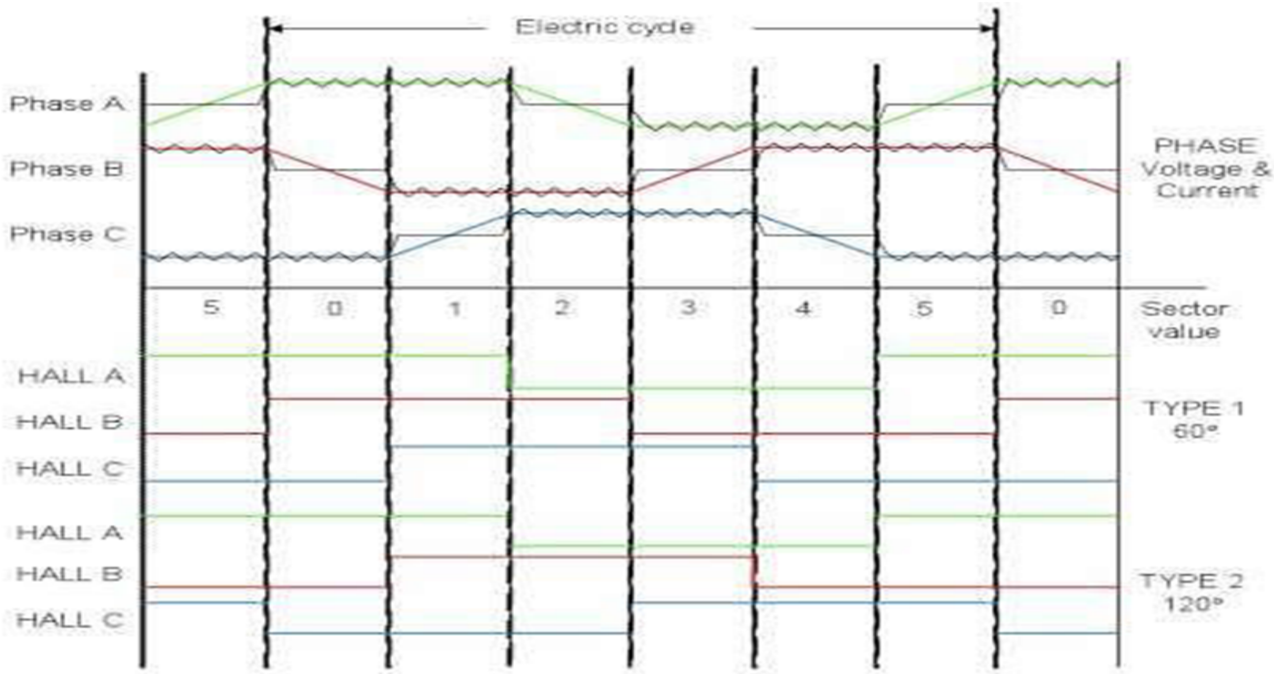
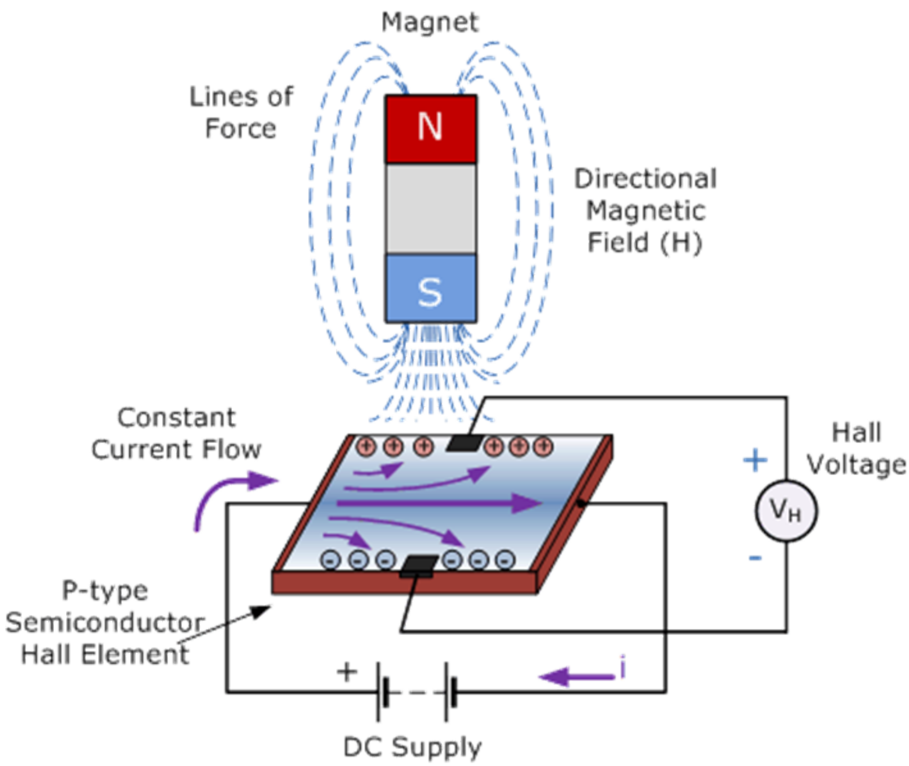


Figure 3 – Voltage and current through the windings

Speed Sensor:

Many e-bikes require not only the torque information but also the cadence for their control. By simply integrating Hall sensors that detect either a magnetic texture on a pole wheel or a ferromagnetic texture in the form of a gear rim on the shaft, the pedalling speed or cadence can be determined.



Hall Effect Sensors consist basically of a thin piece of rectangular p-type semiconductor material such as gallium arsenide (GaAs), indium antimonide (InSb) or indium arsenide (InAs) passing a continuous current through itself. When the device is placed within a magnetic field, the magnetic flux lines exert a force on the semiconductor material which deflects the charge carriers, electrons and holes, to either side of the semiconductor slab. As these electrons and holes move side wards a potential difference is produced between the two sides of the semiconductor material by the build-up of these charge carriers. Then the movement of electrons through the semiconductor.
material is affected by the presence of an external magnetic field which is at right angles to it and this effect is greater in a flat rectangular shaped material.

The effect of generating a measurable voltage by using a magnetic field is called the Hall Effect after Edwin Hall who discovered it back in the 1870's with the basic physical principle underlying the Hall effect being Lorentz force. To generate a potential difference across the device the magnetic flux lines must be perpendicular, (90o) to the flow of current and be of the correct polarity, generally a south pole.

Sideways or slide-by detection is useful for detecting the presence of a magnetic field as it moves across the face of the Hall element within a fixed air gap distance for example, counting rotational magnets or the speed of rotation. Generally, Hall Effect sensors are designed to be in the “OFF”, (open circuit condition) when there is no magnetic field present. They only turn “ON”, (closed circuit condition) when subjected to a magnetic field of sufficient strength and polarity. Hence the frequency of the output pulses will be directly proportional to the speed of rotation.

Motor speed, then, depends upon the amplitude of the applied voltage. The amplitude of the applied signal is adjusted by using pulse width modulation (PWM).
It can be noted from the diagram that the higher side transistors are driven using PWM. By controlling the duty cycle of the PWM signal, the amplitude of the applied voltage can be controlled, which in turn will control the speed of the motor.

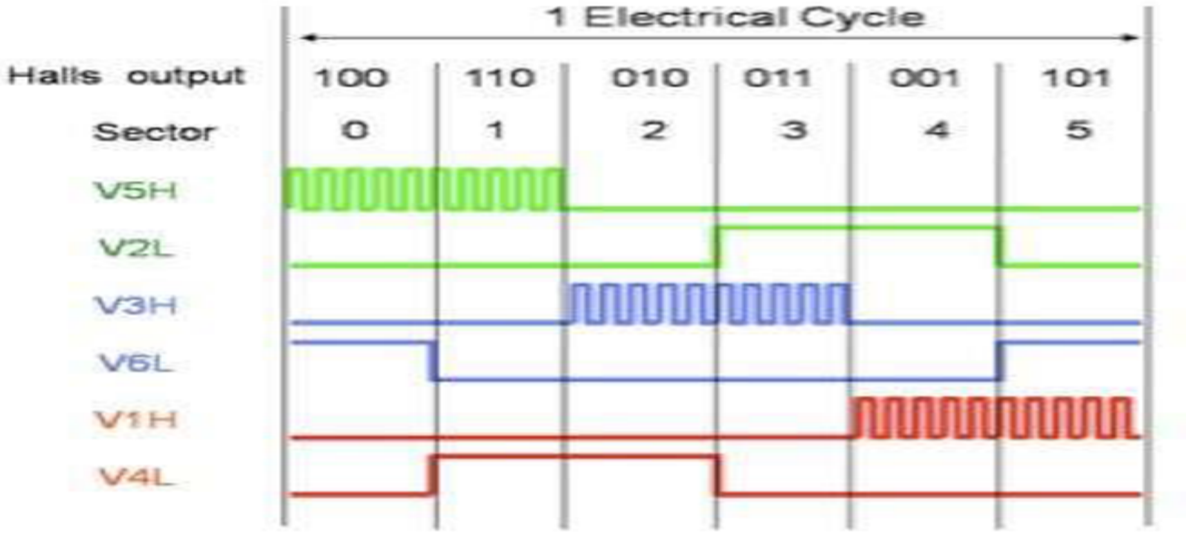


Figure 4: Switching signals of Power devices

Torque sensor:

