

**DESIGN AND FABRICATION OF ELECTRIC BIKE
WITH PMSM AND LITHIUM-ION PHOSPHATE BATTERY**

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in
Electrical and Electronics Engineering
by

B. TARUN (40140006)

ABHAY KAUSHAL (40140701)



**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

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JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

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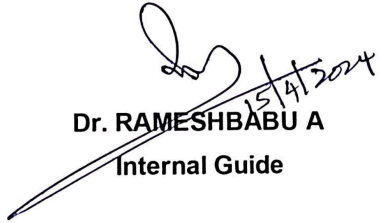
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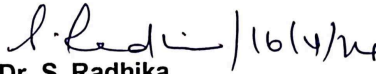
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **B. TARUN (40140006)** and **ABHAY KAUSHAL (40140701)** who carried out the project entitled "DESIGN AND FABRICATION OF ELECTRIC BIKE WITH PMSM AND LITHIUM-ION BATTERY" under our supervision from November 2023 to April 2024.


Dr. RAMESHBABU A

Internal Guide


Dr. S. Radhika

HEAD OF THE DEPARTMENT
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Jeppiaar Nagar, Rajiv Gandhi Salai,
Chennai - 600 119.

Submitted for Viva voce Examination held on

17.04.24


Internal Examiner

W A Abitha Menon


External Examiner

(Dr. S. Lakshminarayanan)

DECLARATION

We **B. TARUN (40140006)** and **ABHAY KAUSHAL (40140701)** hereby declare that the Project Report entitled "**DESIGN AND FABRICATION OF ELECTRIC BIKE WITH PMSM AND LITHIUM-ION PHOSPHATE BATTERY**" done by us under the guidance of **Dr. RAMESHBABU A** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronic Engineering.

DATE: 17/04/2024

PLACE: CHENNAI

1 

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SIGNATURE OF THE CANDIDATE

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Abstract

Electric vehicle is Nowadays replacing it Conventional vehicle such that greenhouse gases can be reduced there by the effects of green house gases like Global warming, melting of ice, Air pollution etc will be reduced drastically. In an attempt to contribute to the above factors, in this project we have developed a E-Bike by replacing the conventional bike-HERO HONDA Splendour bike with Motor and Battery. A PMSM (Permanent Magnet Synchronous Motor) of 750 watts was used. The PMSM was powered by 48V, 30Ah, Lithium Ion Battery. The PMSM motor power's the wheels of the bike by Mechanical chain drive system. The developed E-Bike was tested and it is found that E-Bike can drive 40 Kms in a single charge. The time taken for full charging is 5Hrs, the battery takes nearly 120 minutes to discharging. The E-Bike was tested in different load conditions like High way, Rural roads and found that the speed of the vehicle did not reduce with respect to conventional vehicle and the performance is satisfactory.

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CHAPTER I

INTRODUCTION

1.1 GENERAL INTRODUCTION

Now a days, the Automobile markets are increasing rapidly, so the electric vehicles becoming with better improvements, Government also planning to bring the electric vehicles industries in India, to reduce the dependency on import energy sources, and reduce greenhouse gas emissions and mitigate adverse impacts of transportation including global warming. The main advantages of E-bike are their significantly reduced environmental impact compared to conventional gasoline-powered motorbikes. Additionally ,E-bike offer operating costs due to their energy efficient nature and reduced reliance on fossil fuels and the electricity is generally cheaper than gasoline , resulting in lower fuel expenses for E-bike .And no need for regular oil changes ,contributes to lower maintenance and servicing costs .

The E-bike can offer quick acceleration with high torque Manufactures in worldwide are actively addressing these challenges by investing in charging networks, and improving battery technology. E-bike utilize advanced battery technology, typically lithium – ion batteries, to store and deliver power source to the motor moreover continuous innovations in better technology are increasing the range and reducing charging times of the E-bike.

In conclusion, E- bike rapidly evolving segment of the transportation industry, and their environmental benefits with cost savings, E-bike significant role in the future of sustainable and efficient personal mobility.

1.2 CLASSIFICATION OF ELECTRIC BIKE

E-Bike technology has evolved significantly, with focus on improving efficiency and user experience. PMSM motors have emerged as a promising choice due to their high efficiency, torque characteristics, and regenerative braking capabilities. LiFePO₄ batteries, known for safety and durability, have become a

preferred energy storage option. The E-Bike is a bike which is driven with the help of battery which is coupled to electric motor.

TYPES OF MOTORS USED IN E-BIKE

- **Brushless DC (BLDC) motor:** BLDC motors convert a large portion of electrical energy into mechanical energy, resulting in longer range and less energy consumption.
- **Permanent Magnet Synchronous Motor (PMSM):** Compared to BLDC motors, PMSM's can achieve even greater efficiency, leading to potentially longer range and reduced energy consumption.
- **AC Induction motor:** While less common in electric -bike due to their lower efficiency compared to BLDC and PMSM motor.

1.3 ADVANTAGES OF E-BIKE:

- An E-bike is an environmentally friendly. It is the same as our regular Bike. It is powered by electricity rather than gasoline. No harmful emissions are emitted into the atmosphere. For the same reason, electric bikes don't produce any additional noise.
- E-bike, in general do not require any maintenance. Lubricate the drive system and inspect the chain and wheels on a regular basis to keep it clean.
- Riding an E-bike is fashionable and popular right now. It is also the most efficient approach to cut down on pollution.

1.4 AIM OF THE PROJECT

- The aim of an E-bike is to provide a sustainable and eco-friendly mode of transportation.
- E-bike aim to reduce dependence on fossil fuels, decrease air pollution, and promote a health their lifestyle.
- They offer an alternative to traditional bikes and cars, making commuting easier and more efficient.

1.5 SCOPE OF THE PROJECT

- The scope of E-bike, can vary depending on the specific goals and objectives.
- It can include aspects such as designing and manufacturing E-bikes, conducting research on battery technology and efficiency, exploring market demand and consumer preferences, and developing sustainable infrastructure for E-bike usage.
- The project can also involve analysing the environmental impact and cost-effectiveness of E-bike compared to traditional modes of Transportation.

1.6 OBJECTIVE

- To Replace conventional Hero Honda splendour bike as E-Bike.
- To select a suitable motor that can drive Hero Honda splendour bike.
- To select a suitable lithium-ion battery to power the motor.
- To select a suitable controller for the motor.

1.7 LITERATURE SURVEY

The constant news concerning the demise of fossil fuels, according to Adithya Kumar at AL (2016), has enhanced the importance of using electricity in the future. E-Bike will be used more frequently. The E-Bike will be beneficial to office workers and those who ride short distances. The E-Bike has a motor that assists the vehicle in moving ahead, and it is powered by a variety of sources. The batteries power the motor, which in turn drives the vehicle. Once the battery has been exhausted, it is recharged using a battery charger.

When one of the batteries runs out, remaining batteries will step in to fill the void. During this period, the wheel revolves, rotating the shaft of the dc motor, which produces a voltage output. The voltage aids in the charging of the battery, improving the E-Bike range. It is environmentally friendly and pollution-free because it produces no emissions. Furthermore, it is silent and can be recharged using an AC converter in the event of an emergency or gloomy weather. It is ideal for young elderly individuals, and it meets the needs of the economically disadvantaged. The most important feature of this E-Bike is that it does not consume valuable fossil fuels thereby saving the money.

Annette Muetze, et. Al.,(2008) suggests that more emphasis should be devoted to the deregulation of E-Bike. A common standard/guideline for E-Bike designers/manufacturers will simulate growing popularity while also guaranteeing E-bike that are most efficient in a given operating cycle, such as city, hill, and distance. It might assist to offset the additional cost and weight of larger components. More study into battery and drive technologies, as well as their use with electric E-bike, be an advantage. Maturity of E-Bikes has increased in this regard. Even if the technological maturity of E-Bikes has increased and continues to improve, more effort is needed to make them competitive with other vehicles.

