JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

"DESIGN OF MOTOR AND CONTROLLER FOR E-BICYCLE"

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ABSTRACT

Modern world demands the high technology which can solve the current and future problems. Fossil fuel shortage is the main problem now-a-days. Considering current rate of usage of fossilfuels will let.its life up to next five decades only. Undesirable climate changeis the red indication for not to use more fossil fuel any more. Best alternative for the automobile fuels to provide the mobility & transportation to peoples is sustainable electrical bicycle. Future e-bicycle is the best technical application as a visionary solution for the better world and upcoming generation. E-motorbike comprises the features like artificial intelligence.noiseless operation, light weight vehicles,. E-bicycle is the most versatile future vehicleconsidering its advantages.

INTRODUCTION

A brushless DC electric motor (BLDC motor or BL motor), also known as an electronically commutated motor (ECM or EC motor) or synchronous DC motor, is a synchronous motor usinga direct current (DC) electric power supply.

It uses an electronic closed loop controller to switch DC currents to the motor windings producing magnetic fields which effectively rotate in space and which the permanent magnet rotor follows. The controller adjusts the phase and amplitude of the DC current pulses to control the speed and torque of the motor.

This control system is an alternative to the mechanical commutator (brushes) used in many conventional electric motors.

The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor. They may also use neodymium magnets and be outrunners (the stator is surrounded by the rotor), inrunners (the rotor is surrounded by the stator), or axial (the rotor and stator are flat and parallel).

The advantages of a brushless motor over brushed motors are high power-to-weight ratio, high speed, nearly instantaneous control of speed (rpm) and torque, high efficiency, and low maintenance. Brushless motors find applications in such places as computer peripherals (disk drives, printers), hand-held power tools, and vehicles ranging from model aircraft to automobiles.

In modern washing machines, brushless DC motors have allowed replacement of rubber belts and gearboxes by a direct-drive design.

Brushed DC motors were invented in the 19th century and are still common. Brushless DC motors were made possible by the development of solid state electronics in the 1960

An electric motor develops torque by keeping the magnetic fields of the rotor (the rotating part of the machine) and the stator (the fixed part of the machine) misaligned. One or both sets of magnets are electromagnets, made of a coil of wire wound around an iron core.

DC running through the wire winding creates the magnetic field, providing the power which runs the motor. The misalignment generates a torque that tries to realign the fields. As the rotor moves, and the fields come into alignment, It is necessary to move either the rotor's or stator's field to maintain the misalignment and continue to generate torque and movement. The device that moves the fields based on the position of the rotoris called a commutator.

2. LITERATURE SURVEY OF BLDC MOTOR

[1] M. Daniel pradeep ,"a novel method of speed and voltage control of bldc motor" This paper presents the speed control of BLDC motor by the 3phase semiconductor bridge by the signal sensed by rotor position sensor. In the proposed method the back emf of the motor is stored in the battery and the speed of motor is sensed and is given the pi controller which drives the semiconductor thus, by this proposed method the energy consumption will be less and generated energy can be stored and reused, and it has high, long operating life, noiseless operation, and high speed range ,

[2] Abhishek jain, "controlling of permanent magnet brushless dc motor using instrumentation technique" The paper characterizes the controlling the permanent magnet brushless dc motor with sensor via instrumentation technique. A permanent magnet brushless dc motor is gaining popularity since its uses sensors instead of brushes and commutators. A brushless dc motor has been used in this paper since it has high efficiency, reliable and requires lower maintenance cost. Pwm technique is used for the controlling of fpga (field programmable gate array) device that calculates the duty cycle as required. The paper deals with the analyses of speed control of the brushless dc motor whichcan be done using pid controller

[3] Yasser ali almatheel, " speed control of dc motor using fuzzy logic controller " Dc motor speed is controlled using pid controller and fuzzy logic controller, Pid controller requires a mathematical model of the system while fuzzy logic controller base on International Research Journalof Engineering and Technology

Design of fuzzy logic controller requires many design decisions , for example rule base and fuzzification. The flc has two input ,one of these inputs is the speed error and the second is the changein the speed error. There are 49 fuzzy rules which are designed for the fuzzy logic controller. The center of gravity method is used for the defuzzificztion. Fuzzy logic controller uses mamdani system which employs fuzzy sets in consequent part. Pid controller chooses its parameters base on trial and error method. Pid and flc are investigated with the help of matlab / simulink package program simulation. It is founded that flc is more difficult in design comparing with pid controller, but it has an advance to be more suitable to satisfy non-linear characteristics of dc motor.

he results shows that the fuzzy logic has minimum transient and steady state parameters , which shows that fic more efficiency and effectiveness than pid controller .

[4] S.thamizmani , "design of fuzzy pid controller for brushless dc motor This brushless dc motors are widely used for many industrial applications because of their high efficiency, high torque and low volume. This paper proposed a improved fuzzy pid controller to control speed of brushless dc motor. The proposed controller is called proportional– integral–derivative controller and fuzzy proportional– integral– derivative controller. This paper provides an overview of performance conventional pid controller and fuzzy pid controller. It is difficult to tune the parameters and get satisfied control characteristics by using normal conventional pid controller.

[5] In 2015 Nikita Tiwari, Prof. RiteshDiwan "Speed Control of Brushless DC Motor using Fuzzy and Neuro Fuzzy" In this article the DC drive systems are often used in many industrial applications such as robotics, actuation and manipulators. The purpose of this paper is to control the speed of Brushless DC motor by using Fuzzy logic controller (FLC) and Neuro-fuzzy controller in MATLAB / SIMULINK model. The scopes includes the modelling and simulation of Brushless DC motor, application of fuzzy logic controller to actual DC motor. This paper is going to present the new capacity of assessing speed and control of the Brushless DC motor. By utilizing the Neuro fuzzy controller, the rate can be tuned until it get like the desired output that a user wants.

[6] In 2015 Maloth Purnalal1, Sunil kumar T K2 "Development Of Mathematical Model And Speed Control Of Bldc Motor " In this article the electronically commutated Brushless DC motors are enormously used in many industrial applications which increases the need for design of efficient control strategy for these noiseless motors. This paper deals with a closed loop speed control of BLDC motor and performance of the BLDC motor is simulated. The duty ratio is regulated by PI controller, which governs the duty cycle of the PWM pulses applied to the switches of the inverter to run the motor at steady state speed .

BLDC HUB MOTOR

A brushless DC motor (known as BLDC) is a permanent magnet synchronous electric motor which is driven by direct current (DC) electricity and it accomplishes electronically controlled commutation system (commutation is the process of producing rotational torque in the motor by changing phase currents through it at appropriate times) instead of a mechanically commutation system. BLDC motors are also referred as trapezoidal permanent magnet motors.

Unlike conventional brushed type DC motor, wherein the brushes make the mechanical contact with commutator on the rotor so as to form an electric path between a DC electric source and rotor armature windings, BLDC motor employs electrical commutation with permanent magnet rotor and a stator with a sequence of coils. In this motor, permanent magnet (or field poles) rotates and current carrying conductors are fixed. The armature coils are switched electronically by transistors or silicon controlled rectifiers at the correct rotor position in such a way that armature field is in space quadrature with the rotor field poles. Hence the force acting on the rotor causes it to rotate. **Hall sensors** or rotary encoders are most commonly used to sense the position of the rotor and are positioned around the stator. The rotor position feedback from the sensor helps to determine when to switch the armature current.

3.1 Construction Of A BLDC hub Motor

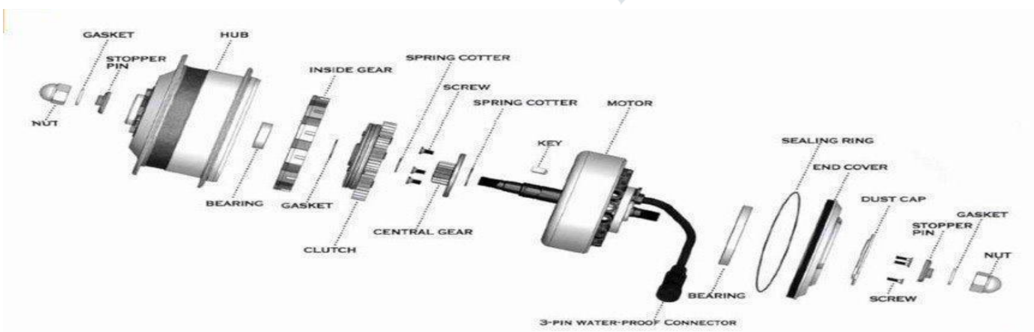


Figure 3.1(a) Bldc hub motor inner layer

Brushless DC motors (BLDC) have been a much focused area for numerous motor manufacturers as these motors are increasingly the preferred choice in many applications, especially in the field of motor control technology. BLDC motors are superior to brushed DC motors in many ways, such as ability to operate at high speeds, high efficiency, and better heat dissipation.