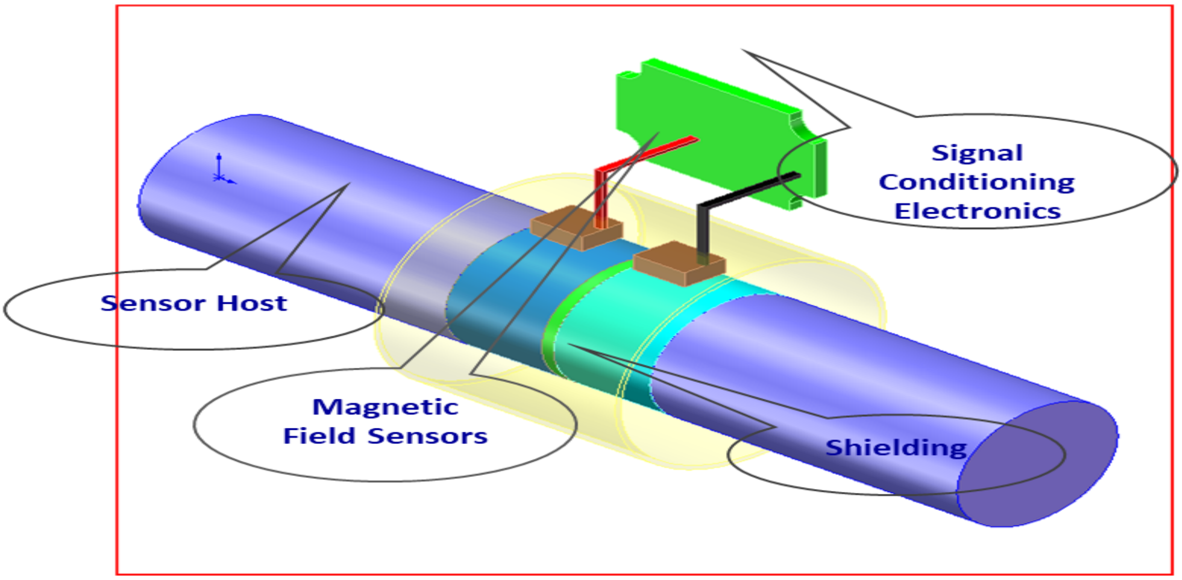
A good electric assist bicycle starts with a torque sensor that measures how hard you push on the pedals. You set a power level—from low assistance to high—and your electric assist bicycle gives you power in proportion to your pedalling, allowing you to ride farther, faster, and with greater ease and enjoyment.
Bikes with a pedal assist function typically have a torque transducer with speed sensor giving rise to a series of pulses, the frequency of which is proportional to pedalling speed and voltage proportional to the torque required.
An e-bike torque sensor acts as a hidden throttle control. The harder a rider pedals, the more assistance will come from the motor. The rider will therefore still feel like he is riding a regular bike however with the legs of an olympic athlete.

Main Advantages:

1. Torque sensors are the most direct form of throttle control
2. Allow for the smoothest and most natural ride
3. Can be used to monitor rider behaviour and characteristics

Torque control is important in various applications where at a given point of time, the motor needs to provide a specific torque regardless of the change in load and speed at which the motor is running. Torque can be controlled by adjusting the magnetic flux, however. flux calculations require complex logic. However, magnetic flux is dependent upon the current flowing through the windings. Thus, by controlling current, torque of a motor can be controlled.

4. A torque sensor forces you to help the e-bike when it needs it the most, when it is accelerating and when climbing. This allows for significant power savings and increase in range.

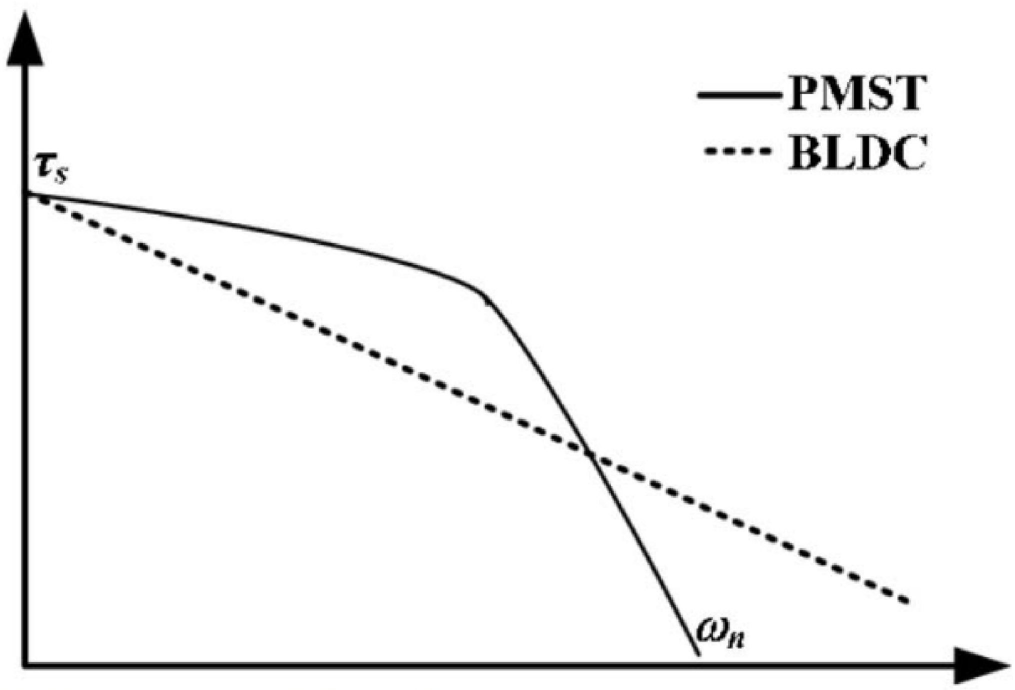


When mechanical torque is applied on the magnetized shaft, the measurable torque induced magnetic field is produced from torqued shaft. The magnetic signal varies in proportion to the torque applied. This change in magnetic field is sensed using sensors and the further conditioned before it is applied to the control circuitry.

Magnetoelastic torque and force sensors, are based on the physical principle of magnetostriction, or inverse magnetostriction. Ferromagnetic materials change their magnetic properties under the influence of external mechanical forces. This change in the magnetic properties leads to a change in the magnetic permeability or susceptibility of the measuring point. This decreases with compression and increase with elongation.

Magnetic Inductive Sensors induce an alternating magnetic field in the target and measure the resulting magnetic fields using secondary inductances. A change in susceptibility and thus in the magnetic resistance results in a change in the magnetic flux. This magnetic flux change is detected by the secondary inductances and converted into a signal proportional to the mechanical force by digital signal processing. This measuring principle is based on the fact that the sensor does not require any mechanical contact or frictional connection to the measuring point and can therefore be mounted without contact. This fact is a decisive advantage when it comes to measuring the torques on a rotating shaft.

The active magnetic torque sensor technology thus has a clear advantage when used in rotary torque measurements.



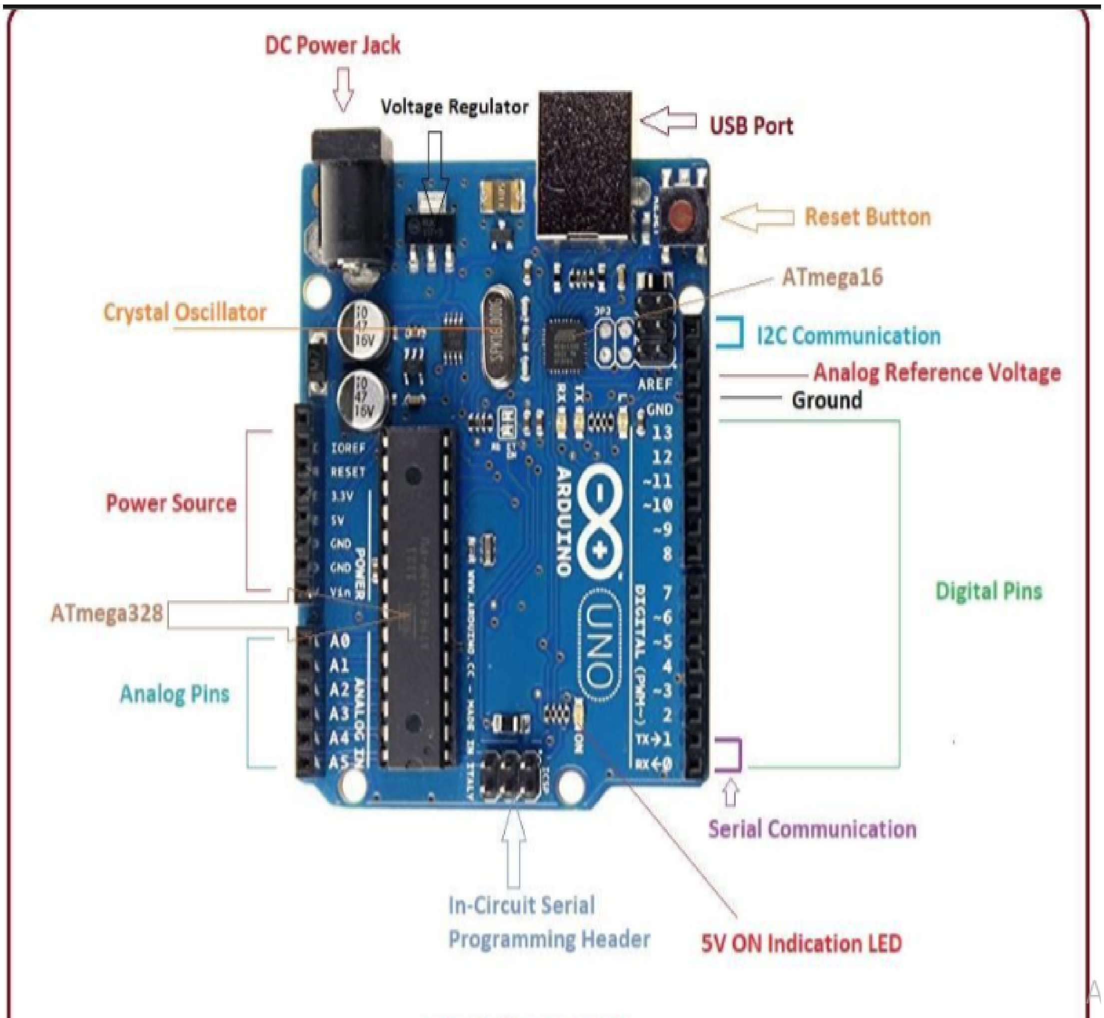
Speed-torque Characteristics of PMST and BLDC.