Carlos Tovar, et.al.,(2009) proposes that cities are living each day with an accumulation of excessive traffic and noise. The air quality and health are two more components of city traffic that are badly damaged. Many air contaminants, like carbon monoxide and suspended particles, are primarily caused by transportation. It is a fantastic car that is both speedy and efficient while still being environmentally friendly. It is possible to enjoy a leisurely and enjoyable cruise while also arriving at locations using this vehicle. An E-Bike costs the same as a regular bike. This means that when you buy this vehicle, you have all of the features of a standard bike plus the added power of battery, which allows you to go faster and for longer than you could on your own. The E-bike's electricity is designed to help the rider maintain a steady, safe speed on or off the road. Furthermore, law considers these vehicles to be equivalent to a standard bike. That is to say, the user does not need a licence to ride an E-Bike.

Ravina More, et. Al.,(2011) proposes different models of calorie measurement need to be reviewed and tested to find which one is the most suitable to be adopted for range of bikes . For more information, to reduce the number of calibrations required for each particular cycles, researchers can look into developing a single model that fits all bikes incentive-based ways for E-Bikes can be tested, such as switching the bike from manual to electric mode once the calorie's burned goal has been met. It is necessary to consider a circuit that can accomplish the same. The anti-theft system is reliant. The features will be implemented using the bike's existing power supply. The end product will be cushioned, waterproof, and temperature insensitive for a specific temperature range to protect it from harsh environmental elements, A result, the project attempts to establish the bike, an attempt will be made to model a similar design

1.8 Existing System

As we are comparing with Ampere Reo Electric bike. In this survey we taking the specifications of Ampere reo electric bike. This bike provides Range up to 55km/per charge with top speed 25km/hr and it will take charging time up to 8 to 10 hours. And it is using Lead acid battery as a power source with 48 kWh And with hub motor 1200w with 16Nm @420 rpm.

In our project, we are taking hero splendour bike and converting into electric by replacing the engine of bike. Here are using the lithium-ion battery with 48volts and 30 ampere Compare to lead acid battery it has Improved Energy Density, Enhanced Fast Charging. Extended Cycle Life.

And we are using the mid drive motor instead of BLDC, hub motor. PMSM means permanent magnet synchronous motor. It has High Energy Conversion Efficiency typically ranging from 85% to 98% and. It will Reduced Energy Consumption. It has Lower Operating Costs, Compare to the BLDC motor.

1.9 Proposed System

This electric bike gives range up to 40km per charge Top speed of this bike is 40km/hr Within 5hours it will charge the full battery pack. We are providing the safety innovations in this bike PMSM will give more torque than the BLDC hub motor.

CHAPTER 2

DESIGN OF ELECTRIC BIKE

2.1 BLOCK DIAGRAM

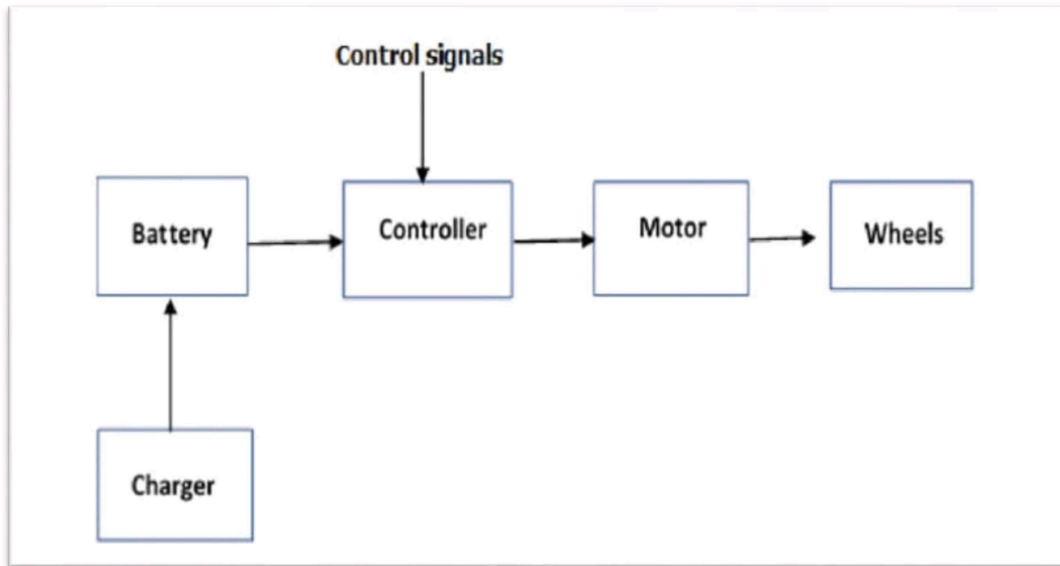


Fig.2.1 Block Diagram

2.1.1 The main components of an e-bike are given below

- Motor
- Battery
- Controller, and Throttle.
- The motor is usually mounted on the frame of the bike and is powered by the battery.
- The controller regulates the amount of power that is sent to the motor, and the throttle allows the rider to control the speed of the bike.
- Other components may include a display screen, brakes, and gears.

- **ELECTRIC MOTOR:** Which converts Electrical energy from the battery into Mechanical power to drive the wheels.
- **BATTERY PACK:** The battery pack is where the electrical motor-bike store Electrical energy.
- **CONTROLLER:** The controller is an electronic unit that manages the power flow between the battery and the electric motor.

2.2 DESIGN OF ELECTRIC BIKE

Here the current from battery moves to controller where all the connections are made. When the power is given to motor, it rotates the wheel using chain and sprocket as shown in the Fig No 2.2 given below.

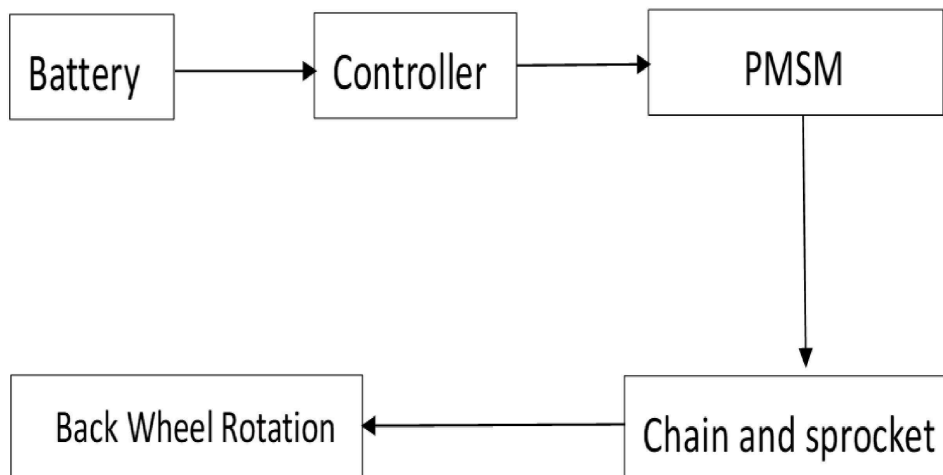


Fig.2.2 Block diagram of E-Bike

2.3 HOW TO TURN ON E-BIKE

Insert the key and key and turn on the ignition. Long press the power button in the instrument console, then the power supply will be active.

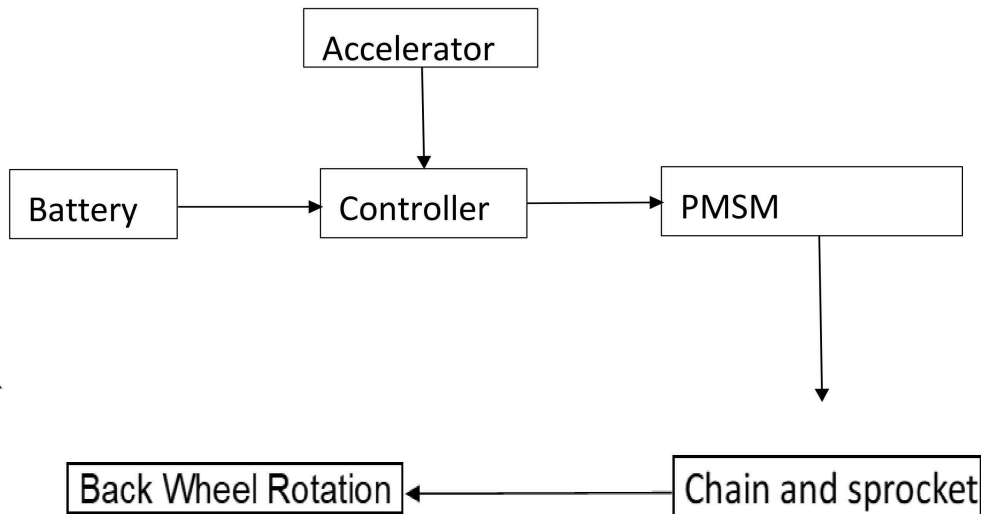


Fig.2.3 Block diagram of converting E-Bike

When we rotate the accelerator to our desired amount, the controller takes the input and give the limited power to the motor and runs accordingly shown in Fig No 2.3 given below.