They are an indispensable part of modern drive technology, most commonly employed for actuating drives, machine tools, electric propulsion, robotics, computer peripherals and also for electrical power generation.

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 a specific number of poles. This is the basic constructional difference between a brushless motor and a typical dc motor.

There can be two types of BLDC motor on the basis of construction :

3.2 a.BLDC Inner Rotor Design

This is a conventional design, where the rotor is located at the core (center) and stator winding surrounds it.

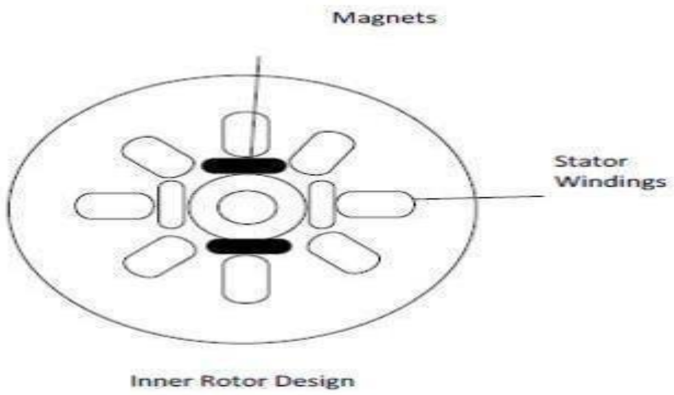


Figure 3.2(a) Rotor inner design

b.BLDC Outer Rotor Design

In this design, the rotor is external. i.e. stator windings are located at the core while the rotor, carrying permanent magnets, surrounds the stator.

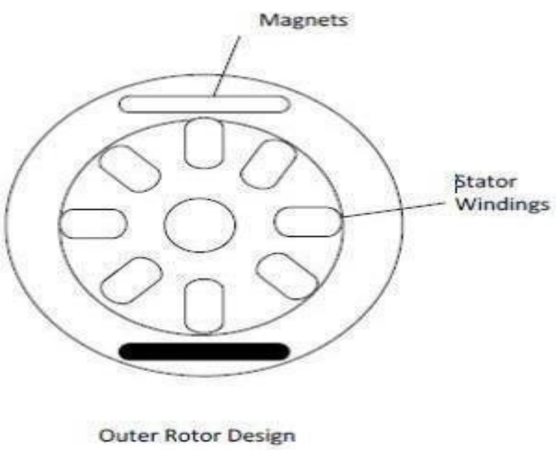


Figure 3.2(b) Rotor outer design

3.3 Rotor

BLDC motor incorporates a permanent magnet in the rotor. The number of poles in the rotor can vary from 2 to 8 pole pairs with alternate south and north poles depending on the application requirement. In order to achieve maximum torque in the motor, the flux density of the material should be high. A proper magnetic material for the rotor is needed to produce required magnetic field density.

Hall Sensors

Hall sensor provides the information to synchronize stator armature excitation with rotor position. Since the commutation of BLDC motor is controlled electronically, the stator windings should be energized in sequence in order to rotate the motor. Before energizing a particular stator winding, acknowledgment of rotor position is necessary. So the Hall Effect sensor embedded in stator senses the rotor position.

Most BLDC motors incorporate three Hall sensors which are embedded into the stator. Each sensor generates Low and High signals whenever the rotor poles pass near to it. The exact commutation sequence to the stator winding can be determined based on the combination of these three sensor's respons.

3.4 MOTOR FUNDAMENTAL CONCEPTS

General Motor Principles

Motors convert electrical energy into mechanical energy using electromagnetic principles. The energy conversion method is fundamentally the same in all electric motors. This document starts with a generaloverview of basic electromagnetic physics before entering discussing the details of motor operation.

a.Magnetic Force

Magnetic poles generate invisible lines of magnetic force flowing from the north pole to the south pole as shown in Figure 1. When magnetic poles of opposite polarity face each other, they generate an attractive force, while like poles generate a repulsive force.

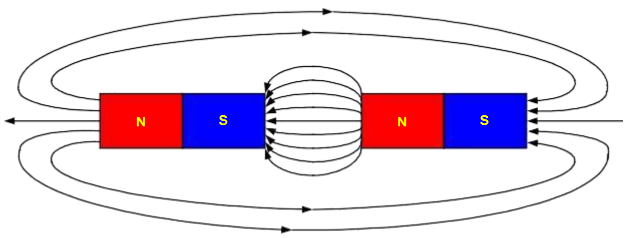


Figure 3.4(a) Unlike-pole repulsion

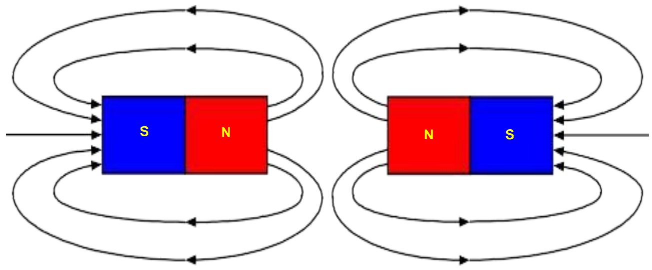


Figure 3.4(b) like -pole repulsion

a. Left-Hand Rule

Current in a conductor generates a magnetic field. Placing a conductor in the vicinity of a separate magnetic can generate a force that reaches its apex when the conductor is at 90° to the external field. The left-hand rule can help the user determine the direction of the force, as shown

a. Right-Hand Rule

The movement of the conductor in the magnetic field induces an electromotive force known as the BEMF. The right-hand rule can determine the direction of the force as shown in.

The Right-Hand Rule: Stretch out the right hand with the four fingers and the thumb on the same plane,the palm facing the north pole of the external magnetic field, and the thumb pointing in the direction of the velocity of v. The four fingers point in the direction of the induced electromotive force.

b. Right-Hand Corkscew Rule.

Right-Hand Corkscrew Rule: For a current flowing in a straight line as shown in Figure , the thumb points in the direction of the current I, and the fingers curl in the direction of the magnetic field B. For a coiled current as shown in Figure 4(b), the fingers curl in the direction of the current I, and thenthe thumb points in the direction of the magnetic field B through the

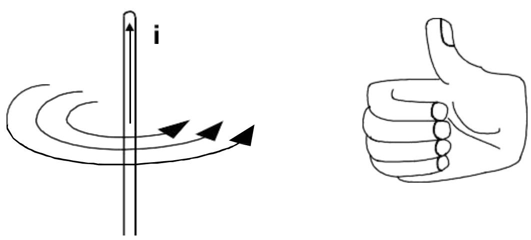


Figure 3.4 (c) Straight line

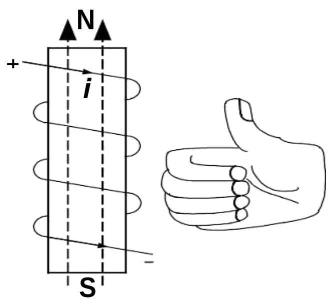
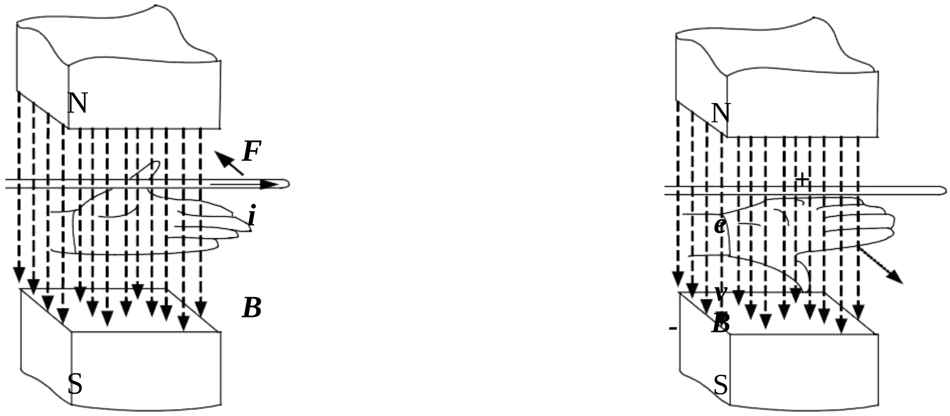


Figure 3.4 (d) Loop

Left-Hand Rule: Extend the left hand with the thumb and four fingers on the same plane with the thumb pointing out. Face the palm towards the north pole of the external magnetic field and the four fingers in the direction of the current; the thumb points in the direction of the force.