CHAPTER 4

METHODOLOGY

Interfacing Torque and Speed sensor:

Arduino Uno has 6 0n-board ADC channels which can be used to read analog signal in the range 0-5V. It has 10-bit ADC means it will give digital value in the range of 0 – 1023 (2^10). This is called as resolution which indicates the number of discrete values it can produce over the
range of analog values. It's a 10-bit SAR model (Successive Approximation Register)
Arduino Uno interrupt pins can be used to measure the speed output from the Hall sensor.



Arduino UNO

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.

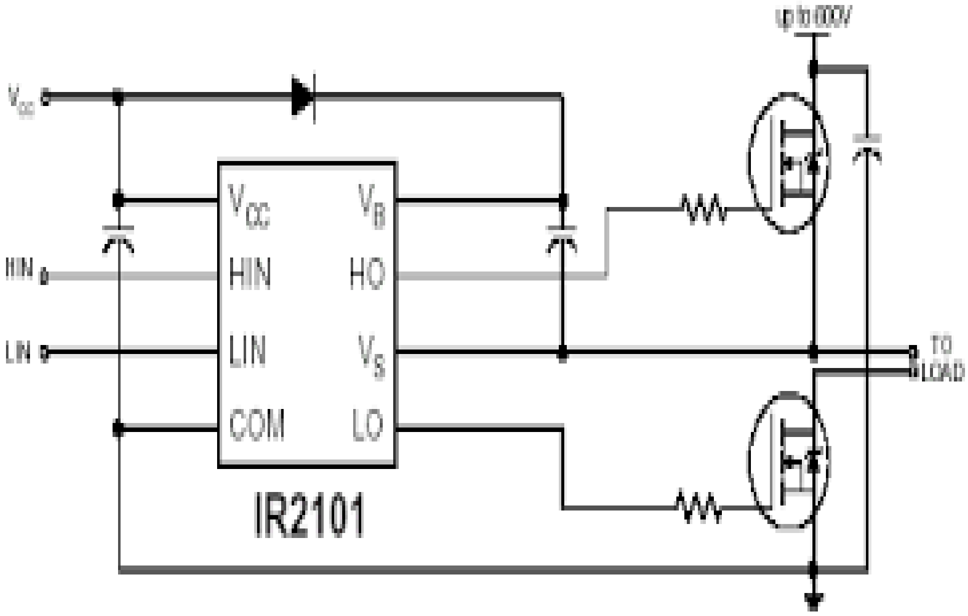
The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts.
Atmega328 microcontroller is placed on the board that comes with a number of features like timers, counters, interrupts, PWM, CPU, I/O pins and based on a 16MHz clock that helps in producing more frequency and number of instructions per cycle.
🎬 Reset pin is added in the board that reset the whole board and takes the running program in the initial stage. This pin is useful when board hangs up in the middle of the running program; pushing this pin will clear everything up in the program and starts the program right from the beginning.
🎬 There are 14 I/O digital and 6 analog pins incorporated in the board that allows the external connection with any circuit with the board. These pins provide the flexibility and ease of use to the external devices that can be connected through these pins. There is no hard and fast interface required to connect the devices to the board. Simply plug the external device into the pins of the board that are laid out on the board in the form of the header.
🎬 The 6 analog pins are marked as A0 to A5 and come with a resolution of 10bits. These pins measure from 0 to 5V, however, they can be configured to the high range using analogReference() function and AREF pin.
13KB of flash memory is used to store the number of instructions in the form of code. 🎬 Only 5 V is required to turn the board on, which can be achieved directly using USB port or external adopter, however, it can support external power source up to 12 V which can be regulated and limit to 5 V or 3.3 V based on the requirement of the project.

Design of the BLDC Motor Drive:

Why MOSFET drive is used?

Power MOSFET need handle high current and voltage, and we need a gate voltage to turn on or turn off the MOSFET, but the output of logic controllers such as CPU or MCU can’t provide enough voltage to operate the MOSFET normally.

So, we need a gate driver between the controller and MOSFET. The gate driver can shift the low voltage from the controller to a higher voltage level for the gate of MOSFET so that the MOSFET can work normally.



Drive current – MOSFETs can have very high gate capacitance. For example, the IRF530NS from International Rectifier is a 90mW device which can withstand 17A continuous drain current at 100V and has 920pF of input capacitance. For lowest ON resistance you would want
to drive the gate as high as possible, say 15V and to minimize power dissipation you want to switch quickly between ON and OFF and vice versa otherwise the transistor will spend a relatively long time in the saturation region rather than the linear or ohmic region. The linear/ohmic region can also be called the triode region. Anyone from a bipolar transistor background may find these terms confusing as saturation region of a bipolar transistor is not synonymous with the saturation region of a MOSFET.

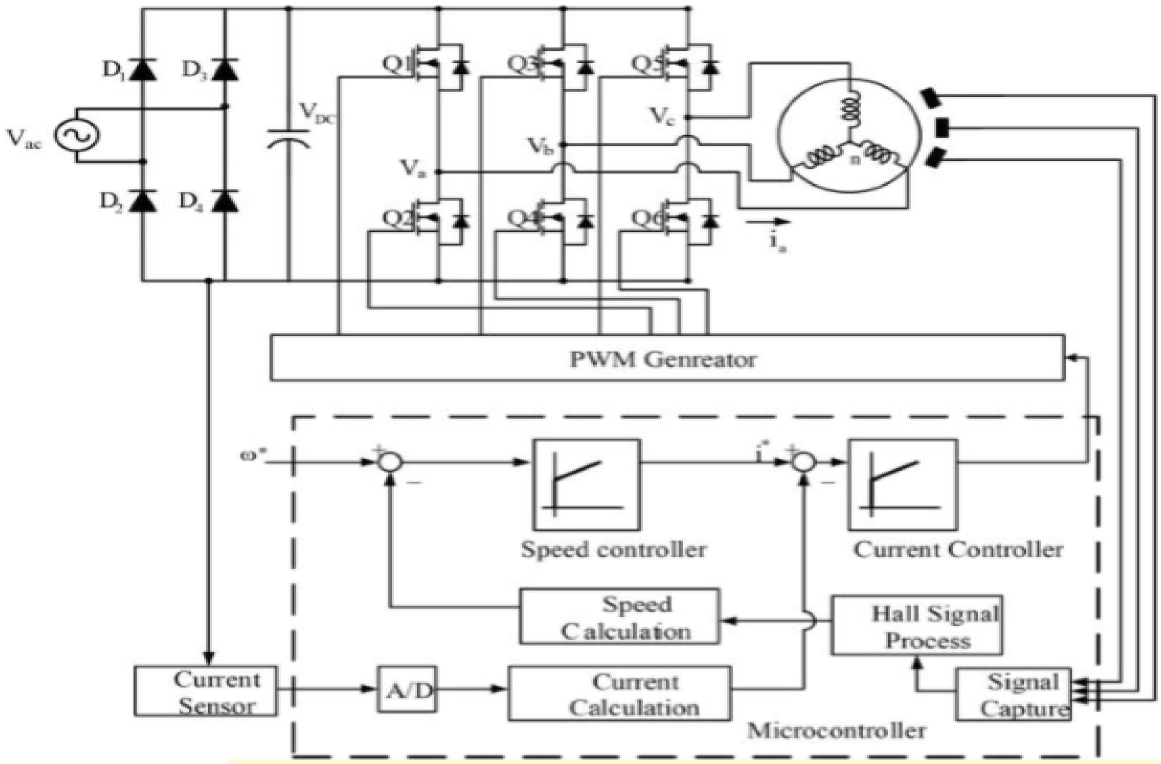
High side drivers – Rather than using an NMOS to sink current and PMOS to source current, a common way of driving high current, high voltage loads is with two NMOS transistors. Higher carrier mobility means that NMOS transistors are lower resistance for a given size and gate capacitance than PMOS so are preferred. However, to use them to source a current you need to drive the gate above your supply voltage and operate it as a “source follower”. The MOSFET drain will be connected to the positive supply and the load to the source. An example would be something like theIRS2001 from International Rectifier

The implementation of a BLDC motor drive:

The system structure with control algorithm of motor drive based on a microcontroller is shown in Figure below.

It consists of a microcontroller, protection circuit, optical coupling isolation, inverter, current sensor, Hall effect sensor, and communication interface. For the design and implementation of an electric bicycle, the AC power source and rectifier are replaced by DC battery.

The microcontroller dsPIC 30FXX series manufactured by Microchip technology incorporate is the core controller of the electric bicycle. It is a 16-bit CPU with the capability of digital signal processing. Moreover, it supports many powerful modules such as built-in PWM module, addressable encoder interface module, and input capture module; these make the design friendly and thus shorten the development schedule. The three-phase bridge inverter comprises six switching power MOSFETs.



The system structure of a motor drive.

The photocoupler is used for electrical isolation between the microcontroller system and bus voltage. The motor currents from the DC bus are sensed through the current detection circuit. The magnet pole and rotor position are detected by the Hall effect sensor. The speed and rotor position can be calculated and precisely controlled, accordingly. The 120°

conduction of pulse width modulation technique for MOSFETs switching, is employed to drive the thee-phase inverter.