2. 4 WORKING OF INSTRUMENT CLUSTER

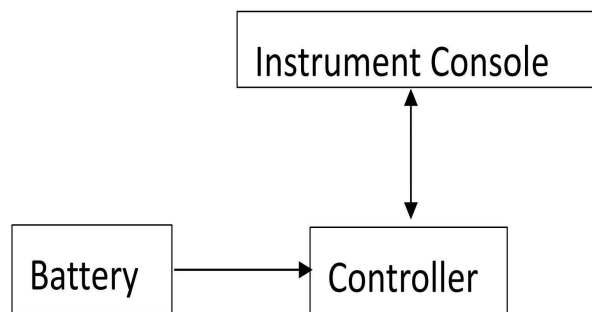


Fig.2.4 Block diagram for instrument cluster

The instrument console displays speed, battery level, odometer. It has three buttons (power button, motor power up button and motor power down button). Power button has two function, long press- for turning on ignition. Short press-for toggling between voltage level, trip meter and odometer as shown in the Fig No 2.4 given below .

2.5 WORKING OF LIGHT AND HORN

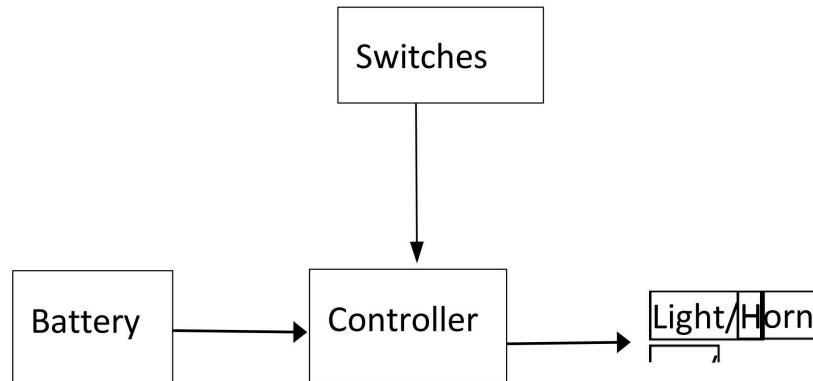


Fig.2.5 Block diagram for lights and horn

There are two switches in handle bar one is for light and another is for horn. when the switches are pressed the controller reads it and sends the output to light/horn as shown in Fig No 2.5 given below.

2.6 DESIGN CALCULATIONS

2.6.1 Mass Range Calculations

Person Weight = 150kg

Battery Pack = 8kg

Motor & controller = 12kg

Bike weight = 80KG

TOTAL = 250KG

So, Battery and Motor are required to propel the bike with the weight of **250kg**.

2.6.2 Motor Load calculation

F_p = Propulsion Force

F_{wf} = Windage & Friction Drag

F_d = Down force from Gravity

Consider the Grad @3.14%

$$\begin{aligned}\alpha &= \tan^{-1}(\text{slope}) \\ &= \tan^{-1}(3.14/100) \\ &= \tan^{-1}(0.0314) \\ \alpha &= 1.8 \text{ degree}\end{aligned}$$

2.6.3 To Finding F_d (Gradient Resistance)

$$\begin{aligned}F_d &= m * a * \sin \alpha \\ &= 250 * 9.81 * \sin 1.8 \\ &= 77.03 \text{ N}\end{aligned}$$

2.6.4 To Finding F_{wf} (Aero Resistance)

C_d => Aerodynamic Area Co-efficient = 0.74

ρ = Density = 1.225kg/m³

A = Frontal Area of Bicycle = 0.37 m²

V = Velocity of Bicycle = 25 km/h=> 6.94m/s

$$\begin{aligned}F_{wf} &= \frac{1}{2} (\rho * v^2 * C_d * A) \\ &= \frac{1}{2} * 1.23 * (6.94)^2 * 0.88 * 0.57 \\ F_{wf} &= 14.85 \text{ N}\end{aligned}$$

2.6.5 To Finding F_r (Rolling Resistance)

C_R = Rolling CO-efficient => 0.004(for bike)

$$\begin{aligned}F_R &= C_R * mg * \cos \alpha \\ &= 0.004 * 250 * 9.81 * \cos 1.8 \\ &= 9.80 \text{ N}\end{aligned}$$

2.6.6 Total Propulsion Force, F_p

$$\begin{aligned}F_p &= F_d + F_{WF} + F_R \\&= 77.03 + 14.85 + 9.80 \\&= 101.68 \text{ N}\end{aligned}$$

$$\begin{aligned}\text{Propulsion Power} &= F_p * \text{Velocity} \\&= 101.68 \text{ N} * 6.94 \text{ m/s} \\&= 705.65 \text{ W}\end{aligned}$$

Thus, The Motor is to be **75**

2.7 DESIGN OF BATTERY PACKS

$$\text{Voltage}(V) = 48\text{volts}$$

$$\text{Current}(I) = 30\text{amps}$$

$$\text{Power}(W) = 1440\text{watts}$$

$$V = \text{Battery voltage (complete pack)}$$

$$V = 48\text{v}/3.2\text{v}$$

$$V = 15S$$

$$I = \text{Battery current /cell current}$$

$$I = 30/6$$

$$I = 5P$$

$$\text{Total cells} = S * P$$

$$\text{Total cells} = 75$$

$$\text{Cell} = 6 \text{ amp}$$

$$I = 5 \text{ p}$$

$$\text{Total amp} = 5 * 6$$

$$= 30 \text{ amps}$$

BMS required for $S = 15s$, $V = 48\text{v}$, $I = 30\text{amps}$

2.8 SELECTION OF BATTERY PACK:

How many series? How many parallel?

Single cell has = 3.2v Normal Voltage
 = 6Ah capacity

5 cells in Parallel = 5 *6Ah
 = 30Ah

15 cell group in series = 15*3.2v
 = 48v

15S, 5P configuration will be 48v, 30Ah.

CHAPTER 3

SELECTION OF COMPONENTS

3.1 Introduction of PMSM Motor

Introducing the Permanent Magnet Synchronous Motor (PMSM) in electric bikes brings several advantages. PMSM motors offer higher power density, improved efficiency, and smoother operation compared to other motor types. With their compact size and high torque capabilities, PMSM motors enhance the overall performance and range of electric bikes. This technology contributes to more enjoyable and efficient riding experience.