(a) Left-Hand Rule **(b) Right-Hand Rule**

Figure 3.4 (e) Left-Hand Rule and Right-Hand Rule

The magnitude of the force can be calculated from the equation below:

Where F is the electromagnetic force, B is the magnetic field density, I is the conductor current, L is the length of the conductor, and θ is the angular difference between B and I.

Given that a coil usually has two effective conductors: *a-b* and *c-d* shown in Figure 3(a), these two conductors induce two forces of opposite direction when current passes through in the magnetic field.

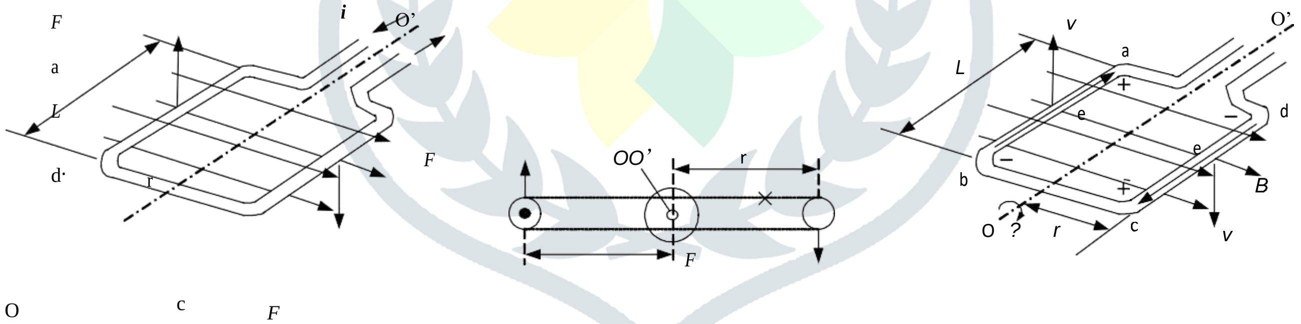


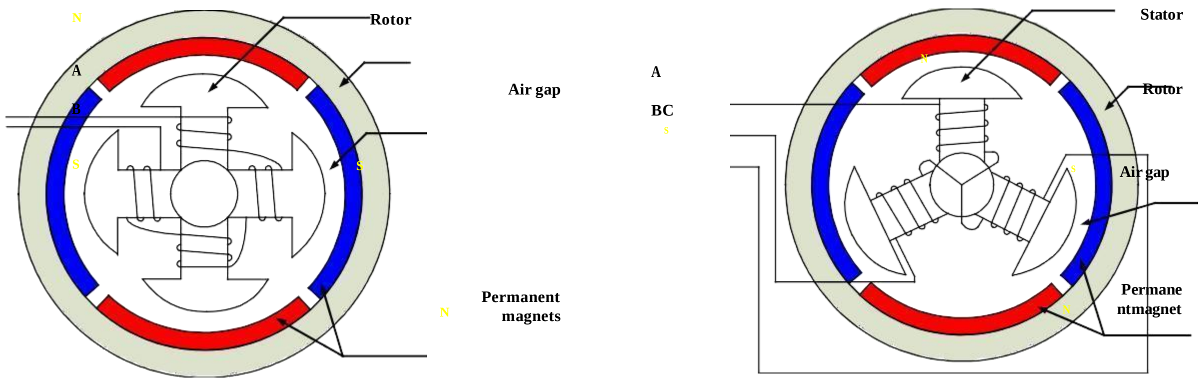
Figure 3.4(f) Coil in a Magnetic Field

The torque is the product of the tangential force acting at a radius with units of force multiplied by length.If there are N continuous coil turns, and based on the parameters in Figure 3, the generated torque equals

3.5 Stator

There are three classifications of the BLDC motor: single-phase, two-phase and three-phase. This discussion assumes that the stator for each type has the same number of windings. The single-phase and three-phase motors are the most widely used. Figure 5 shows the simplified cross section of a single-phase and a three-phase BLDC motor. The rotor has permanent magnets to form 2 magnetic pole pairs, and surrounds the stator, which has the windings.

Stator



(a) Single-phase (b) Three-phase

Figure 3.5 Simplified BLDC Motor Diagrams

A single-phase motor has one stator winding—wound either clockwise or counter-clockwise along eacharm of the stator—to produce four magnetic poles as shown in Figure 5(a). By comparison, a three- phase motor has three windings as shown in Figure 5(b). Each phase turns on sequentially to make therotor revolve.

There are two types of stator windings: trapezoidal and sinusoidal, which refers to the shape of the back electromotive force (BEMF) signal. The shape of the BEMF is determined by different coil interconnections and the distance of the air gap. In addition to the BEMF, the phase current also followsa trapezoidal and sinusoidal shape. A sinusoidal motor produces smoother electromagnetic torque thana trapezoidal motor, though at a higher cost due to their use of extra copper windings.

Rotor

A rotor consists of a shaft and a hub with permanent magnets arranged to form between two to eight pole pairs that alternate between north and south poles. Figure 6 shows cross sections of three kinds ofmagnets arrangements in a rotor.

There are multiple magnet materials, such as ferrous mixtures and rare-earth alloys. Ferrite magnets are traditional and relatively inexpensive, though rare-earth alloy magnets are becoming increasingly popular because of their high magnetic density. The higher density helps to shrink rotors while maintaining high relative torque when compared to similar ferrite magnet

3.6 Operational Motor Theory

Motor operation is based on the attraction or repulsion between magnetic poles. Using the three-phase motor shown in Figure 7, the process starts when current flows through one of the three stator windingsand generates a magnetic pole that attracts the closest permanent magnet of the opposite pole. The rotor will move if the current shifts to an adjacent winding. Sequentially charging each winding will cause the rotor to follow in a rotating field.

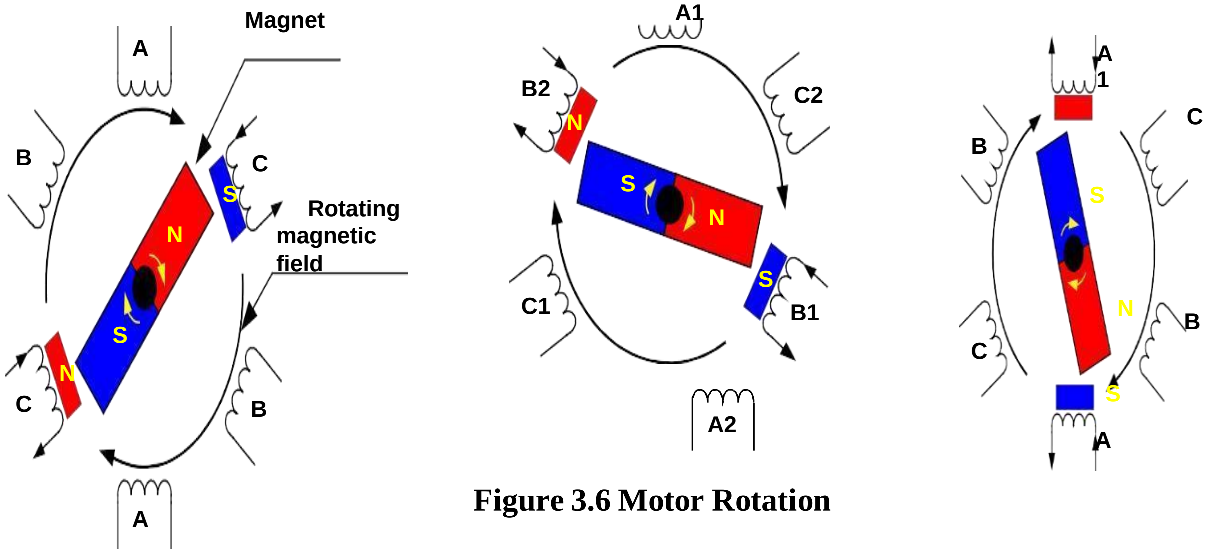


Figure 3.6 Motor Rotation

The torque in this example depends on the current amplitudeand the number of turns on the stator windings, the strength and the size of the permanent magnets, the air gap between the rotor and the windings, and the length of the rotating arm.