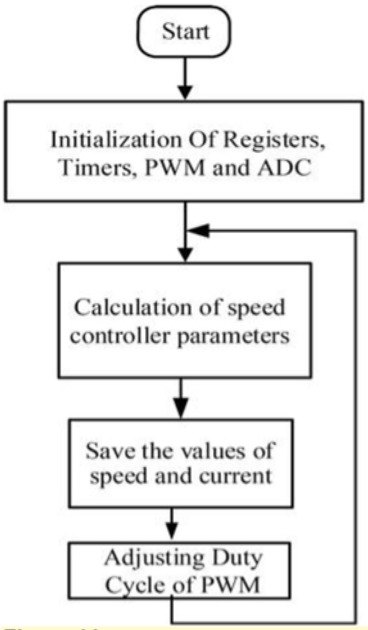


Figure 11.

Main program of a motor drive for electric bicycle.

This flowchart is the main program of a motor drive for electric bicycle design. The initializations for I/O configuration, Timer 1, Timer 2, ADC, and PWM settings are firstly processed in the main program. Most of the functions for electric bicycle are programmed in the microcontroller firmware, which includes the circuit protection mechanism, PWM generation, motor currents calculation, rotor position and speed calculation, and rotor pole position

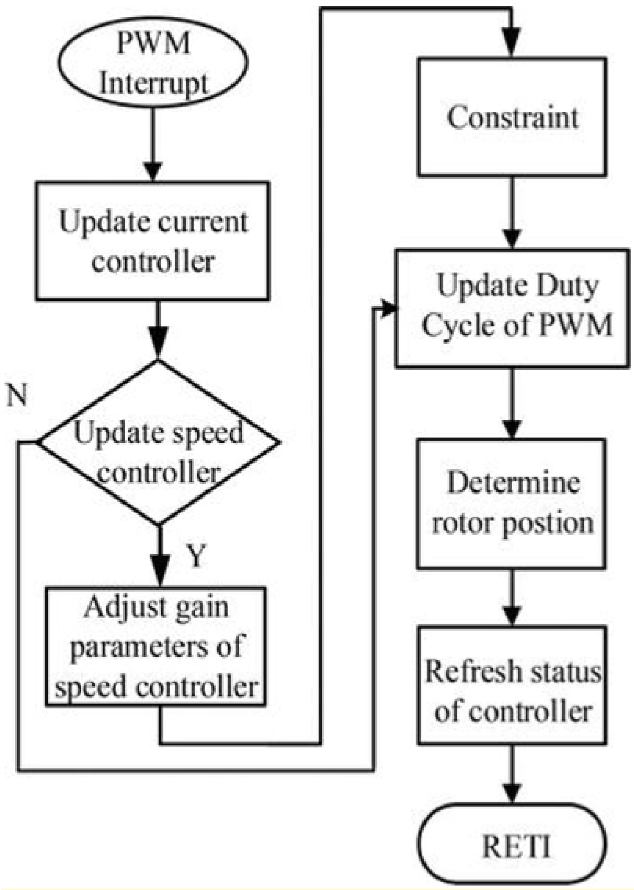


Figure 12.

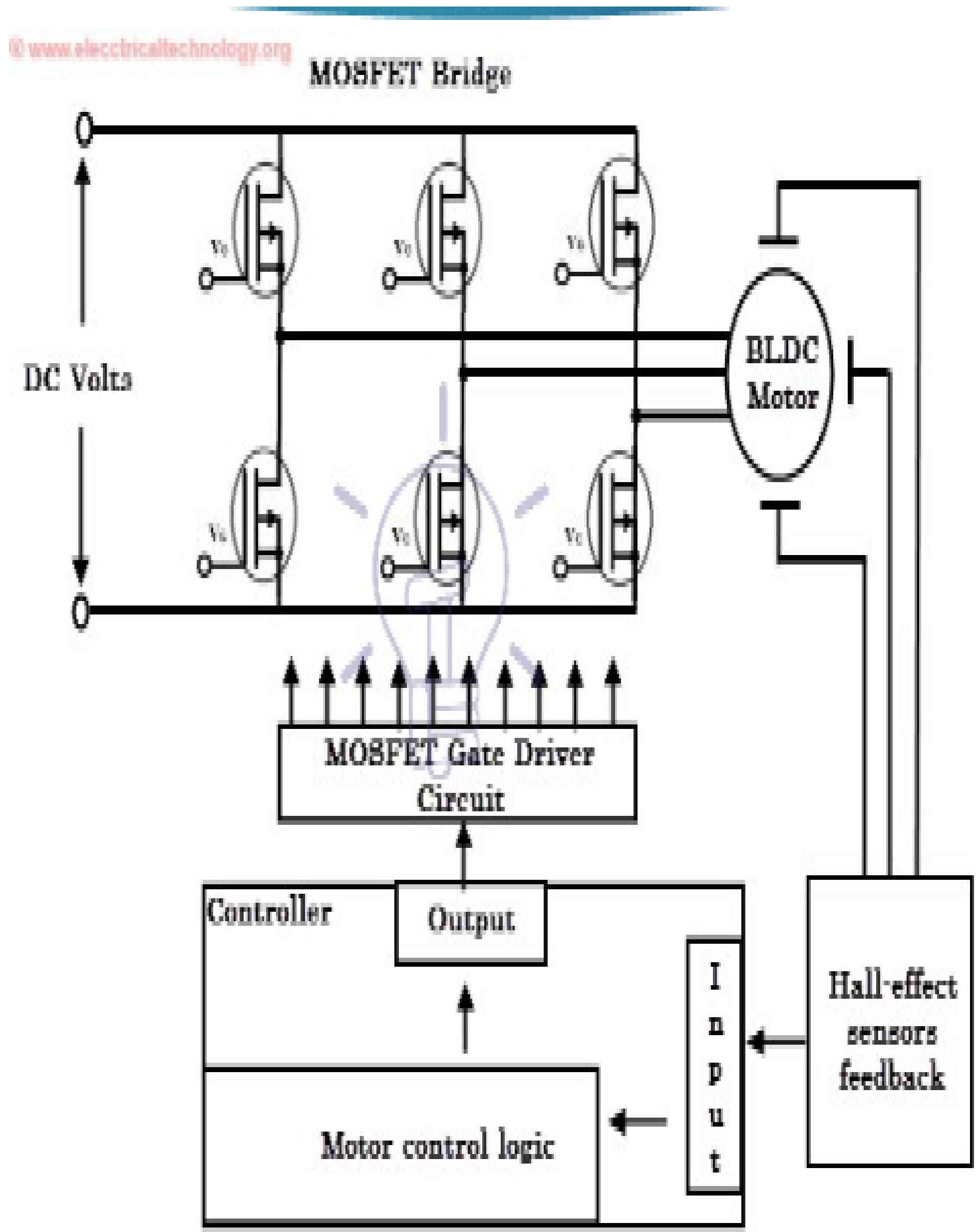
The PWM interrupt routine.

The speed and currents are usually implemented in the PWM interrupt routine, as shown in flowchart beside. The sensing current is firstly calculated and fed to the current controller. Since PWM frequency is 20 kHz, the current controller is updated for every 50 μs. After the calculation of current controller, the speed calculation is then performed by speed controller. The speed is constrained by the limiter in the operating speed range

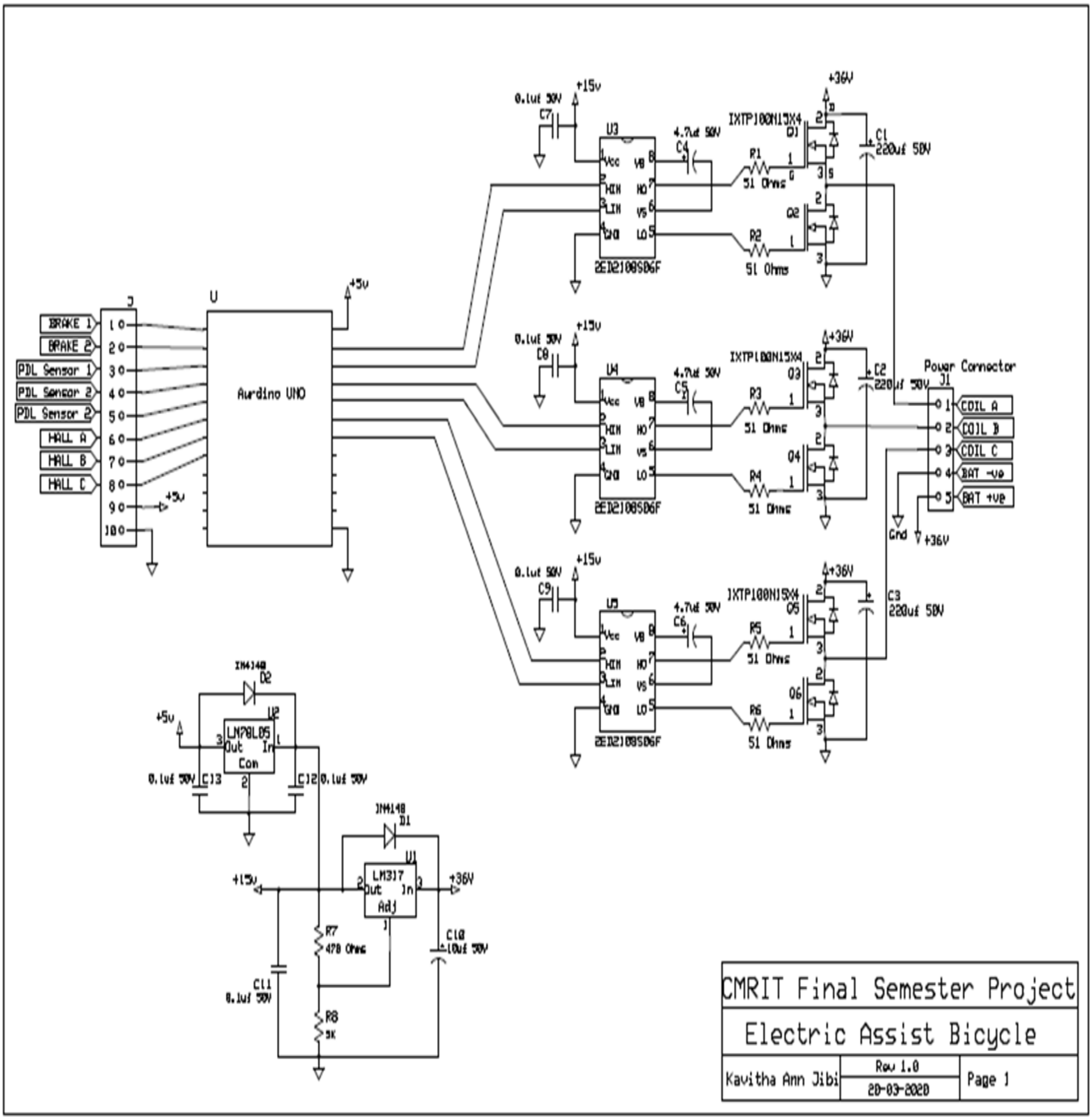
In summary, the speed control of motor drive for the electric bicycle is described in this chapter. The hardware structure including a microcontroller,current sensor, and communication interface is well designed. Further, the system software and firmware of microcontroller are programmed and described in detail.
Based on the proposed simple method to find the rotor corner frequency, the range of proportional gain of speed controller can be determined so as to avoid the system oscillation. This result can not only speed up the design and implementation of speed controlled motor drive, but also reduce the development time.