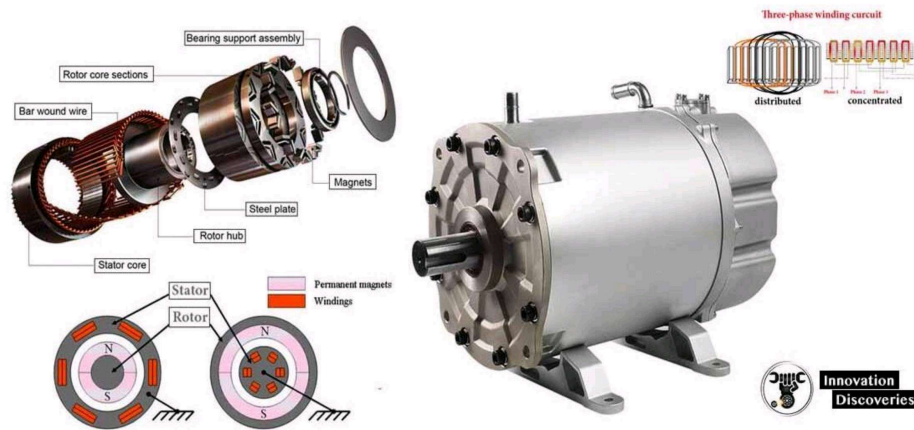


Fig.3.1 PMSM construction

3.1.1 Highlights of PMSM Motor are given below

- 48VDC,750W (OUTPUT) ,3000RPM OF PMSM
- In -runner with shaft output and keyway
- External Control
- Built in Hall Sensor with Hall Effect Angle of 120degrees
- Operating temperature up to +80c

3.2 BATTERY

Battery is the heart of the electric bike. It supplies the energy to motor. Battery acts as a condenser by storing the electric energy produced by generator due to electrochemical transformation and supplying it on demand. It is also known as accumulator of electric charge. This generally occurs while starting the system. It can deliver high electrical current for starting an engine. Lead-acid, Nickel-Cadmium, Nickel Metal Hybrid and Lithium-ion batteries are currently used for electric bike. For electric bike, 2-3 battery are used and connected in series to produce larger input supply to motor which is equal to 24-36V and it can be extended depends upon the rating of motor. Batteries used for electric bike.

Compared to other high-quality rechargeable battery technologies, Li-ion batteries provide a number of benefits (nickel-cadmium or nickel-metal hydride). They have one of the highest energy densities of any battery technology available today (100-265 Wh/kg or 250-670 Wh/L). Li-ion battery cells can also deliver 3.6 volts, which is three times higher than Ni-Cd or Ni-MH technology. This means they can supply a lot of current for high-power applications, which is a good thing. Li-ion batteries are also low-maintenance, as they don't need to be cycled on a regular basis to keep their life. Li-ion batteries have no memory effect, which is a harmful phenomenon in which a battery can remember a decreased capacity after repeated partial discharge/charge cycles. This is an advantage over Ni-Cd and Ni-MH batteries, which also exhibit this behaviour. In addition, Li-ion batteries have a low self-discharge rate of 1.5-2 percent each month. They don't contain the hazardous cadmium found in Ni-Cd batteries, making them easier to dispose of.

Li-ion batteries have supplanted Ni-Cd batteries as the market leader in portable electronic gadgets as a result of these benefits (such as smartphones and laptops). Lithium-ion batteries are also utilised to power electrical equipment in some aerospace applications, such as the new and more ecologically friendly Boeing 787, where weight is a major cost consideration. Much of the promise of Li-ion technology in terms of renewable energy derives from its prospective uses in battery-powered cars. The Nissan Leaf and the Tesla Model S, which are now the most popular electric automobiles, both employ Li-ion batteries as their primary fuel source.

Li-ion batteries, while their technological potential, have a number of flaws, particularly in terms of safety. Li-ion batteries have a proclivity for overheating and are susceptible to damage at high voltages. This can result in thermal runaway and combustion in some situations. This has resulted in severe issues, including the grounding of the Boeing 787 aircraft following reports of onboard battery fires. A number of shipping companies refuse to send batteries in bulk by plane due to the risks connected with these batteries. Safety systems for lithium-ion batteries are required to regulate voltage and internal pressures, which can increase weight and performance in some circumstances.

3.2.1 LiFePO₄:

Lithium-Ion Phosphate (LiFePO₄) batteries offer several advantages for electric bikes (e-bikes) that make them a popular choice among riders and manufacturers. Here are some key advantages, including high energy density, long cycle life, and safety features, specific to LiFePO₄ batteries for e-bikes.

3.2.2 SIGNIFICANCE OF LiFePO₄ BATTERIES IN E-BIKE TECHNOLOGY:

- **Safety:** LiFePO₄ batteries are known for their excellent thermal stability and safety features. They are less prone to overheating and thermal runaway, reducing the risk of fire or explosion
- **Long Cycle Life:** LiFePO₄ batteries offer a longer cycle life compared to some other lithium-ion battery chemistries. They can withstand a higher number of charge and discharge cycles.
- **High Energy Density:** LiFePO₄ batteries have a relatively high energy density, allowing them to store a significant amount of energy in a compact space.
- **Fast Charging Capability:** LiFePO₄ batteries can support fast charging, reducing the time it takes to charge an E-Bike.

3.2.3 INTEGRATION OF PMSM AND LiFePO4 BATTERIES IN E-BIKE:

- **Performance and Efficiency:** Several studies have shown that e-bikes equipped with PMSM motors exhibit superior performance in terms of acceleration and hill-climbing ability compared to other motor types. LiFePO4 batteries contribute to longer riding ranges and reduced charging times, enhancing overall e-bike efficiency.
- **Safety and Durability:** The safety of e-bikes with LiFePO4 batteries is well-documented. Their stable chemistry and resistance to thermal runaway reduce the risk of accidents and fires. PMSM motors have also demonstrated reliability and durability in various e-bike applications.
- **Environmental Impact:** E-bikes powered by LiFePO4 batteries contribute to reducing greenhouse gas emissions and air pollution in urban areas, aligning with sustainable transportation goals as shown in Fig No 3.2 is given below.



Fig.3.2 LiFePO4 Battery

3.3 BATTERY PACK COMPONENTS

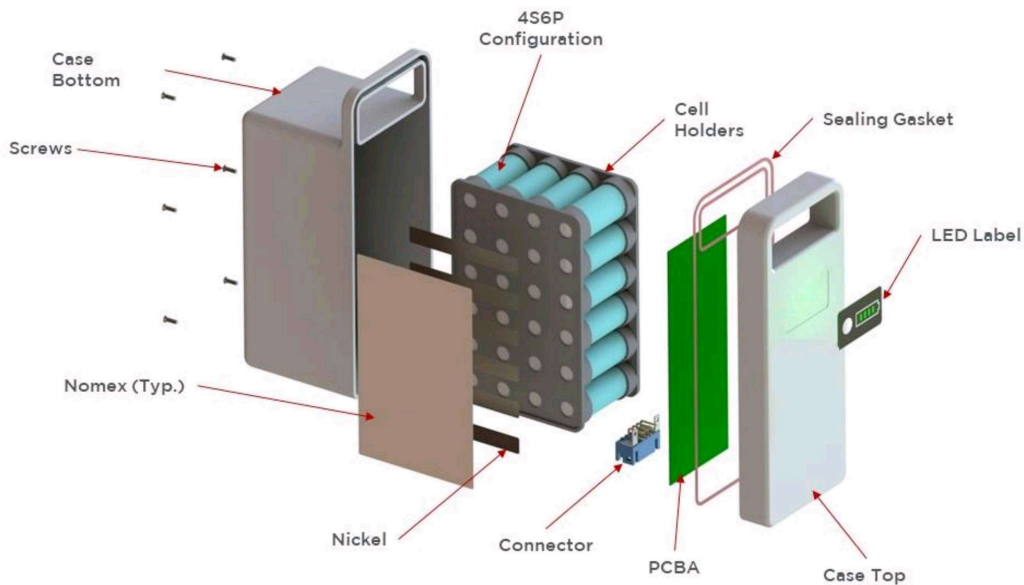


Fig.3.3 Battery pack components

- **WELDING :-** Welding is process of joining two or more pieces of metal together by melting the materials at the joint and allowing them to cool, thus creating a strong bond as shown in Fig No 3.3 is given below.
- **SPOT WELDING :-** Resistance spot welding is aslo known as spot welding
Spot welding is the proces od joining metals by applying pressure and passing low voltage,high current for a length of time through the metal area were the heat required for the welding is generated by the resistance to the flow of the current through the electrode as shown in Fig No 3.3.1is given below.



Fig.3.4 Spot welding

3.4 BMS

The battery management system is in place to keep track of each battery cell's specific performance. Rather of allowing for individual performance, the BMS assures that each battery cell drains, performs, and acts in the same way as every other cell in the battery.

If you have uniform cell performance, which is otherwise impossible, you will have consistent performance and full operation of your motor. The BMS also extends the life of your battery. Individual cells without a BMS can overcharge and explode, or they can drain too far and become un-rechargeable, hastening their overall deterioration. A defective BMS in your battery is the cause of failure if your E-Bike battery explores or fails out much sooner than the manufacturer claims. In fact, a defective BMS is one of the most prevalent causes of your E-Bike poor performance.