Working Principle and Operation of BLDC HUB Motor

BLDC motor works on the principle similar to that of a conventional DC motor, i.e., the Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it experiences a force. As a consequence of reaction force, the magnet will experience an equal and opposite force. In case BLDC motor, the current carrying conductor is stationary while the permanent magnet moves.

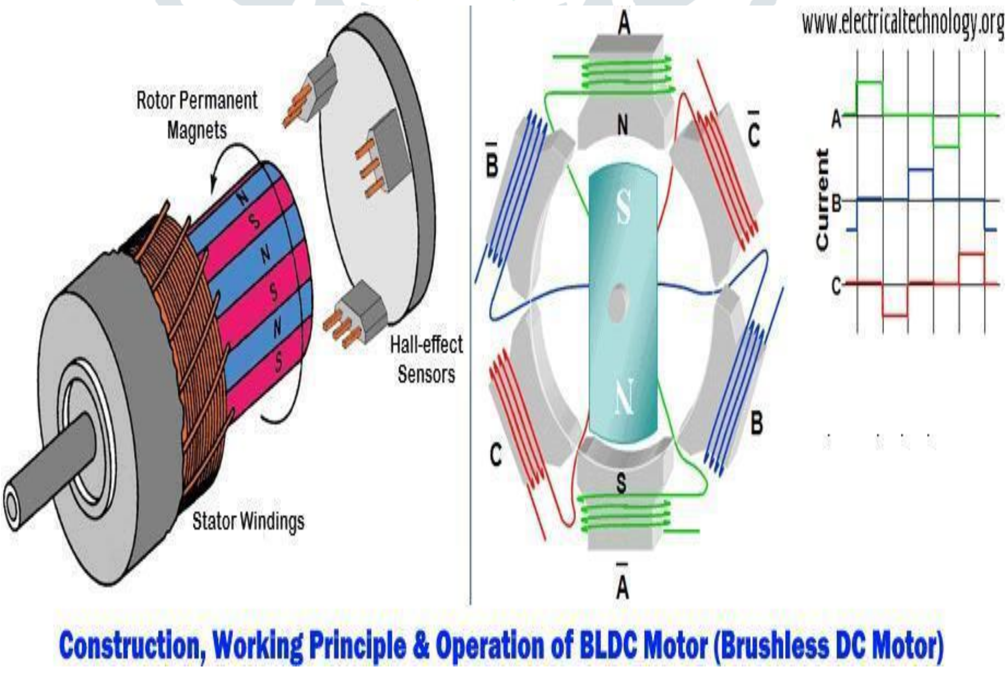


Figure 4.1(a) working principal

When the stator coils are electrically switched by a supply source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makesto generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate.

Consider the figure below in which motor stator is excited based on different switching states. With the switching of windings as High and Low signals, corresponding winding energized as North and South poles. The permanent magnet rotor with North and South poles align with stator poles causing motor to rotate.

Observe that motor produces torque because of the development of attraction forces (when North-South or South-North alignment) and repulsion forces (when North-North or South-South alignment). By this way motor moves in a clockwise direction.

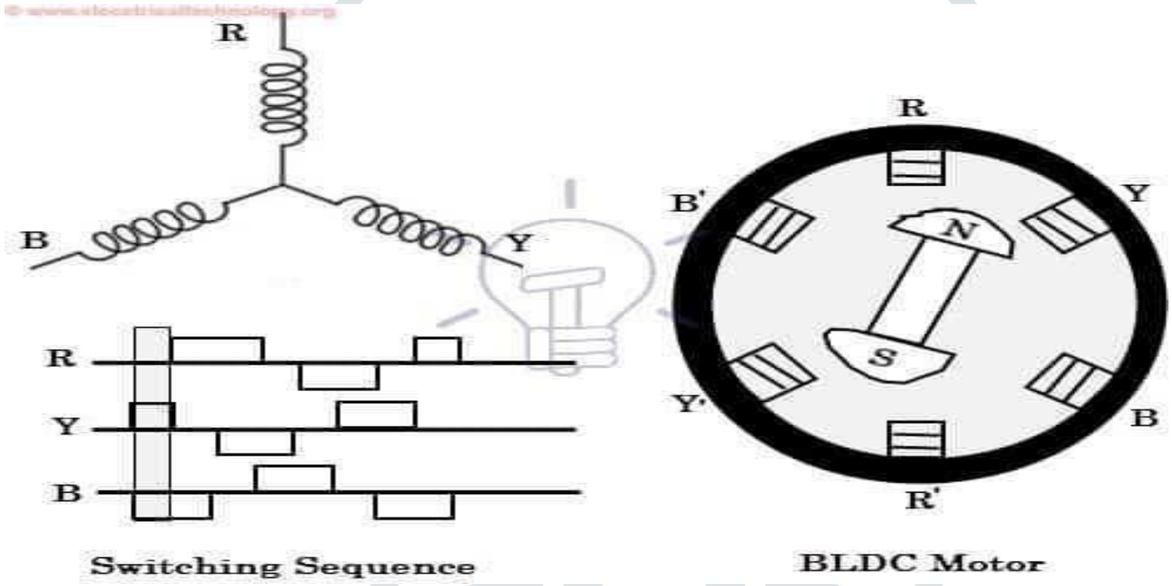


Figure 4.1 (b)switching frequency

Here, one might get a question that how we know which stator coil should be energized and when todo. This is because; the motor continuous rotation depends on the switching sequence around the coils. As discussed above that Hall sensors give shaft position feedback to the electronic controller unit.

Based on this signal from sensor, the controller decides particular coils to energize. Hall-effect sensors generate Low and High level signals whenever rotor poles pass near to it. These signals determine the position of the shaft.

Stator windings of a BLDC motor are connected to a control circuit (an integrated switching circuit). The control circuit energizes proper winding at proper time, in a pattern which rotates around the stator.

The rotor magnet tries to align with the energized electromagnet of the stator, and as soon as it aligns, the next electromagnet is energized. Thus the rotor keeps running.

Commutator helps in achieving unidirectional torque in a typical dc motor.

Obviously, commutator and brush arrangement is 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'.**

Brushless Vs. Brushed DC Motor

Brushes require frequent replacement due to mechanical wear, hence, a brushed DC motor requires periodic maintenance. Also, as brushes transfer current to the commutator, sparking occurs. Brushes limit the maximum speed and number of poles the armature can have. These all drawbacks are removed in a brushless DC motor. Electronic control circuit is required in a brushless DC motor for switching stator magnets to keep the motor running. This makes a BLDC motor potentially less rugged.

Benefits of BLDC motor over brushed motors

Benefits of BLDC motor over brushed motors are listed below,

- Increased efficiency
- Reliability
- longer lifetime
- No sparking and less noise
- more torque per weight etc.

Comparison of Various Motor Types

Feature	BLDC Motor	Brushed DC Motor	Actual Advantage
Commutation	Electronic commutation based on rotor position information	Mechanical brushes and commutator	Electronic switches replace themechanical devices
Efficiency	High	Moderate	Voltage drop on electronic device is smaller than that on brushes
Maintenance	Little/None	Periodic	No brushes/commutator maintenance.
Thermal performance	Better	Poor	Only the armature windings generate heat, which is the stator and is connectedto the outside case of the BLDC.
Output Power/ Frame Size (Ratio)	High	Moderate/Low	Modern permanent magnet and no rotorlosses.

Speed/Torque Characteristics	Flat	Moderately flat	No brush friction to reduce useful torque.
Dynamic Response	Fast	Slow	Lower rotor inertia because of permanentmagnets.
Speed Range	High	Low	No mechanical limitation imposed bybrushes or commutator
Electric Noise	Low	High	No arcs from brushes to generate noise,causing EMI problems.