Block Diagram of the Motor Drive

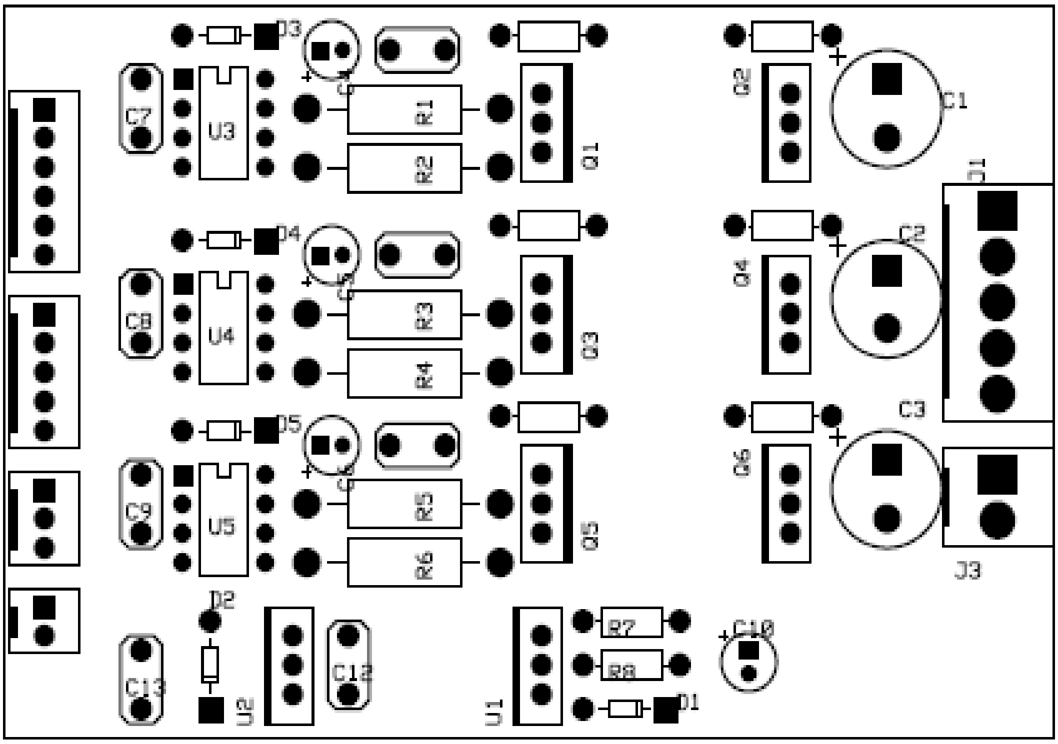
Motor Drive:



Schematic Diagram:



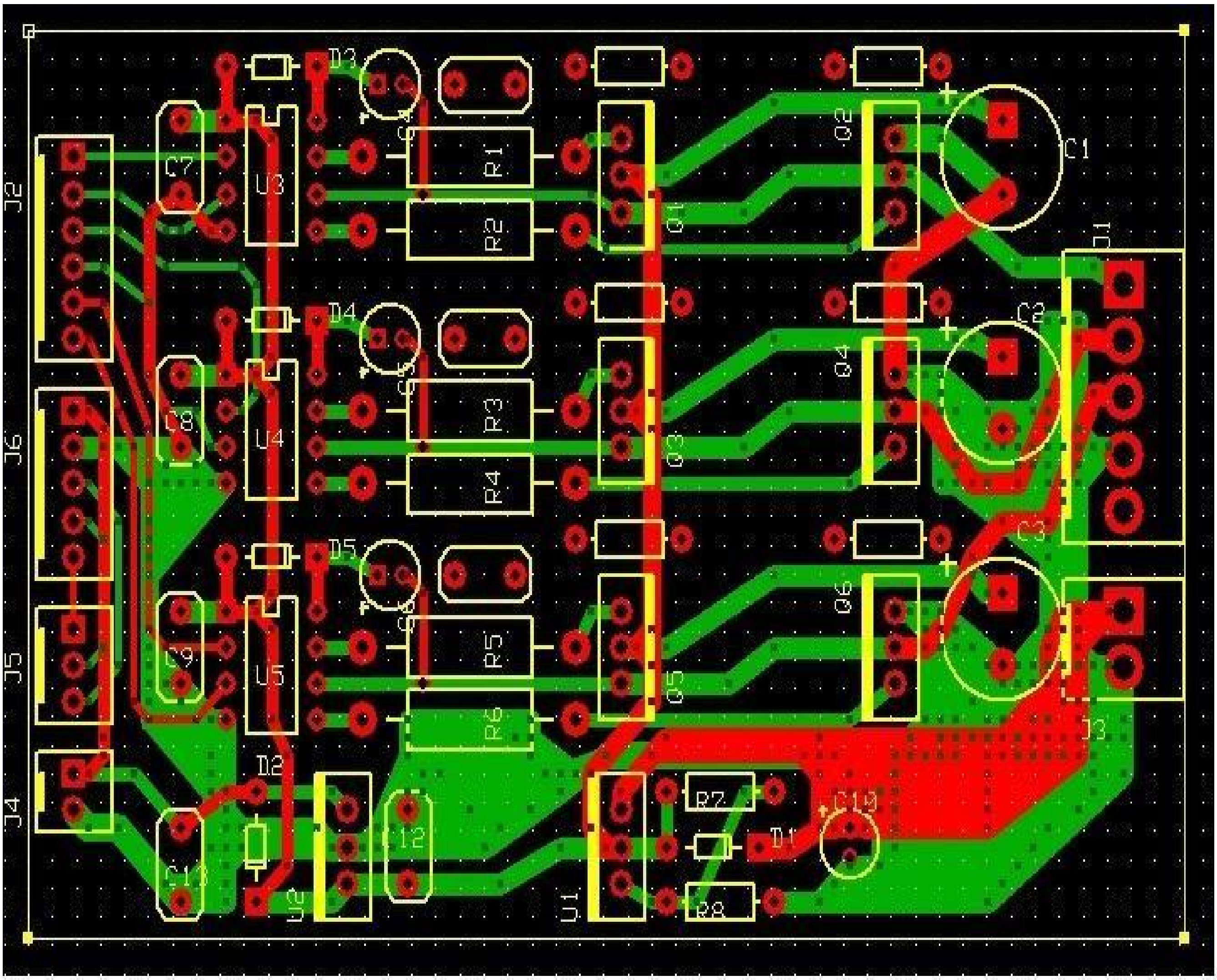
PCB Layout and Design



It is a step-by-step approach to PCB design begins with a project file that contains design documents. As the team builds the design, the documents populate with project preferences, project outputs, and the required electrical rule checks. Altium Designer provides version control for your documents through managed repositories.

Setting up the project and developing a schematic within Schematic Designer becomes easier through a comprehensive. Working within Schematic Designer, teams can create components from local libraries or place components direct from the Altium's globally accessible Content Vault. Adding links to the PCB footprint allows each symbol to become a component that includes specifications within the local libraries. Every PCB footprint stores in local PCB libraries and includes electrical and mechanical elements.