3.4.1 Tips to Manage Your BMS System are given below

- Don't charge your battery with a charger that isn't rated for it.
- Never leave your battery in a hot, cold, or wet environment.
- After Long Periods of Inactivity, Refresh the BMS System.



Fig3.5 BMS

3.5 CHARGER

- **Voltage Output: 54.6V** - This is the output voltage provided by the charger. It should match the voltage requirements of the electric vehicle's battery.
- **Current Output: 6A** - This indicates the maximum current (in amperes) that the charger can deliver to the electric vehicle's battery. It's important to ensure that the charging current is suitable for the vehicle's battery specifications.
- **Power Output:** The power output can be calculated by multiplying the voltage and current values.

In this case, it would be $54.6V \times 6A = 327.6 \text{ watts (W)}$. Charging Connector Type: 3Pin, Input Voltage: AC170V-300V, Input Frequency: 47-63Hz

Protection Features: Safety features such as overvoltage protection, overcurrent protection, short circuit protection, and overheating protection to ensure safe charging.

- **Charging Time:** 6Ah Battery in 1 Hour Compatibility: 48v lithium battery.



Fig.3.6 Charger

3.6 CONTROLLER

One of the most crucial components of an electric bike is the electric bike controller; it is the e-brain that controls the motor's speed, start, and stop. It's connected to everything else in the car, including the battery, motor, throttle (accelerator), display (speedometer), PAS, and any other speed sensors.



Fig.3.7 Controller

The TA controller is made up to main chips (microcontroller) and peripheral components (resistors, sensors, MOSFET, etc). Inside the controller, you'll find a PWM generating circuit, an AD circuit, a power circuit, a power device driver circuit, a signal acquisition and processing circuit, an over-current and undervoltage protection circuit, and a single acquisition and processing circuit.

The controller supplies the working voltage to the external device, such as the switch +5V, headlamp +5V, and so on, after attaching the battery. Based on the input from the throttle or PAS, the PWM generates an appropriate pulse pattern for the MOSFET driving circuit. To control the motor speed, the MOSFET driving circuit manages the MOSFET circuit's turn-on and turn-off.

When the voltage is lower than the controller set value, the under-voltage circuit protects the battery from discharge, and the PWM circuit stops the output. The controller, battery, and motor cannot operate at greater currents because of the over-

current protection circuit. The basic job of an electric bike controller is to collect all inputs from all electric components (throttle, speed sensor, display, battery, motor, and so on) and determine which signal should be returned to them (motor, battery, display).

The controller's many protection functions will differ from the controller's design. Some basic security functions are listed below. Protection against overvoltage. When the battery voltage becomes too high, the controller checks it and shuts down the motor. This prevents overcharging of the battery. Protection against low voltage.

When the battery voltage drops too low, the controller checks it and shuts down the motor. This prevents the battery from becoming overcharged. Protection against overheating. The temperature of the FET (field-effect transistor) is monitored by the controller, which shuts down the motor if it gets too hot. The FET power transistors are therefore protected. Protection against overcurrent. If the motor is receiving too much current, reduce the current supplied to it.

This safeguards the motor as well as the FET power transistors. Protection from braking. Even though the controller was receiving other signals at the same time, the motor shut down while braking. When a user simultaneously presses the brake and throttle, the brake function takes precedence.

3.6.1 WIRING DIAGRAM OF CONTROLLER

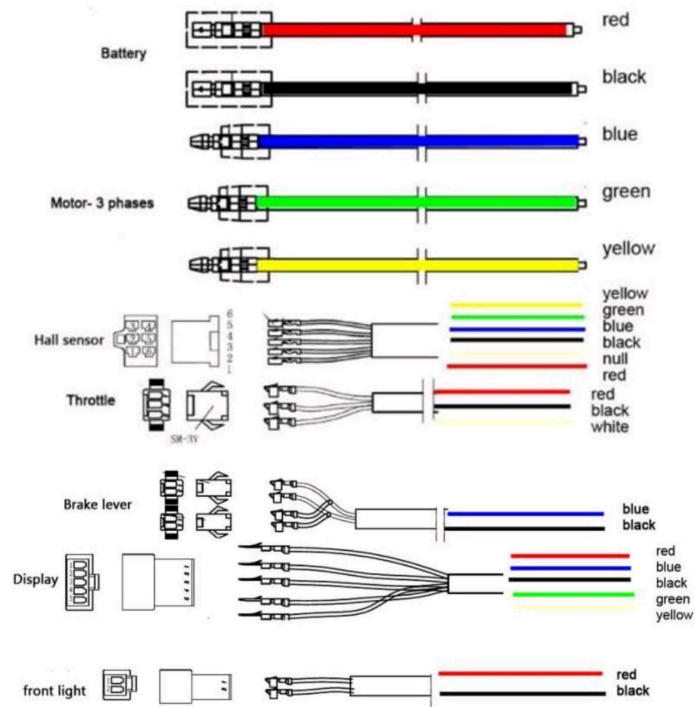


Fig.3.8 Controller Connecting wires

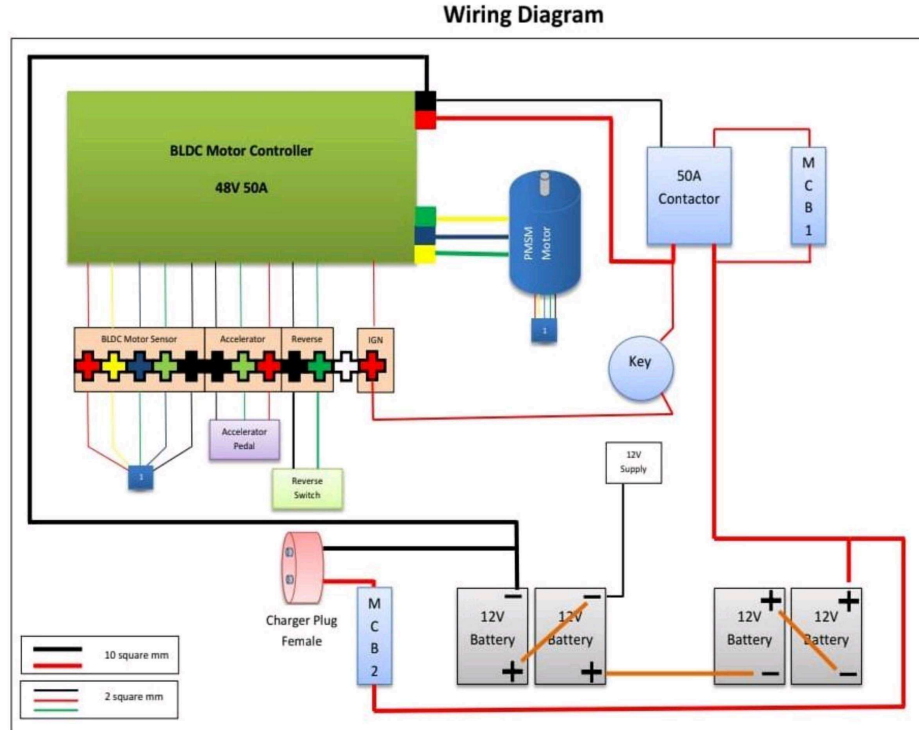


Fig.3.9 Wiring Diagram

3.6.2 Controller-Motor Connections

- **Ignition:** Connect the 24/48V Battery Positive to the Controller Red Wire Bullet Connector via a key switch.
- **Motor Direction:** Connect the Controller Phase Wires and the Hall Sensor wires to the respective wires from the motor as given below to achieve the desired direction.