Comparison between BLDC Motor and AC Induction Motor

Feature	BLDC motor	AC induction motor	Actual Advantage
Speed/Torque Characteristics	Flat	Nonlinear — lower torque atlower speeds	Permanent magnet design with rotor position feedback gives BLDC higher starting and low-speed torque
Output Power/ Frame Size (Ratio)	High	Moderate	Both stator and rotor have windings forinduction motor
Dynamic Response	Fast	Low	Lower rotor inertia because of permanentmagnet

MATLAB SIMULATION

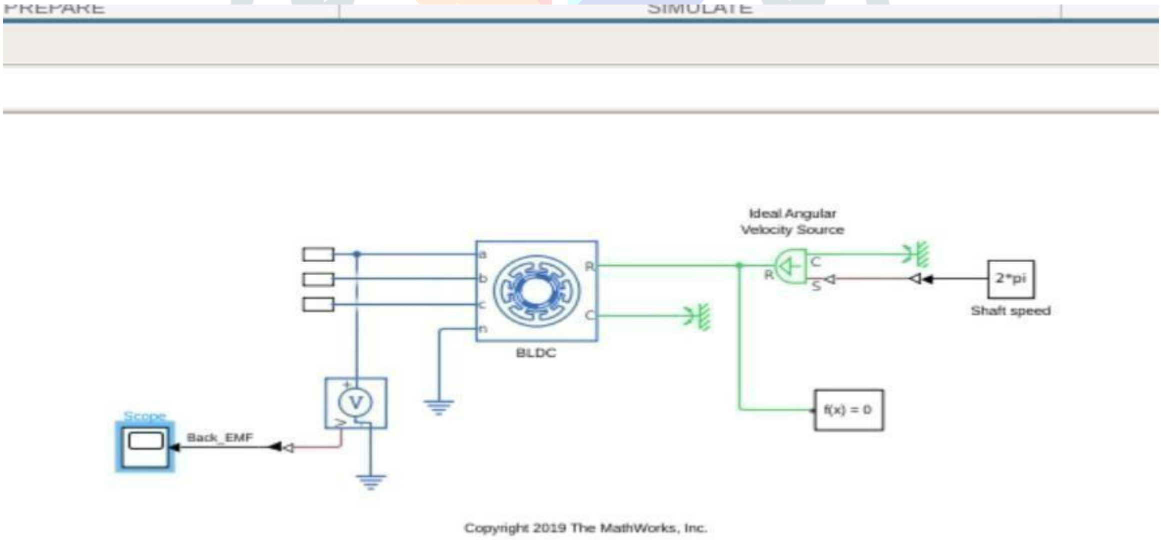


Figure 6.1(a) Bldc simulation

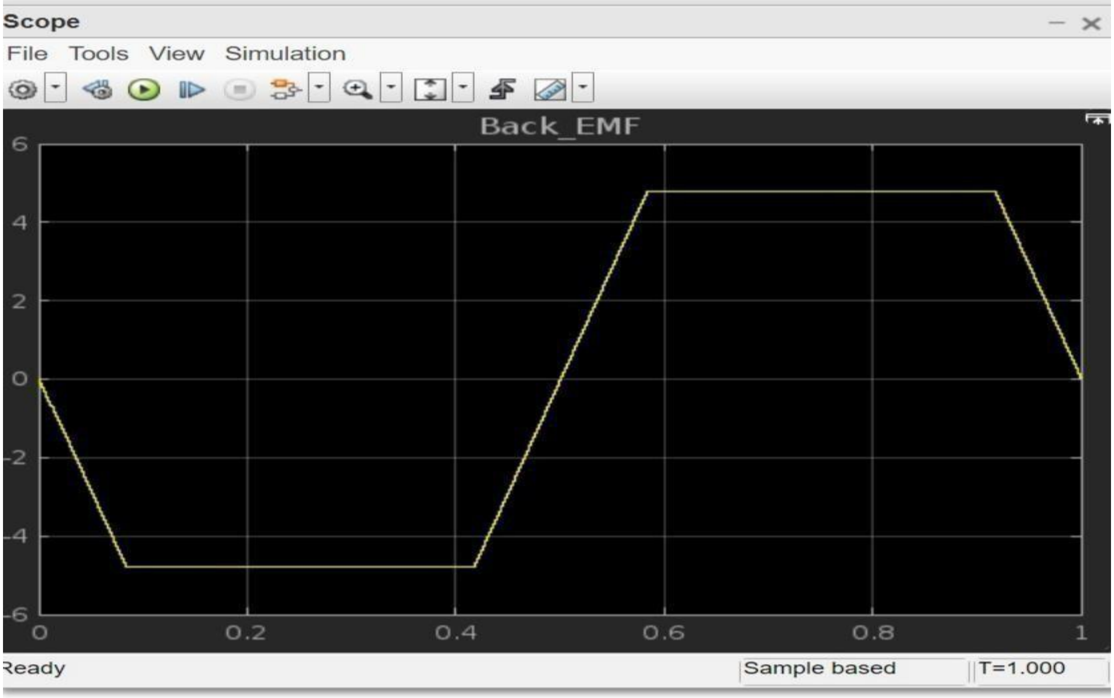


Figure 6.1 (b) sample output

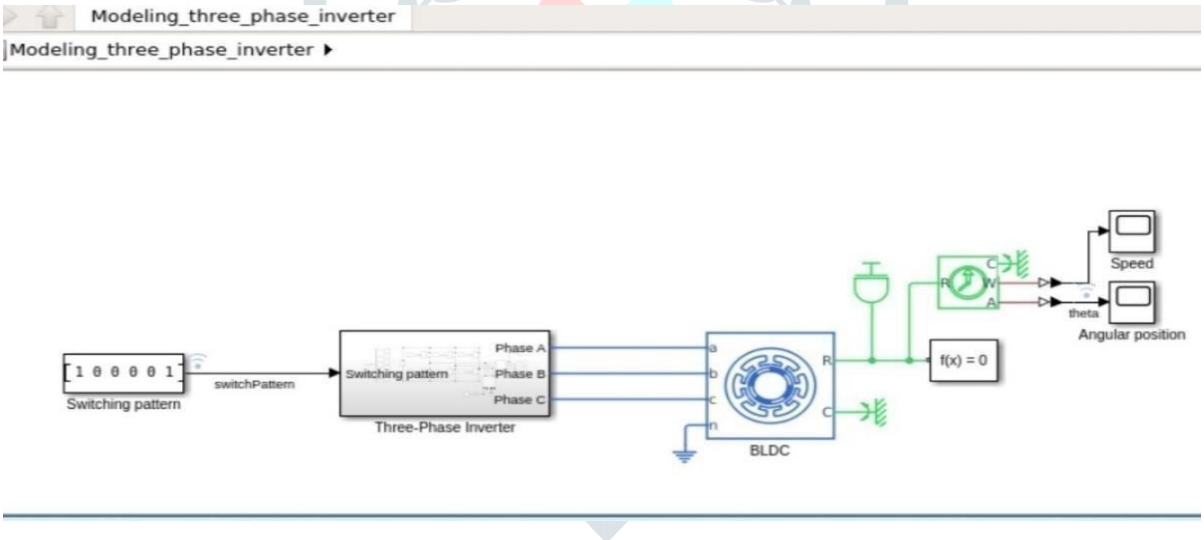


Figure 6.1(c) modeling three phase inverter

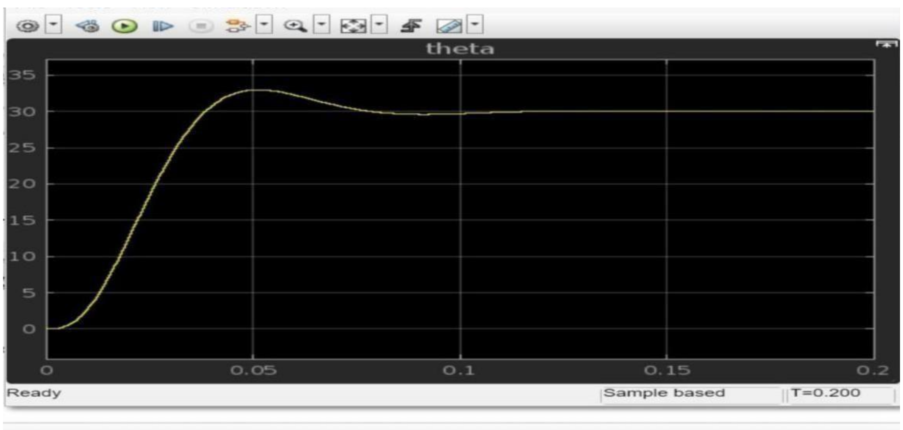


Figure 6.1 (d) sample output

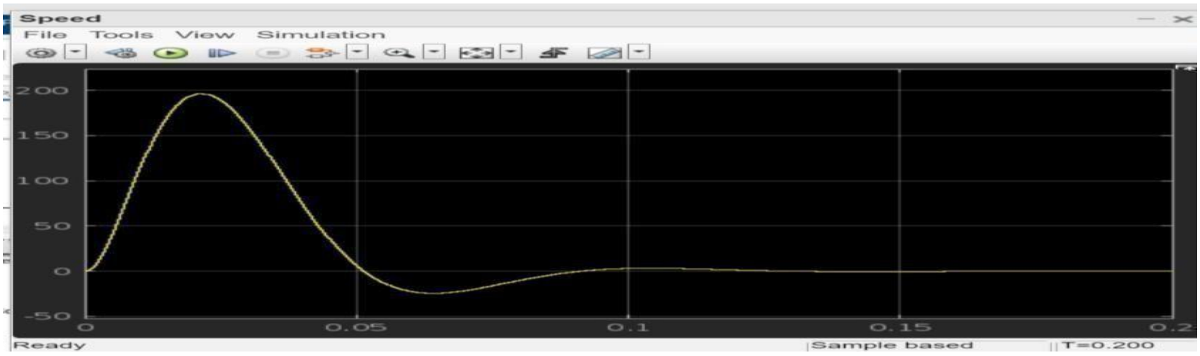


Figure 6.1 (e) sample output

7.1 Controller

Figure 7.1 (a) Controller

E-bicycle controller

The electric bike controller is one of the main parts of an electric bike, it is the brain of the e-bike, controlling the motor's speed, start, stop. It is connected to all the other electronic parts such as the battery, motor, and the throttle(accelerator), display(speedometer), PAS or other speed sensors if exist.

A controller is composed of main chips (microcontrollers) and peripheral components (resistors, sensors, MOSFET, etc). Generally, there are PWM generator circuit, AD circuit, power circuit, power device driver circuit, signal acquisition and processing circuit, over-current and under-voltage protection circuit inside the controller

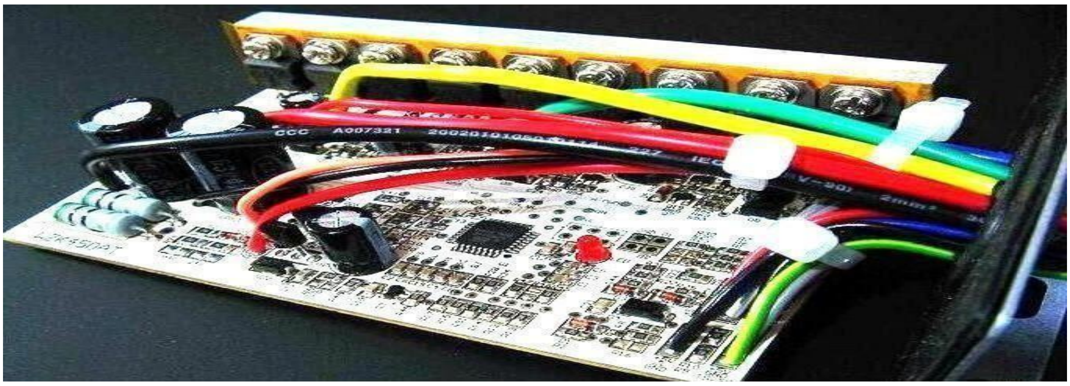


Figure 7.1 (b) micro chip board

7.2 Electric bicycle controller working

Figure 7.2 (a)

After connecting the battery, the controller supplies the working voltage to the external device through the power circuit, such as the switch +5V, headlight + 5V, etc.

The PWM outputs a corresponding pulse waveform to the MOSFET drive circuit based on the inputof the throttle or PAS. The MOSFET drive circuit controls the turn-on and turn-off of the MOSFET circuit to control the motor speed.

The under-voltage circuit is to protect the battery from discharging when the voltage is lower than the controller set value, at this time the PWM circuit stops the output.