- Manage complexity within size limitations of your board.
- Work through your component footprints.
- Keeping your footprints within IPC compliances

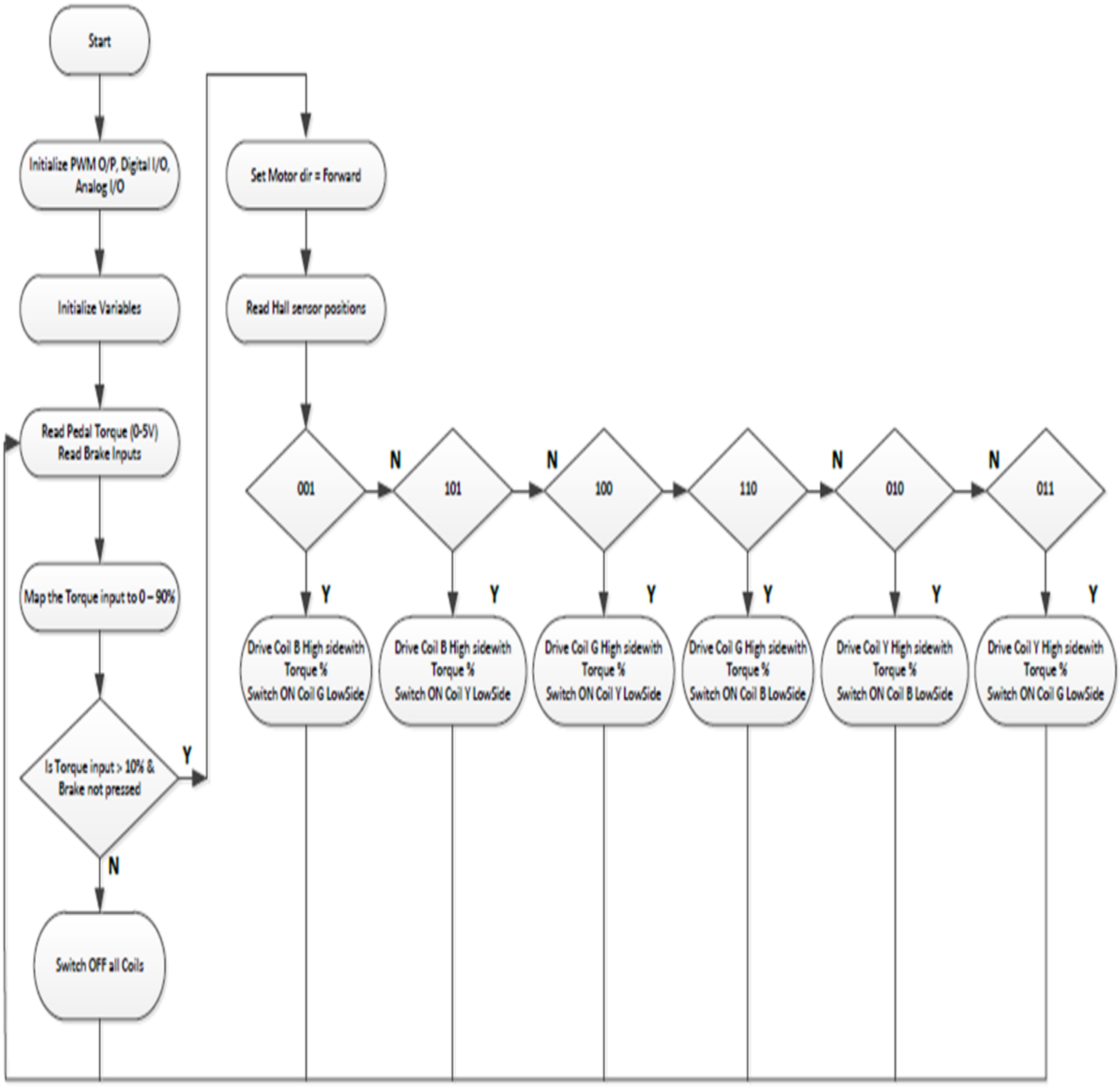


Here, the PCB design has been made with two layers. The two layers has been designed so that the process of soldering the components onto the PCB board would be easy and neat. Also, it will help us to avoid any overlapping of connections or short circuiting. In the diagram shown above, we have followed a rule while designing the PCB which is, that the red lines are the horizontal connections and the green lines are the vertical connections.

CHAPTER 4

CODE FOR ARDUINO AND IT'S TESTING

Flowchart for the algorithm used:



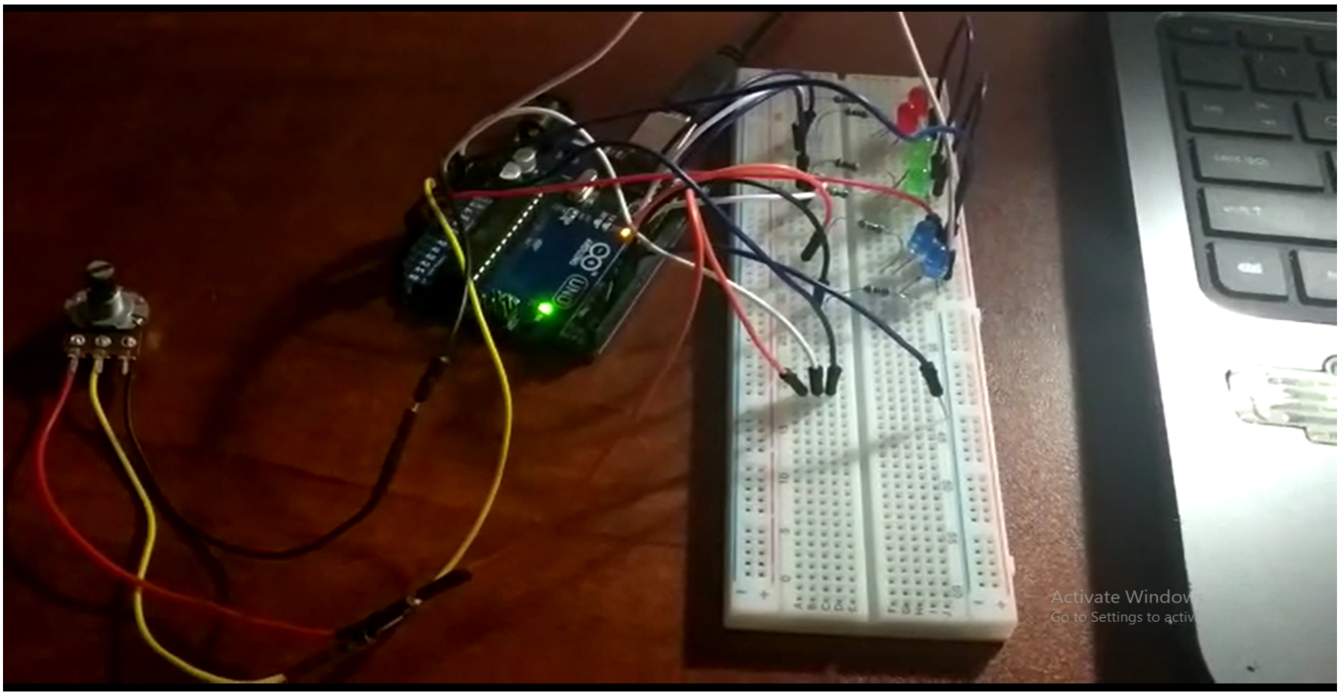
Code for the Arduino Microcontroller

```
//hall input pins
int hall_sensor_y = A3;
int hall_sensor_b = A2;
int hall_sensor_g = 15;
//MOSFET Drive pins
const int y_motor_lout = 5;
const int y_motor_pwm_hout = 6;
const int b_motor_lout = 7;
const int b_motor_pwm_hout = 9;
const int g_motor_lout = 8;
const int g_motor_pwm_hout = 10;
enum WheelDirection {
DIR_FORWARD,
DIR_STOP
};
float throttle = 0.0;
boolean MotorOff = false;
float Cn = 0;
void setup()
{
//y phase winding control pin modes
pinMode(y_motor_lout, OUTPUT);
pinMode(y_motor_pwm_hout, OUTPUT);

//b phase winding control pin modes
pinMode(b_motor_lout, OUTPUT);
pinMode(b_motor_pwm_hout, OUTPUT);
//g phase winding control pin modes
pinMode(g_motor_lout, OUTPUT);
pinMode(g_motor_pwm_hout, OUTPUT);
//Hall sensor pins modes
```

```
pinMode(hall_sensor_y, INPUT);
pinMode(hall_sensor_b, INPUT);
pinMode(hall_sensor_g, INPUT);
//Two MOSFETs will be ON at a time, the high side MOSFET will on PWM mode
analogWrite(y_motor_pwm_hout, 0);//set motor to stop
analogWrite(b_motor_pwm_hout, 0);//half bridge driver, hi part is active high
analogWrite(g_motor_pwm_hout, 0);
//The low side MOSFET will be digital output
digitalWrite(y_motor_lout, HIGH);// lo part is active low
digitalWrite(b_motor_lout, HIGH);
digitalWrite(g_motor_lout, HIGH);
}

// MOTOR DRIVE FUNCTION
void MoveWheel(WheelDirection (dir), float (speed))
{
if (MotorOff) return;
//empty all motor registers
//half bridge driver, hi part is active high
//lo part is active low

analogWrite(y_motor_pwm_hout, 0);//set motor to stop
analogWrite(b_motor_pwm_hout, 0);
analogWrite(g_motor_pwm_hout, 0);
digitalWrite(y_motor_lout, HIGH);
digitalWrite(b_motor_lout, HIGH);
digitalWrite(g_motor_lout, HIGH);
int hall_y = digitalRead(hall_sensor_y);
int hall_b = digitalRead(hall_sensor_b);
int hall_g = digitalRead(hall_sensor_g);

if (dir == DIR_STOP)
 {
 // do nothing
 }
```

```
else if (dir == DIR_FORWARD)
 {
 if (hall_y == 0 && hall_b == 0 && hall_g == 1)
  {//001
  analogWrite(b_motor_pwm_hout, speed);
  digitalWrite(g_motor_lout, LOW);
  }
 else if (hall_y == 1 && hall_b == 0 && hall_g == 1)
  {//101
  analogWrite(b_motor_pwm_hout, speed);
  digitalWrite(y_motor_lout, LOW);
  }
 else if (hall_y == 1 && hall_b == 0 && hall_g == 0)
  {//100
  analogWrite(g_motor_pwm_hout, speed);
  digitalWrite(y_motor_lout, LOW);
  }
 else if (hall_y == 1 && hall_b == 1 && hall_g == 0)
  {//110
  analogWrite(g_motor_pwm_hout, speed);
  digitalWrite(b_motor_lout, LOW);
  }
 else if (hall_y == 0 && hall_b == 1 && hall_g == 0)
  {//010
  analogWrite(y_motor_pwm_hout, speed);
  digitalWrite(b_motor_lout, LOW);
  }
 else if (hall_y == 0 && hall_b == 1 && hall_g == 1)
  {//011
  analogWrite(y_motor_pwm_hout, speed);
  digitalWrite(g_motor_lout, LOW);
  }
 }
}
```