Direction – Clockwise (From the Shaft Side)

Motor Phase Connection	Yellow	Blue	Green		
Controller Phase Connection	Green	Blue	Yellow		
Motor Hall Sensor Connection	Yellow	Blue	Green	Red	Black

Controller Hall Sensor Connection	Yellow	Green	Blue	Red	Black
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Direction – Anti-Clockwise (From the Shaft Side)

Motor Phase Connection	Yellow	Blue	Green		
Controller Phase Connection	Yellow	Blue	Green		
Motor Hall Sensor Connection	Yellow	Blue	Green	Red	Black
Controller Hall Sensor Connection	Blue	Green	Yellow	Red	Black

- **Throttle / Accelerator** Connect the 3 pin male connector (Pink, Black, Green) to the throttle/accelerator plug. Ensure that the color codes match while connecting. Pink: +5 VDC, Black: Ground, Green: 0-3.4 VDC
- **Reverse** Option 1: From the Motor Controller, use the 2 pin female connector (Yellow/Green, Black) wires. Short the two wires using a switch or Joystick to achieve reverse direction. In this option, the motor run only at half the rated RPM of the motor.
- **Three Speed Option** Use the 3 pin Blue Female Plug (Red/White, Black, Yellow/Red) to achieve three speed options. Connect the Black to Yellow/Red to achieve maximum speed.
 - Speed 1 - Default
 - Speed 2 - Connect or short the Black wire to Red/White wire to achieve speed
 - Speed 3 - Connect or short the Black wire to Yellow/Red wire to achieve maximum speed
- **High Brake** Use the single pin male bullet connector (purple wire) to achieve motor braking. Connect the purple wire to +12V / +48VDC to brake the motor.
- **Meter/Display** Use the single pin female bullet connector (purple wire) as input to the display unit.

3.7 INSTRUMENT CLUSTER

We're utilising a cluster to show how much the battery is charging and how fast the e-bike is going. The instrument cluster is an important aspect of every vehicle because it is the vehicle's face that displays its current state. It can provide critical signals of electrical component faults (EFI/ISG related) in addition to basic vehicle information. Clusters can collect vehicle data using simple technologies like encoders as well as more complicated interfaces like CAN, SAEJ1850, and so on.

Although electric car instrument clusters have a lower system complexity, they must be more user-friendly, power-efficient, and cost-effective. To achieve the strict compliance

standards, careful design and selection of cluster components is required. The MCU is the most common of the constituent components, with only a few vendors supplying automotive grade with the requisite feature sets.



Fig.3.10 Instrument cluster

3.8 THROTTLE

Regular electric bikes typically have a throttle that works just like a motorbike or scooter - twist it to go forward, and it doesn't have a reverse gear. However, there are some e-bike throttles that are specifically designed to include a reverse function.

Here's how these throttles with forward and reverse gear work:

- **Functionality:** These throttles function similarly to a regular throttle for forward motion. You twist the grip to control the speed of the electric motor. However, they also have a separate button or switch for engaging reverse gear. When activated, the motor spins in the opposite direction, allowing the bike to move backward at a slow speed.
- **Benefits:** There can be a few advantages to having a throttle with reverse gear on an e-bike:
- **Maneuvering in tight spaces:** Reverse gear can be very helpful when maneuvering your e-bike in tight spaces like parking lots or garages. It allows you to easily back up without needing to get off the bike and push.
- **Safety:** In some situations, being able to reverse slowly can be a safety benefit. For example, if you accidentally go down a short dead-end path, you can use reverse to back out instead of having to turn the bike around.
- **Availability:** E-bikes with throttles that include reverse gear aren't as common as those without. They are typically seen on custom-built e-bikes or some higher-end models. However, you can also find these throttles available for purchase separately if you want to upgrade your existing e-bike. These aftermarket throttles usually come with the necessary wires and connectors for easy installation on most e-bikes.

Things to Consider:

- **Legality:** In some regions, there may be regulations regarding the use of e-bikes with reverse gear. It's always a good idea to check your local laws before using a reverse function on your e-bike.

- **Safety:** While reverse gear can be helpful, it's important to use it cautiously. Be aware of your surroundings when reversing and make sure the path behind you is clear.

Overall, throttles with forward and reverse gear offer some added convenience and functionality for e-bikes. If you frequently ride in situations where tight maneuvering or occasional need to reverse might be helpful, then this could be a worthwhile upgrade for your e-bike.



Fig. 3.11 Throttle

3.9 LIGHTS AND HORN:

Increased Visibility:

Lights: Having a bright front light allows you to see the road ahead at night and in low-light conditions. Even during the day, a front light helps you be more visible to motorists and pedestrians. A rear light makes you visible to traffic following behind you.

Daylight Running Lights: Some e-bikes even have daytime running lights (DRL) which are low-powered lights that stay on constantly, similar to car headlights. This can significantly improve your visibility during the day.

Most e-bikes are equipped with battery-powered LED lights, which are bright, energy-efficient, and last a long time on a single charge. Some high-end models may come with integrated lights powered by the bike's main battery.

A horn is a crucial tool to alert pedestrians and other cyclists of your presence, especially when riding on shared paths or in situations where they might not see you coming.

By equipping your e-bike with proper lights and a horn, you'll be significantly enhancing your safety and visibility on the road, making your rides more enjoyable and ensuring everyone around you is aware of your presence.



Fig.3.12 Head Light



Fig.3.13 Indicators



Fig.3.14 Horn

3.10 Chain Type:

We are using the standard roller chain type for this E-Bike ,because this most common type of motorcycle chain and are a good option for most riders.They are relatively inexpensive and easy to maintain.

A motorcycle chain is a continuous loop made up to many interlocking metal links. These links connect to two sprockets: a smaller one on the engine's output shaft and a larger one on the rear wheel. Here's a breakdown of how the chain connects

- **Chain links:** Each link consists of several parts:
- **Inner plates:** Two inner plates that hold everything together.
- **Outer plates:** Two outer plates that connect to the sprocket teeth.
- **Pins:** These solid or hollow pins run through the inner plates and connect them, allowing for rotation.
- **Bushings :** These surround the pins and reduce friction between moving parts.
- **Rollers :** These rollers (on the outer plates) ride on the sprocket teeth, enabling smooth transmission of power

3.10.1 Connecting the Chain:

Not all the links are identical. A special type of link called a master link allows the chain to be opened and closed for installation or removal.

The master link typically has a clip or a plate mechanism that secures it to a standard link.

When installing the chain, the master link is positioned strategically, often with the closed end facing the front of the bike for additional security.

3.10.2 Sprocket Engagement:

The chain connects to the sprockets by its rollers fitting snugly between the sprocket teeth.

As the engine powers the motorcycle, the smaller sprocket on the engine shaft rotates.

This rotation pulls the chain links along, causing the rollers to engage with the teeth of the larger rear sprocket.

This chain-sprocket interaction transfers power from the engine to the rear wheel, ultimately propelling the motorcycle forward.

Overall, the motorcycle chain acts as a flexible yet robust link between the engine and the rear wheel, transmitting power through a series of interlocking links and precisely shaped sprockets.