The over-current protection circuit limits the working of the controller, battery, motor at an over higher current.

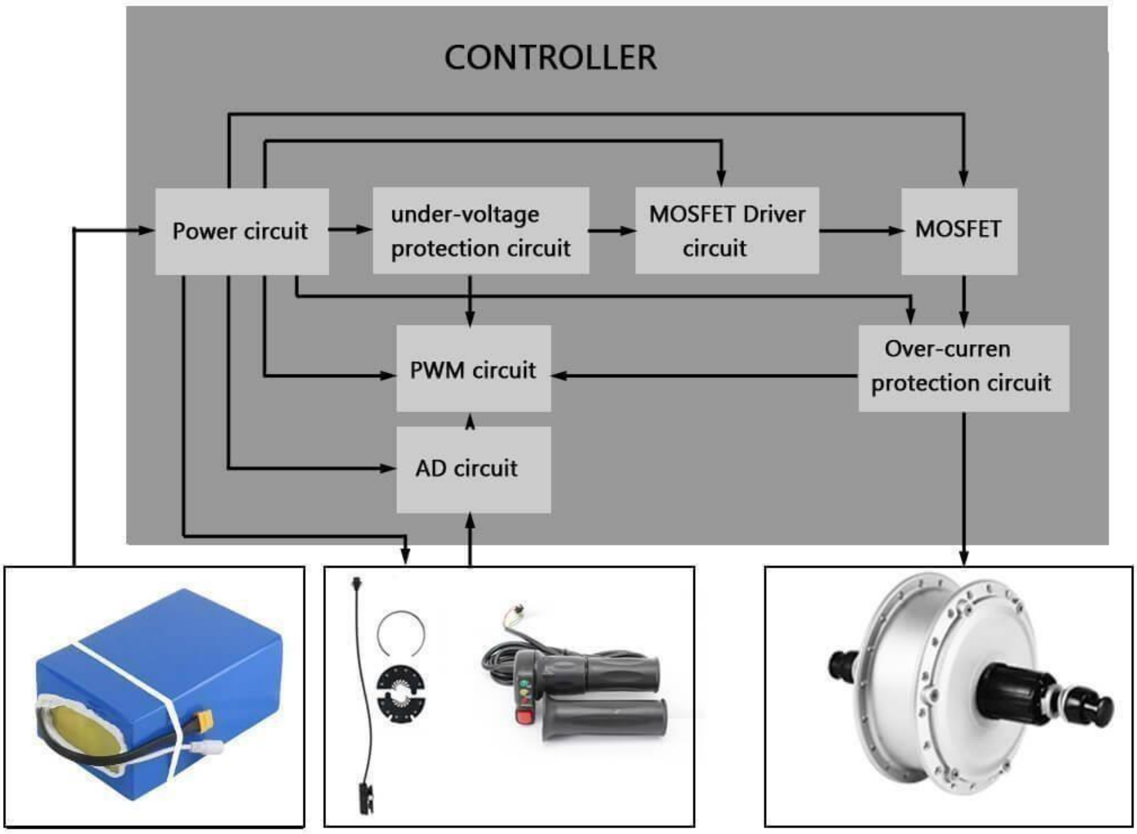


Figure 7.2 (b)EV bicycle controller

Functions of an electric bicycle controller

The core function of an electric bike controller is to take all the inputs from all the electric components (throttle, speed sensor, display, battery, motor, etc.) and then determine what should be signaled in return to them (motor, battery, display).

1) Over-voltage protection. The controller monitors the battery voltage and shut down the motor when the battery voltage is too high. This protects the battery from over-charge.

2) Low-voltage protection. The controller monitors the battery voltage and shut down the motor when the battery voltage is too low. This protects the battery from over-discharge.

3) Over-temperature protection. The controller monitors the temperature of the FET(field-effect transistor) and shut down the motor if they become too hot. This protects the FET power transistors.

4) Over-current protection. reduce the current to the motor if too much current is being supplied. this protects both the motor and the FET power transistors.

5) Brake protection. The motor shut down when braking even though other signals taken by the controller at the same time. For example, if the user applies brake and throttle at the same time, the brake function wins.

How to choose the electric bicycle controller

The controller should be chosen to fit the other parts- motor, battery, display, etc.

1. The controller driving type- is it a sine wave or square wave controller

Sine wave controller advantage:

(1) lower noise.

(2) Higher motor efficiency when climbing or with a heavy load.

(3) Sine Wave controllers have a much smoother and more predictable control of all the operation.

Sine wave controller disadvantage:

(1) Higher price.

(2) Works with the matched motors only.

(3) Higher power consumption.

Square wave controller advantage:

(1) Lower price

(2) Works with different motors

(3) Higher efficiency at sudden accelerate or brake

(4) Higher utilization of the power voltage

Square wave controller disadvantage:

(1) Bigger noise.