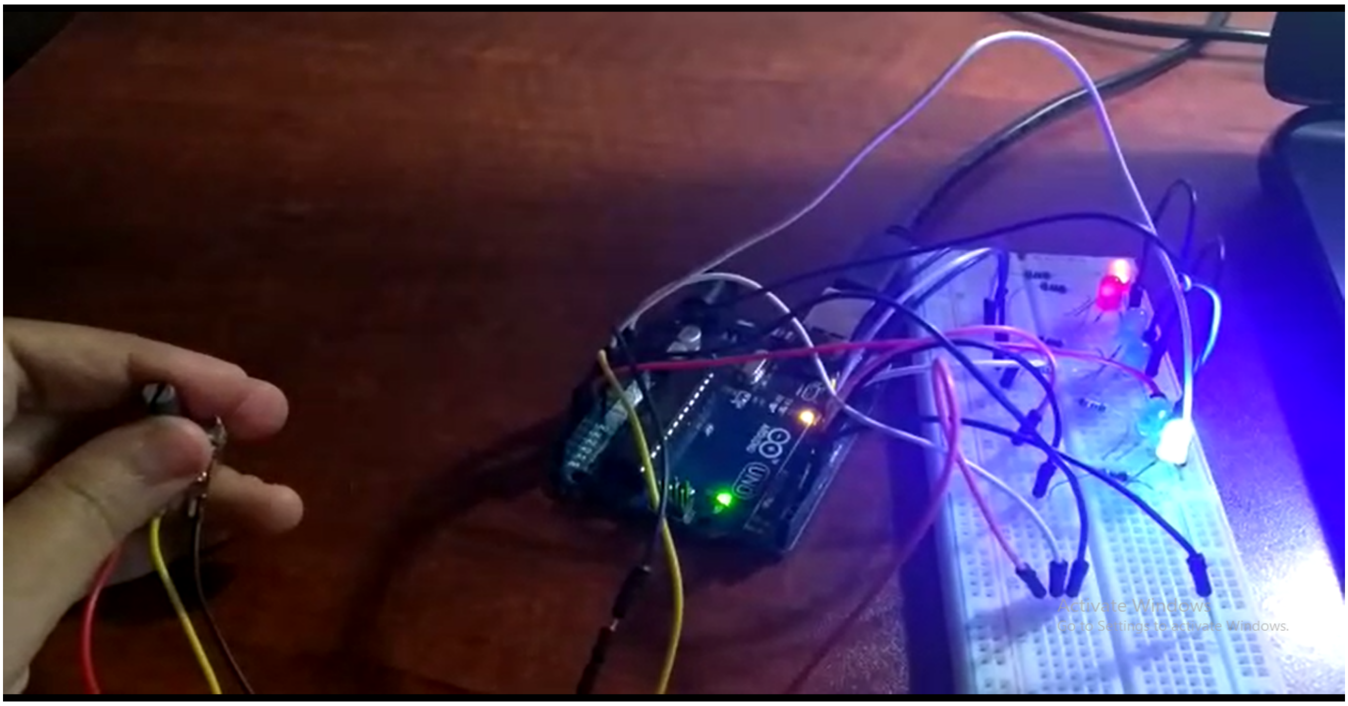
Testing Circuit



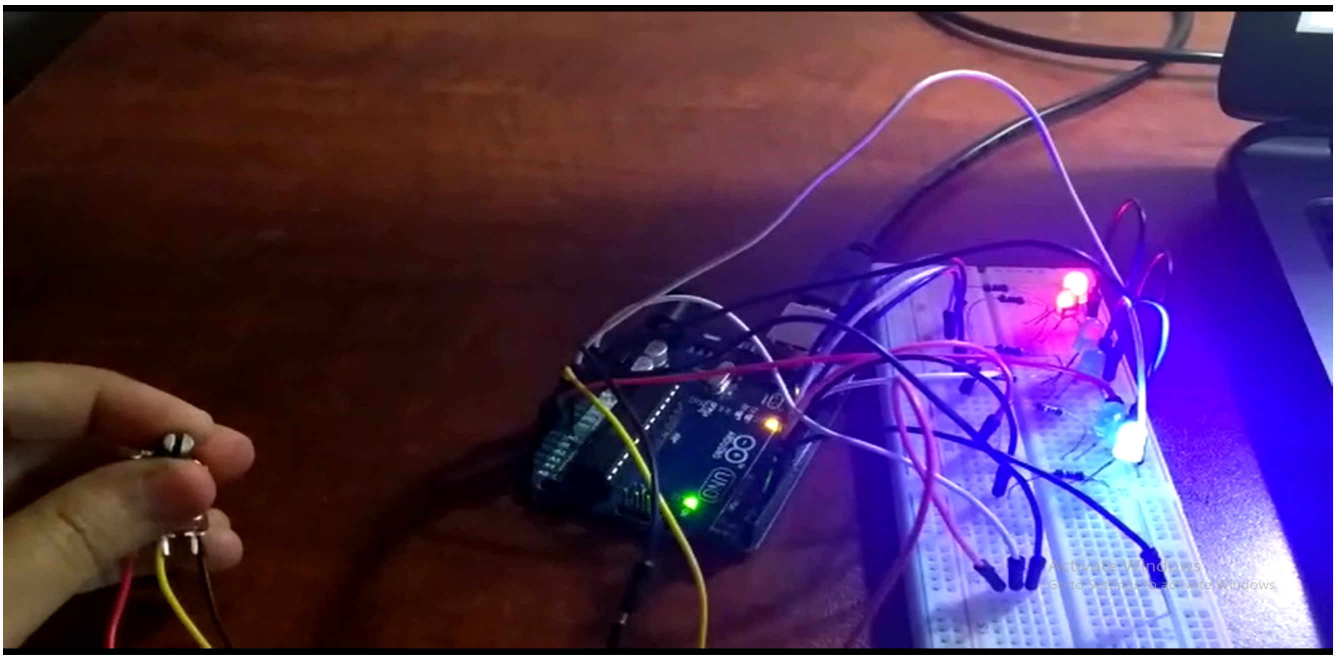
The picture above depicts the actual circuit diagram that we connected for the testing of our algorithm for the torque sensor.

The same code which has been mentioned above, was fed into the Arduino IDE, and then it was interfaced to the circuit as seen above.

In the circuit, we have used a 10k potentiometer to replicate the effects of a torque transducer. The 10k potentiometer generates a voltage range of 0-5V which is what we are mapping with our torque transducer. The LED pins are representing the 6 MOSFETs which has been explained in the commutation implementation part earlier in the report.



When we slowly start to increase the potentiometer, we can see the BLUE lights switched on with maximum brightness at once. However, the RED light was very dim at first.



And by further increasing the potentiometer the intensity of the RED light also increased while the intensity of the BLUE light remained at it's maximum as a constant.
This explains the part of the commutation implementation where we are giving the generated PWM signal from the Arduino microcontroller only to the high side MOSFETs and not the low side MOSFETs. Also, since only two coils of the stator winding are being

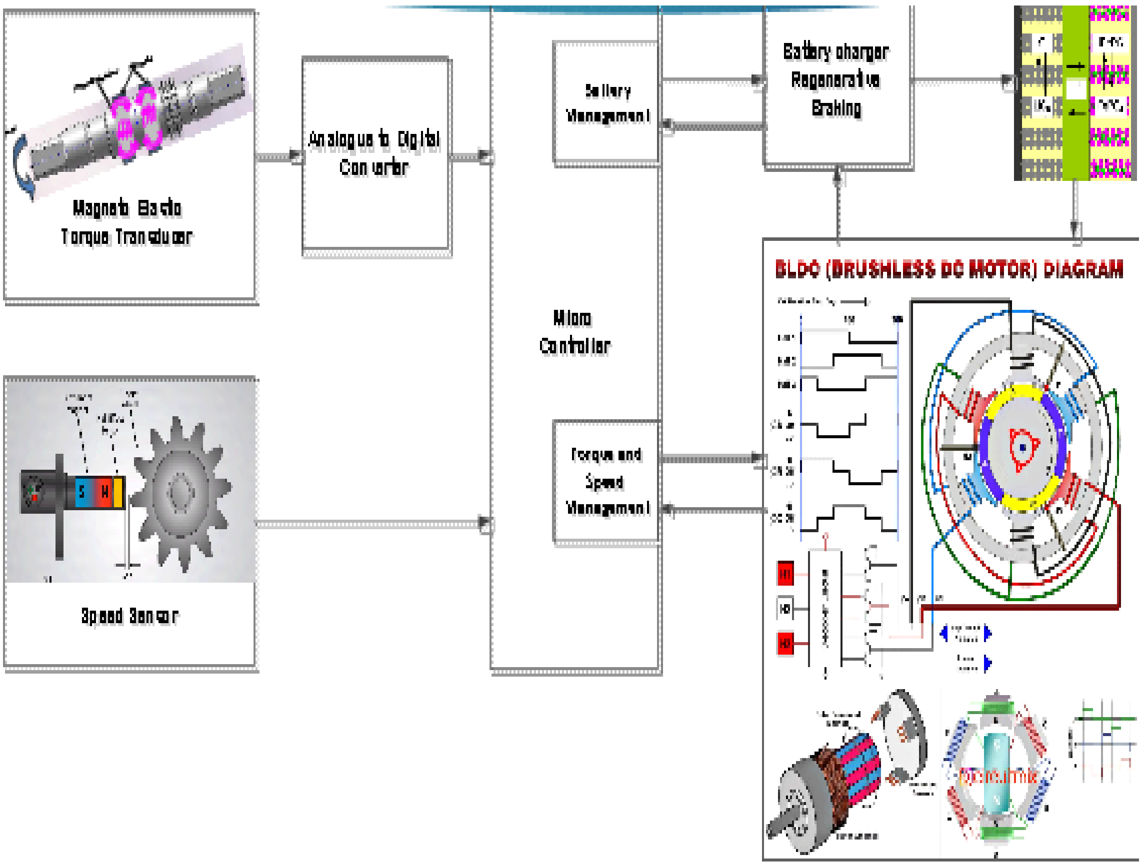
energized at any particular instant, hence, as seen in the image above only RED and BLUE lights are receiving current and hence turning ON.