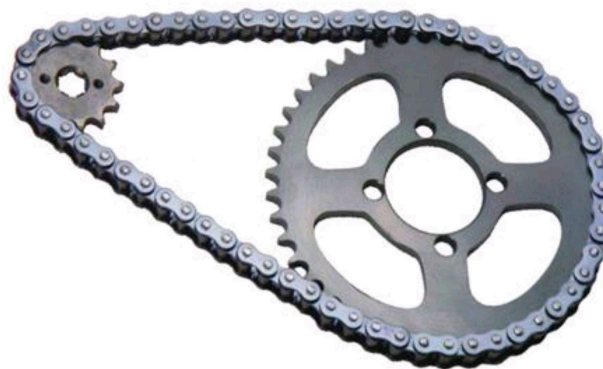


Fig.3.15 Chain Drive

CHAPTER 4 DEVELOPING AND TESTING OF ELECTRIC BIKE

4.1 WIRING DIAGRAM OF E-BIKE

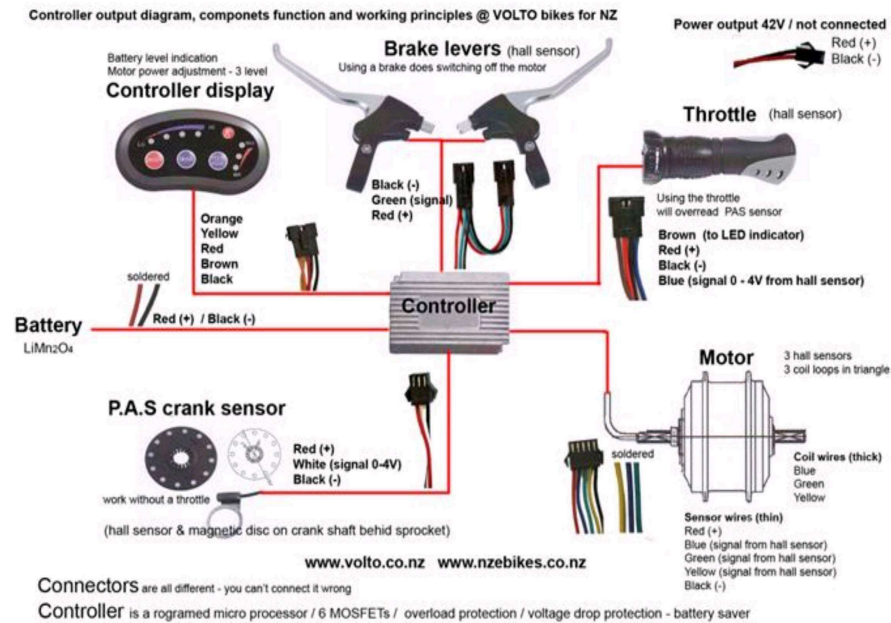


Fig.4.1. Wiring diagram of E-Bike

Electric bike wiring diagrams can vary depending on the specific components used, but here's a general explanation of how the main parts are connected through a controller:

4.1.1 Components:

- **Battery:** The power source of the bike, typically Lithium-ion (Li-ion) in various voltages (e.g., 24V, 36V, 48V).
- **Motor:** Provides electric power to assist pedaling. Common types are hub motors (in the wheel) and mid-drive motors (connected to the crankset).

- **Controller:** The brain of the system, regulating power flow between battery, motor, and other components. It receives signals from throttle and display.
- **Throttle:** Controls the motor's assist level, typically a twist grip or thumb lever.
- **Display:** Shows information like battery level, speed, and pedal assist mode.

4.1.2Connections:

- **Battery to Controller:** The battery's positive and negative terminals connect to the designated power input terminals on the controller.
- **Motor to Controller:** The motor's phase wires (usually 3) connect to the motor output terminals on the controller.
- **Throttle to Controller:** The throttle wires connect to the throttle input terminals on the controller, often including wires for positive voltage, ground, and signal wire.
- **Display to Controller:** The display connects to the controller through a communication port, often using a cable with multiple wires depending on the system.

4.2 BOARD CONDITION

We were searching for a second-hand or third-hand bike to purchase, but we ended up finding a bike in poor condition and decided to buy it. This bike is in good conditions, but few parts rusted so we removed those parts. The front and rear tiers are shaking so we changed both tiers, new tubes are fixed in the tiers. The headlight, side light, and brakes are not there. Handling of the bike is normal. The seat cover is also damaged.

Research Work

Overall bike weight is 112 kg, and it has a 92cc engine, seat height is 785mm and length*width*height is 2000*720*1052mm³, height is 1052mm, ground clearance 165mm, wheel size for Front 457.2mm, Rear is 457.2mm, Brakes of front and Rear is Drum and it is Integrated Braking system.



Fig.4.2 Boared condition

Firstly, we decided to remove the parts of the bike such as engine , fuel system , exhauster , some parts which are not wanted ,then we went to the mechanical shop to Remove parts of the bike. A mechanical person removed the engine, Fuel system, exhaust.

4.3 REMOVED PARTS

All these parts were removed by a Mechanical person. like Engine, fuel system, and exhauster, then we calculate the engine weight as 25 kgs. fuel system and exhauster is 2kg, mechanical person taken this parts as a charge of removing this parts. we did not remove the chain drive system because we are using the chain drive system for this bike.



Fig.4.3 Engine



Fig.4.4 Fuel System



Fig.4.5 Exhauster

“After removing the parts of the bike such as the engine, fuel system, and exhaust the now the bike look like as shown in Fig No 4.7 is given below and weight comes to around 80kgs .it has some space to place components like motor, battery, and controller. Inside the petrol tank, we can place some small components so we do not remove the petrol tank. We have to place the motor, battery, controller

so ,firstly we tested this components with our guide.



Fig.4.6 Removed parts

4.4 TESTING OF COMPONENTS :

Testing of the components was completed successfully by our project Guide and lab in charge, for this testing we needed a motor, battery, controller, and throttle, so firstly we gave a power supply to the controller from the battery with red and black wires and then from to controller to motor same colour wires are connected such as blue, Yellow, Green. One plug wire is connected from the controller to the motor and the throttle is connected to the controller. An electric clock wire is connected to the battery supply. When the connection is done the throttle rises slowly the motor starts rotating.



Fig.4.7 Testing of Components

4.5 SOFTWARE DESIGN OF BIKE

Before starting this project we design the bike with the help of mechanical student . according to this dimensions we design this bike.

length*width*height is $2000*720*1052\text{mm}^3$, height is 1052mm, ground clearance 165mm, wheel size for Front 457.2mm, Rear is 457.2mm.

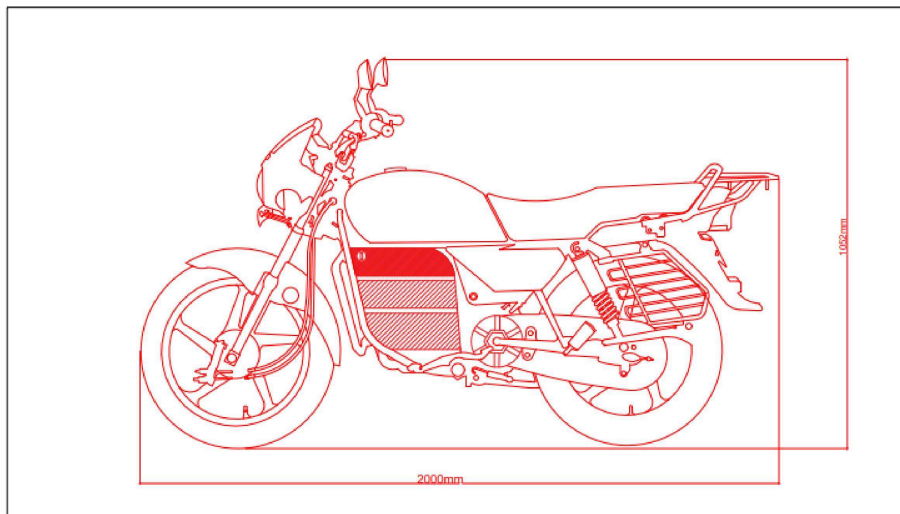


Fig.4.8 Software Design of E-bike

4.6 Bike chain Drive to wheel

After the complete testing of components, the next step is fixing the components. We have to arrange the exact space for the components to be fixed properly in the bike. To fix the motor, we need an iron plate for support. We drill the iron plates and use screws to fix the motor. Already we fixed the sprocket to the shaft. The chain drive is connected between the rear wheel and the motor sprocket. After this work, we need to fix the battery, so again, we use the iron plate to fix the battery, and we can easily remove and insert the battery. The controller is placed on top of the motor.



Fig.4.9 Chain Drive to Wheel

4.7 FIXING COMPONENTS

After fixing all the components, some parts got rusted so we cleaned the rusting parts, to prevent rusting we did painting work. we fixed the display meter which helps to show battery percentage and speed, the throttle is connected to both sides of the handle, and the Headlight, and side indicator were also fixed with the help of a 12V DC battery lastly we fixed the wiring connections for motor, controller, and battery and we did testing again it working good.



Fig.4.10 Fixing components

4.7.1 After Fixing components

We have fixed all the components of the bike, including the headlight and side lights. The rusted rods of the bike have been coated with black paint. After the repairs, we checked the bike's weight, which is approximately 105kg. However, if we remove the petrol tank, the bike's appearance will not be nice, so we decided to keep the petrol tank in its original position. It may also be useful for future purposes, such as storing the tank and all the wires of the components inside the bike. All the components have been fixed perfectly."