(2) The control is not linear, not smooth, and punched sometimes.

(3) Lower motor efficiency when climbing or with a heavy load.

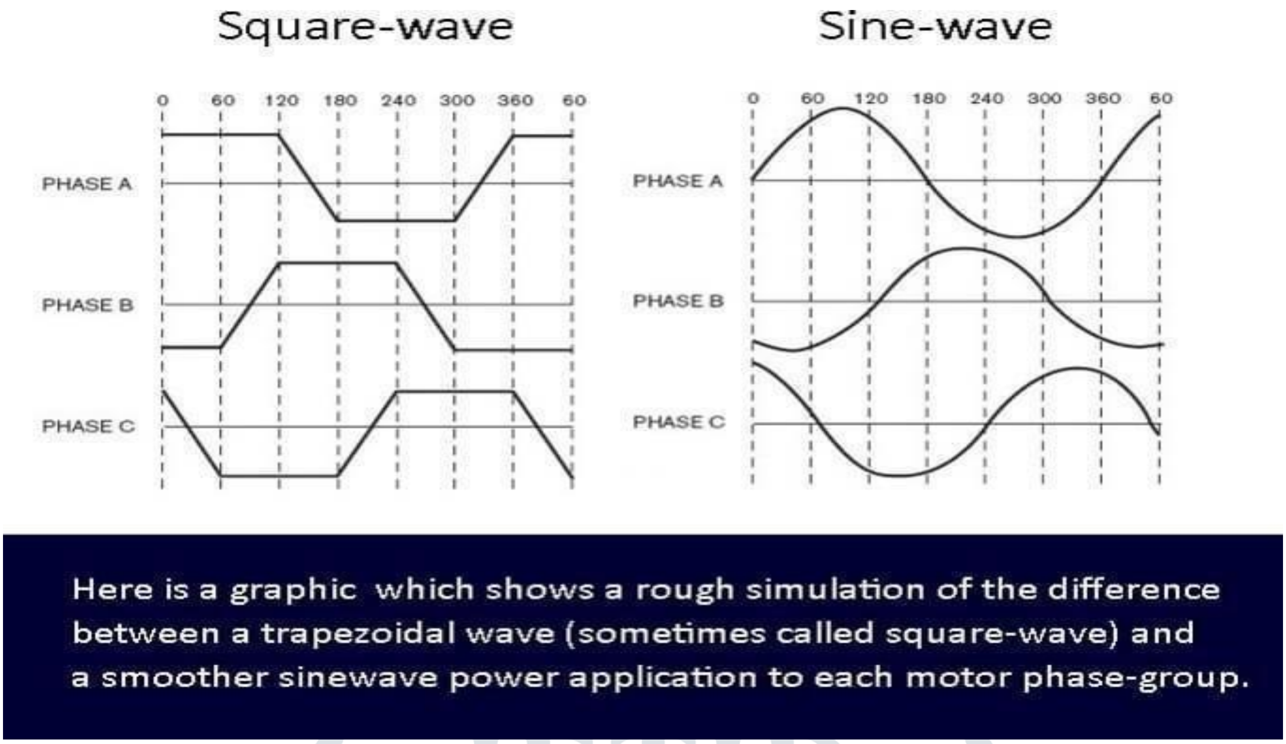


Figure 7.2 (c) square and sine wave

2.Is it a Hall sensor drive or non-Hall-sensor or dual mode controller

Generally, if a motor has hall sensors, the controller should be hall-sensor or dual mode. Hall sensorin the motor will sense the motor rotation, and the controller will output the corresponding voltage to the motor according to the sensor signals. It is more stable, with lower power consumption and bigger start torque. When the motor hall sensor damaged, the hall-sensor controller may prompt errorand stop work while a dual mode controller works well.

3. The controller Voltage- 24V or 36V or 48V or 60V or others

The controller voltage should match the voltage of the motor and the battery.

4. The controller current(rated current and max current)

The controller current should be smaller than the battery output current.

Generally, the max current is 18A for a 6-MOSFET controller, 25A for a 9-MOSFET controller, 35A for a 12- MOSFET controller, 40A for a 15- MOSFET controller, 50A for a 18- MOSFET controller

5. Controller functions

How to connect the electric bike controller

The wire types and wire terminal(connector) of the e-bike controller could be different in the different controller design. You need the electric bike controller wiring diagram to ensure the right wiring connections.

Most e-bike controller will have these wires motor, battery, brakes, throttle/ accelerator or PAS Pedal Assist System (some controllers have both types of wires, some have one of them).

Some more wires are found in the advanced controllers, such as Display or speedometer, Three speeds, Reverse, LED light, etc.

Here is one KT controller wiring diagram.

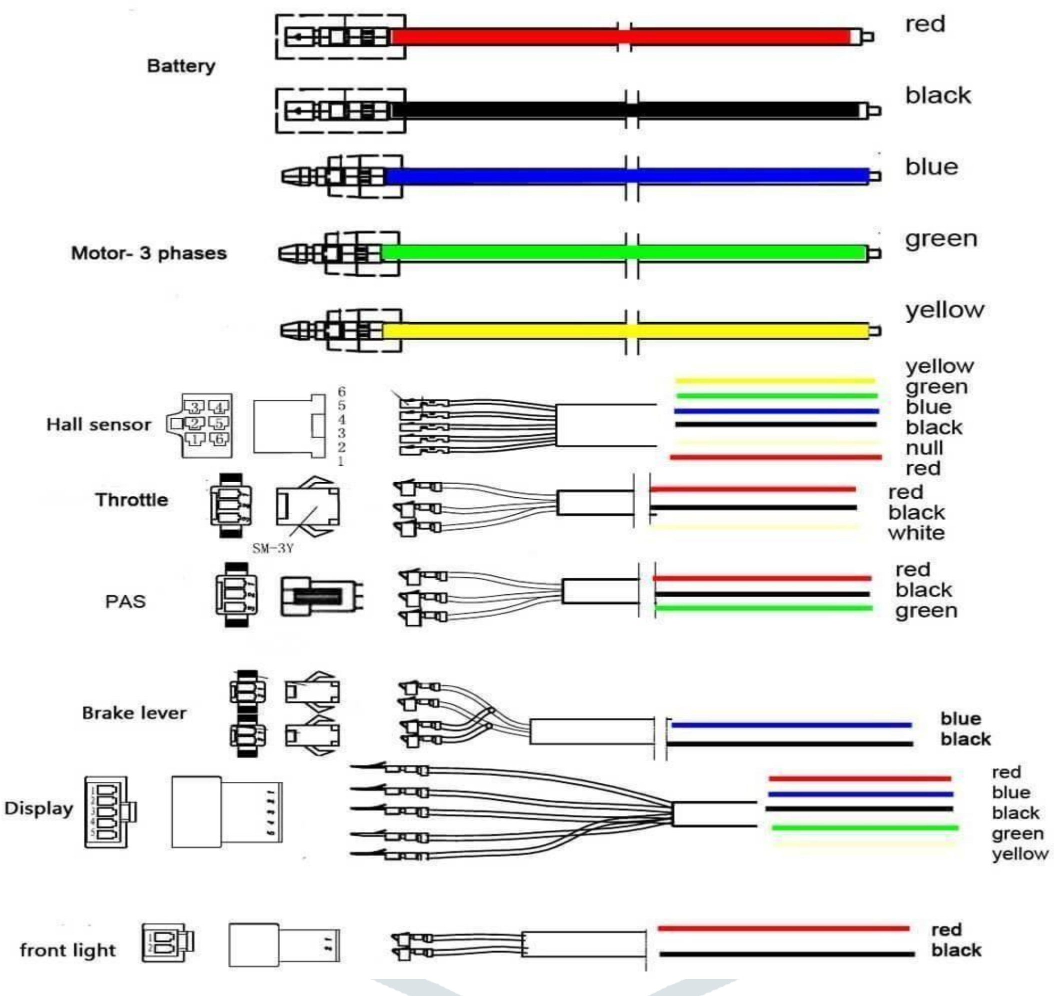


Figure 7.2 (d) controller wiring diagram

APPLICATIONS

Brushless DC motors are integral to many applications, especially those in the Medical Device, Industrial Automation, Aerospace and Defense, Security and Access, and other industries.

MEDICAL

BLDC motors are ideal for high speed surgical and dental hand tools, including small bone and large bone tools and dental tools such as drills. They are also very effective for respirators and ventilators, infusion and insulin pumps, dental imaging, and analyzers.