Since, the PWM signals are meant to operate only the high side MOSFETs, therefore, only the RED light is having a varying intensity according to the duty cycle of the generated PWM signal and not the BLUE lights.

So, using this circuit we were able to verify and check our algorithm and hence the ocde of Arduino for the torque sensors which was successful and indicated proper commutation implementation process of MOSFETs as desired by varying the duty cycle of the generated PWM signal.

CHAPTER 5

PROPOSED MODEL



Principle of Magnetoelasticity:

When mechanical force is applied on the opposite faces of the magnetized cube, the measurable magnetic field on the outside of the cube experiences a change in the direction. The angle of inclination of the magnetic field is measurable. It varies in proportion to the force applied. It is a highly linear phenomenon.

CHAPTER 6

ADVANTAGES AND APPLICATIONS

The few advantages are:
Regulating the power required based on actual pedal torque requirement. Could extend this to many upcoming EV applications.

BLDC motors are: high durability, high efficiency, relatively low weight and small dimensions in comparison to other electric motor constructions. BLDC motors are the pillars of futuristic Electric vehicles

A simple BLDC motor control algorithm for low cost motor drive applications using general purpose microcontrollers

Less power loss due to lower mechanical components

This project of an Electrically Assisted cycle, is itself one the straight applications. However, the other few applications that we can have using the same technology are:

- Appliances
- Medical
- Automobiles
- Aerospace
- Instrumentation
- Military

CHAPTER 7

CONCLUSION AND FUTURE WORK

We aim at building an electrically assisted cycle using a BLDC hub motor.
It will be a product which would be easy to use, smooth, silent with zero emissions.
It would significantly reduce the manpower, especially while commuting through an inclined plane. It will be a low cost product, thus making it feasible and available to a larger part of the Indian population. As there is synchronization between the electric motor and ICE propulsions, less petrol consumption can be seen with less charging cycle of batteries (long life per charge). If one vehicle can save about an average of 30% of petrol fuel, then an
average of about 40%-60% of national fuel can be conserved by using this type of vehicle. Also, electric bill can also be saved, as the batteries last long per charge. An idea of charging the batteries through ICE can also be implemented here. The durability and convenience to consumer can be improved by using this type of vehicle. Charging of Lithium-Ion batteries can be done through idling or running ICE during the vehicle propulsion or by solar charging scheme discussed can also be used. Further algorithms can be developed in synchronizing the electric motor and ICE turning on and off periods relevantly depending on the driving cycle. So, fuel efficiency of the vehicle can be much improved.
Many of the software like ELPH, ADVISOR, SIMULINK / MATLAB can be used for analysis in design of the vehicle more suitable for any region.

This methodology of design can be relevantly adopted and verified for three-wheeler (Auto-rickshaws) and four-wheeler vehicles in future. ADVISOR is a 2002 built SIMULINK / MATLAB based tool designed by National Renewable Limited, USA. It can be used for analyzing certain pre-defined models of the ICE, Electric, and HEV for fuel efficiency, pre-defined driving cycles and emissions for all type of modes of driving. Figure 6.1 and Figure 6.2 shows the analysis structures of a parallel hybrid four-wheeler car in ADVISOR simulator. Figure 6.1: ADVISOR model design for parallel hybrid type of configuration.

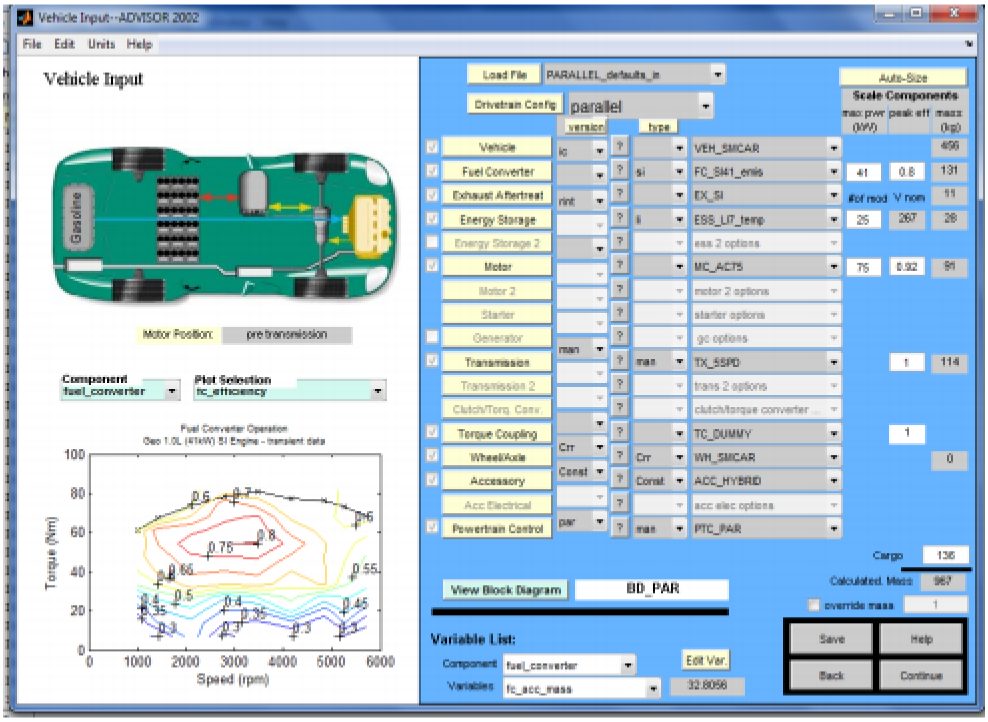


Figure 6.1: ADVISOR model design for parallel hybrid type of configuration

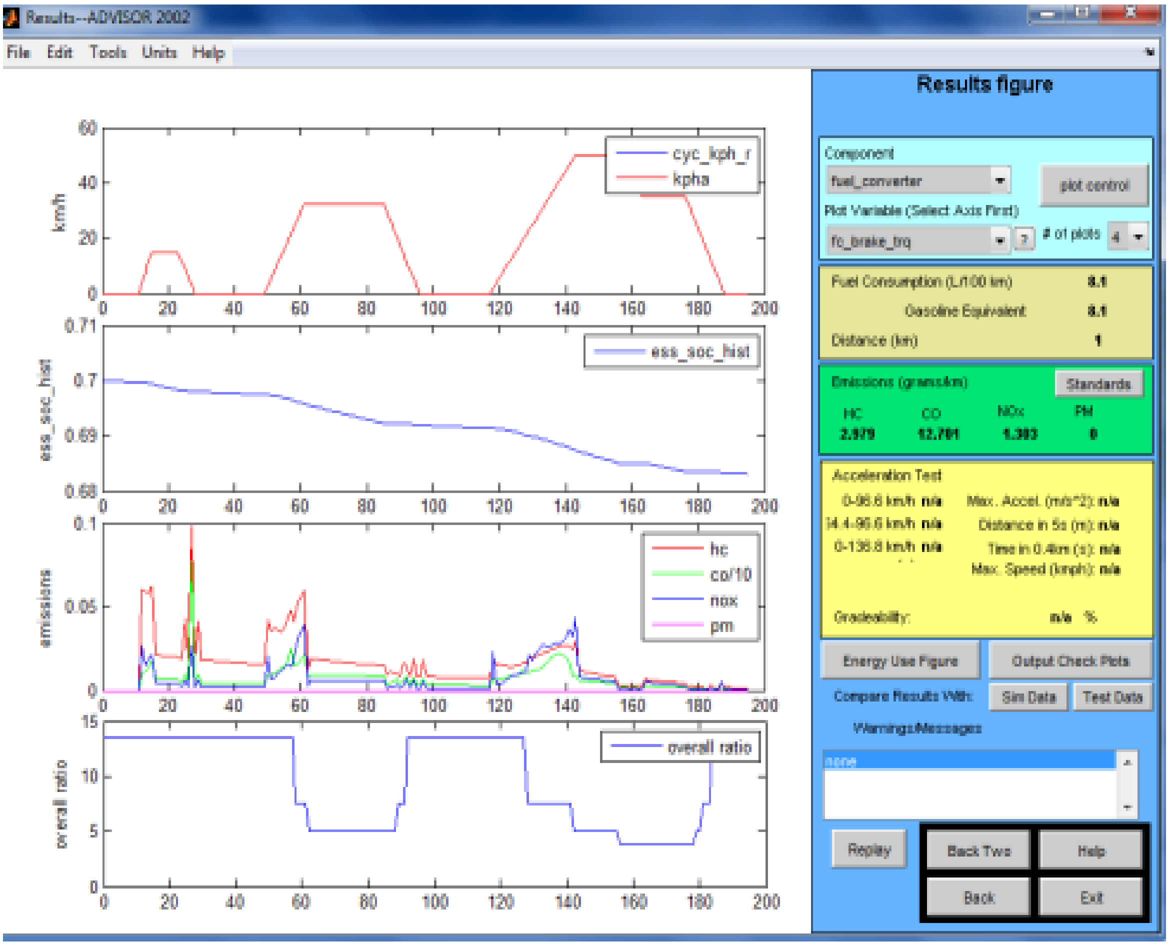


Figure 6.2: ADVISOR analysis for parallel hybrid electric model

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