Fig.4.11 Final view of bike

4.8 Testing of BIKE

During our bike testing, we noticed that, the bike can travel up to 50 kilometers per charge at a speed of 60 kilometers per hour, without any load. The maximum speed of the bike is 80 kilometers per hour, but when carrying a normal load, it can travel at a speed of 50 kilometers per hour. However, if the load is increased, the speed and range decrease accordingly. It takes approximately 5 hours to charge the battery fully.

During the testing with more load, we found that the motor's permanent magnets broke and the winding was damaged. The reason behind this was the high stress on the motor, which occurred due to the absence of gear reduction. To control the high stress on the motor, we need to use gear reduction. The gear reduction process involves setting the gear reduction ratio accurately. A gear reducer is a mechanical system of gears arranged in such a way that the input speed can be lowered to a slower output speed, but with the same or more output torque. The gear reduction process is used when the drive gear is smaller and has fewer teeth than the driven gear.

"We sent the damaged motor to the manufacturer under warranty. They informed us that the cause of the damage was insufficient gear reduction ratio. After repairing the motor, they will install the necessary gear reduction and take steps to avoid making the same mistake again.

4.9 IEEE Standards:

- IEEE 1725™ - Standard for Rechargeable Batteries for Cellular Telephones: While not specific to electric bikes, this standard provides guidelines for the design and testing of rechargeable batteries, which are crucial components in electric bike systems.
- IEEE 2030™ - Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads: This standard focuses on interoperability aspects related to energy technology and information technology, which can be relevant for electric bike charging infrastructure and integration with the power grid.
- IEEE 1547™ - Standard for Interconnecting Distributed Resources with Electric Power Systems: This standard addresses the interconnection requirements for distributed energy resources, which could include electric bikes with energy storage capabilities.
- IEEE 1815™ - Standard for Electric Power Systems Communications—Distributed Network Protocol (DNP3): While primarily focused on communication protocols for electric power systems, this standard may be relevant for communication interfaces within electric bike systems, especially in the context of smart grid integration or data exchange with charging infrastructure.
- IEEE 802.11™ - Wireless LAN Standards: Electric bikes may incorporate wireless communication for various purposes such as connectivity with mobile devices, remote monitoring, or firmware updates. IEEE 802.11 standards provide specifications for wireless local area network (WLAN) technology, which could be utilized in electric bike systems for wireless data transfer.
- IEEE 1615™ - Standard for Environmental and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations: While primarily focused on communication devices in electric power substations, this standard includes guidelines for environmental and testing requirements. Some of these requirements may be applicable to communication devices used in electric bike systems, especially those designed for smart grid integration or connectivity with charging infrastructure.

4.10 Constraints

- **Battery Capacity and Range:** The capacity and energy density of batteries limit the range and performance of electric bikes. Despite advancements in battery technology, there is still a trade-off between battery size, weight, and range.
- **Weight:** The addition of batteries, motors, and other electrical components can significantly increase the weight of electric bikes compared to traditional bicycles. This added weight can affect handling, maneuverability, and portability, especially for folding or transportable electric bike models.
- **Cost:** Electric bikes tend to be more expensive than traditional bicycles due to the cost of batteries, motors, and electronic components. This can be a barrier to adoption for some consumers, although prices have been decreasing as technology advances and economies of scale improve.
- **Charging Infrastructure:** Availability of charging infrastructure can be a constraint, especially for long-distance or multi-day trips. While charging stations are becoming more common in urban areas, rural or less developed regions may have limited charging options.
- **Regulations and Standards:** Electric bikes are subject to regulations and standards that vary by region, including speed limits, power restrictions, and safety requirements. Adhering to these regulations can pose challenges for manufacturers and influence the design and performance of electric bike systems.
- **Maintenance and Serviceability:** Electric bikes require maintenance and servicing of electrical and mechanical components, including batteries, motors, brakes, and electronic controls. Access to skilled technicians and replacement parts may be limited in some areas.
- **Perception and Social Acceptance:** Despite their environmental benefits and potential for reducing traffic congestion, electric bikes may face scepticism or resistance from some segments of society. Overcoming negative perceptions and promoting the benefits of electric biking can be a challenge.
- **Security:** Electric bikes are susceptible to theft, especially high-end models with valuable components such as batteries and motors. Implementing effective security measures, such as locks, alarms, and GPS tracking systems, is essential to deter theft and protect investments.

4.11 Trade-off:

- **Range vs. Battery Size and Weight:** Increasing the range of an electric bike typically requires a larger and heavier battery. Manufacturers must balance the desire for longer range with considerations of bike weight, cost, and practicality.
- **Performance vs. Cost:** Higher-performing electric bikes, with more powerful motors and longer-lasting batteries, tend to come with higher price tags. Consumers must decide whether the improved performance justifies the increased cost.
- **Weight vs. Portability:** Electric bikes can be heavy due to the added weight of batteries and motors. This can affect portability, especially for folding or transportable models. Designers must balance the desire for lightweight construction with the need for durability and performance.
- **Speed vs. Legal Restrictions:** Some jurisdictions impose speed limits on electric bikes, restricting their maximum assisted speed to maintain safety on roads and bike paths. Manufacturers may need to limit the top speed of electric bikes to comply with local regulations, which can impact their market appeal.
- **Cost vs. Quality and Features:** Lower-priced electric bikes may sacrifice quality, durability, or features to reduce costs. Consumers must weigh the trade-off between upfront savings and long-term reliability and performance.
- **Maintenance vs. Complexity:** Electric bikes have more complex systems than traditional bicycles, with electrical components such as motors, controllers, and batteries requiring maintenance and occasional repairs. Consumers must consider the trade-off between the convenience of electric assist and the potential for increased maintenance requirements.
- **Environmental Impact vs. Manufacturing Processes:** While electric bikes offer environmental benefits compared to gas-powered vehicles, their production still involves resource extraction, manufacturing processes, and transportation, which can have environmental impacts. Manufacturers must balance the environmental benefits of electric bikes with the sustainability of their production processes.
- **Speed vs. Range:** Increasing the speed of an electric bike can decrease its range, as higher speeds consume more battery power. Designers must find a balance between speed and range to meet the needs of different riders and use cases.

4.12 PROBLEM STATEMENT:

- **Infrastructure Planning:** Designing an infrastructure plan that includes docking stations, charging stations, and maintenance facilities strategically located throughout the city to ensure convenient access and availability to users.
- **Technology Integration:** Developing a user-friendly mobile application or web platform that allows users to locate nearby e-bikes, unlock them, and pay for rentals seamlessly. Integration of GPS tracking and anti-theft mechanisms is also crucial for security and operational efficiency.
- **Fleet Management:** Implementing a system for fleet management, including maintenance schedules, battery monitoring, and redistribution of bikes to ensure balanced availability across different locations.
- **Regulatory Compliance:** Adhering to local regulations and obtaining necessary permits for operating e-bike rental services in urban areas. This may include compliance with safety standards, insurance requirements, and zoning regulations.
- **User Experience:** Enhancing the user experience through features such as flexible rental plans, responsive customer support, and incentives for regular users. Providing options for different user demographics, including tourists, commuters, and recreational riders, is essential.
- **Sustainability:** Ensuring the sustainability of the rental system by using renewable energy sources for charging stations, promoting responsible riding behavior, and minimizing environmental impact through efficient operations and maintenance practices.
- **Community Engagement:** Engaging with local communities to address concerns and solicit feedback regarding the placement of infrastructure, impact on existing transportation systems, and integration with public transit networks.
- **Financial Viability:** Developing a sustainable business model that accounts for initial investment costs, operational expenses, revenue generation through rental fees, and potential partnerships or sponsorship opportunities.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION:

While PMSM motors and LiFePO₄ batteries offer numerous advantages, challenges remain, including cost and range limitations. Future research should focus on addressing these challenges, optimizing motor and battery designs, and exploring innovative charging solutions.

5.2 FUTURE SCOPE:

PMSM motors and LiFePO₄ batteries have emerged as key to possible in the evolution of electric bikes. Their contributions to performance, efficiency, safety, and environmental sustainability make them significant components of the e-bike industry. Continued research and development in this field will likely lead to further improvements in e-bike technology, making them even more attractive as a sustainable urban transportation option.

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