- High speed surgical hand tools

- Small bone surgical hand tools
- Large bone surgical hand tools
- Dental hand tools
- Respirators & ventilators
- Infusion & insulin pumps
- Dental imaging
- Analyzers
- Surgical robotics
- Bionics and Exoskeleton systems

INDUSTRIALAUTOMATION

Brushless DC motors are used in industrial nut runners and screwdrivers, air pumps, conveyors, and electronic assembly devices.

- Industrial nut runners
- Industrial screwdrivers
- Air pumps
- Conveyors
- Electronic assembly
- Electric grippers

AEROSPACE&DEFENSE

The longevity and reliability of BLDC motors make them a good choice for aircraft on-board instrumentation, gyroscopes, and satellites. They are also commonly used in valves, fuel metering systems and electric actuators.

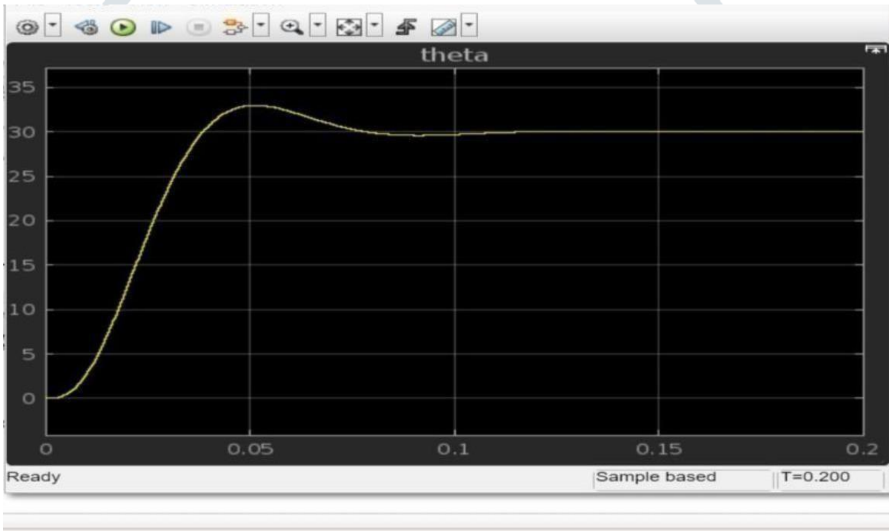
- Aircraft on board instrumentation
- Gyroscope
- Satellites
- Valves
- Fuel metering system
- Electric actuator
- Detection and service robots

FUTURE SCOPE

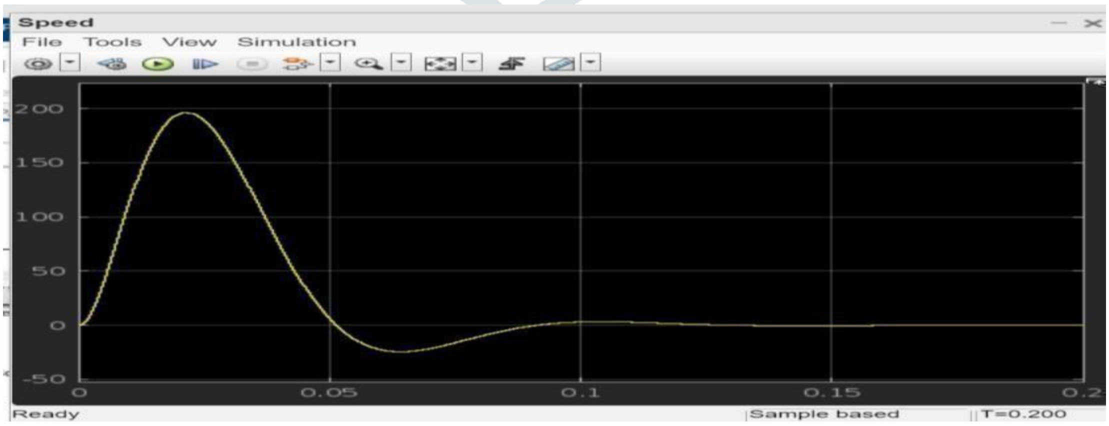
The future scope of electric vehicles is therefore enormous. We have already seen that technology for these vehicles is here and becoming far more advanced. We now know that such vehicles can provide us with great flexibility and we will soon see that potential. It will also be interesting to see the impact of regulations which will come into force .These regulations are set to reduce petrol enginevehicles use. As electric vehicles grow in popularity, so will the need to reduce their use. It is clear that there will be a need to develop new zero emission technologies.

RESULTS AND CONCLUSION

From MATLAB simulation we have obtain that



Sample output of three phase inverter Angular position



Sample output of three phase inverter speed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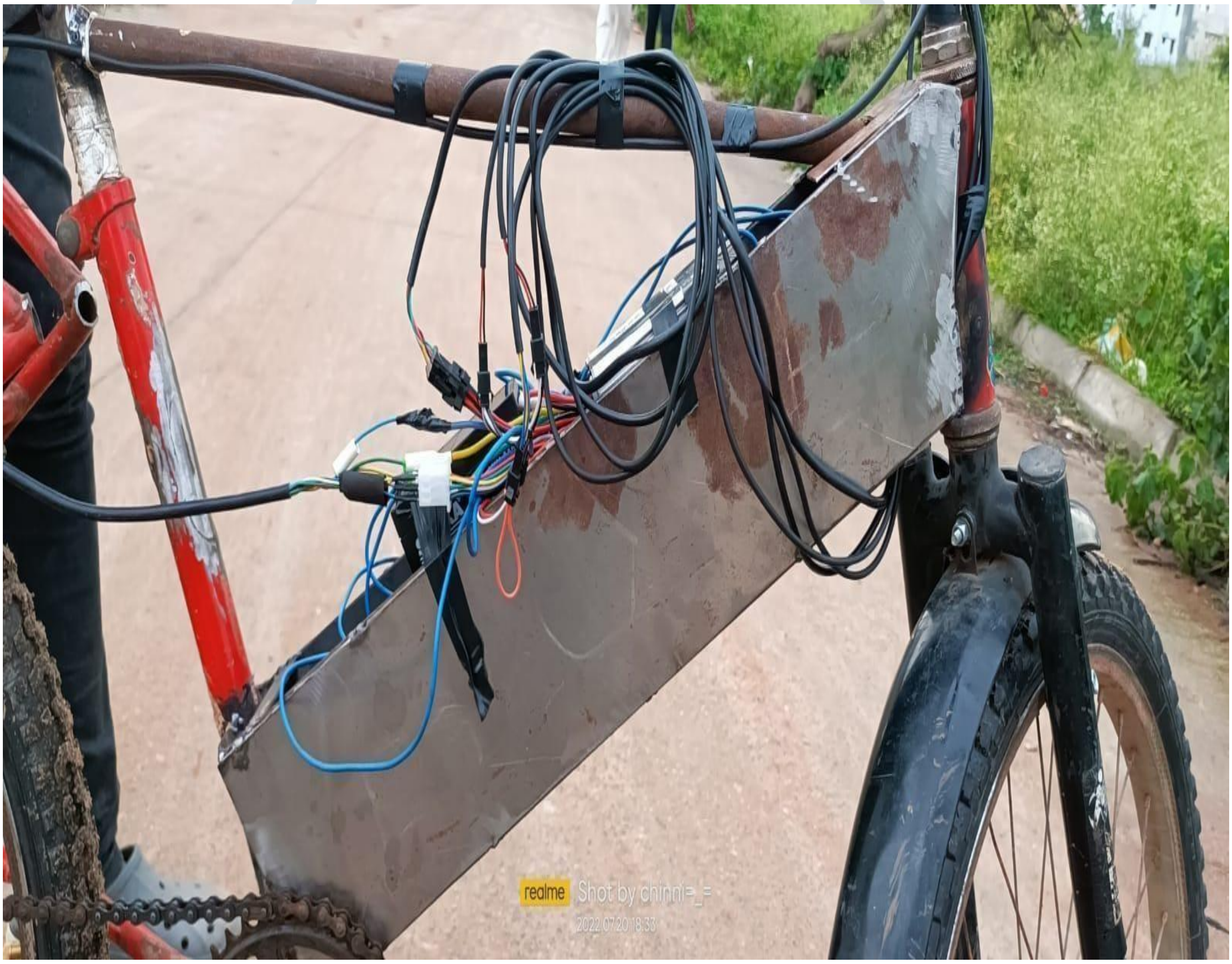
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