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Integrating Mechanical and Electrical Engineering in Electric Vehicle Design and Development

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ABSTRACT: The necessity for environmentally friendly transportation options has fueled the electric vehicle (EV) market's explosive expansion, completely changing the automotive landscape. This abstract presents a thorough analysis of the topology of electrical vehicle systems, clarifying the essential elements, structures, and interactions that allow contemporary EVs to operate effectively and dependably. The design of an electric power train-based vehicle was covered in this article, along with consideration for the battery pack, motor, and chassis choices. By outlining the main parts of an electric vehicle system, such as the control unit, power electronics, energy storage system (battery), and electric motor. These constituents provide the fundamental structure of the electric vehicle (EV), facilitating its propulsion, energy storage, and general functionality. A universal charging system that can safely and efficiently charge the majority of EVs in a variety of exterior conditions is necessary due to the rise in EV usage. This article provides a thorough overview of all the factors to be taken into account when creating a universal charger, including hardware design factors like topology.

KEYWORDS: Electric Vehicle, Motor, Battery Management System (BMS), Battery Charging System, Motor Controller, Universal Charger.

I. INTRODUCTION

Due to the rapidly declining supplies of natural gas, diesel and petrol, the energy crisis is one of the biggest issues facing the globe today. The problem of vehicle-related pollution in cities and metropolitan areas is never-ending, and the amount of natural gas and oil consumed has been rising steadily every ten years [1].

Fig. 1. Model

A vehicle classified as an alternative fuel vehicle is one that doesn't run exclusively on petrol or diesel, but also includes any technology that powers an engine without using petroleum, such as electric vehicles, hybrid vehicles, solar-powered vehicles, and hydrogen fuel. The creation of more advanced power systems and cleaner alternative fuels for automobiles has been a top goal for many governments and automakers worldwide due to a number of factors, including environmental concerns, rising oil prices, and the possibility of peak oil. Rechargeable batteries are typically used to power electrically assisted bikes. A number of factors, including battery capacity, motor power, road conditions, operation weight, control, and assisted power management, affect how well these bikes drive [2].

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The major objective of designing an electric motorcycle is energy efficiency and sustainability. The chassis design takes into account the ease of assembly of all components and offers sufficient strength to guard against any damage following an accident or collision. It is made to have its centre of gravity lowered for better handling, easy control, and resistance to tipping over on any gradient [3].

Motors are used in all two-wheeled electric vehicles, such as bikes, scooters, and motorcycles, to transmit energy to the wheels. These electric motors differ from one another in terms of size, form, torque output, and methods of operation, though. Selecting the motor that provides the best speed and torque output is therefore the most crucial stage in the creation of an electric vehicle. The drive motor choice for an electric vehicle is determined by the greatest power and torque that it needs. Numerous parameters, including the rolling resistance, gradient resistance, and aerodynamic resistance, must be considered in order to determine torque [4].

The efficiency of battery packs has an impact on how well electric vehicles operate. In contrast, brushless DC motors offer superior specifications compared to conventional brushed DC motors. These benefits include longer operational lives, noiseless operation, larger speed ranges, reduced maintenance, and improved speed versus torque characteristics. Battery management systems and drive controllers are utilised to smoothly manage and run the motor and battery over the long term [2].

II. DETAILS OF MODEL

This prototype was built using parts of the Bajaj Spirit's frame. the direct mounting of a BLDC hub motor onto the wheel assembly, improving the compactness and efficiency of electric vehicle design. The battery's location on the vehicle deck maximises accessibility and weight distribution for better performance and less maintenance. The idea behind this variation is to turn motorbikes with internal combustion engines into electric vehicles. After testing the motorcycle on the road with various loads, the BLDC motor could achieve a top speed of 50 km/h at 609 RPM. It can readily support the combined weight of two Indians, who typically weigh 60 kg a piece [1].

After comparing the power output to that of other electric vehicles, high power loss was examined. Furthermore, the greatest range in this instance is merely 80 kilometres. Reducing this loss is necessary in order to achieve the goal of using less battery power [1].

III. DETAILS OF PARTS

When connected to the rear wheel, a 72-volt motor produces a peak torque of 15.68 Nm. This constant torque is plenty for a two-person bike. As a result, it has a 70–80 km range and can travel up to 80 km/h in turbo mode. The car has an 80–100 km range while operating in Eco mode at a speed of roughly 30–40 km/h. While the car reaches its top speed of 90 km/h in sports mode, it does so at a significantly slower pace than in eco and turbo modes [6].

The power consumption of motor variators can be increased or decreased by analysing the speed and range characteristics at varying loads. The range of the bike must be chosen based on the power consumption.

Parts of bike:

A. Chassis

It is the structural support structure for every automotive vehicle, giving the motor, batteries, suspension system, and other components that are hinged to it structural stability. The chassis of a hole vehicle gives it strength to handle centrifugal forces during cornering, fatigue loads from integrated components, large dumps, etc. Typically, steel is used to make chassis, while some vehicles use steel alloys to minimise weight without sacrificing strength. Design material selection is influenced by a number of variables, including load, function, climate, and lifetime.

The material is the fundamental component of a sturdy, dependable, and safe frame. The following criteria were taken into account when choosing the material:

- High tensile and yield strength
- Firmness
- lightweight
- low cost

B. Motor

Specifications of the 1000 Watt BLDC HUB Motor:

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- Power Output: 1000 Watts
- Operating Voltages: 48V, 60V, and 72V
- Winding Material: Copper
- Winding Size: 12 inches
- Motor Type: Direct-Drive Brushless DC (BLDC) Motor
- Additional Feature: Extra powerful design

These specifications highlight the motor's power rating, voltage compatibility, winding material, size, and type, emphasizing its suitability for various electric propulsion applications.

Fig. 2. Motor

C. Battery

TABLE I. BATTERY SPECIFICATION

Parameter	Rating & Details
Product Type	Battery Pack
Technology	Lithium Ion (NMC)
Nominal Voltage	72.00V
Storage Capacity	36.00Ah
Cells Used -3C Rated	3.6V,4.5Ah Cylindrical Cells
Number of Cells in Series	20
Number of Cells in Parallel	8
Full Charge Voltage per Cell	4.20V +/- 0.05V

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Lower Cutoff Voltage per Cell	3.00V +/- 0.05V
Full Charge Battery Pack Voltage	84.00V
Lower Cutoff Voltage	60.00V
BMS Rating	19 Series NMC 40A continuous
BMS peak Current Sustainability	80A (≤10 seconds)
Continuous Current Sustainability	40A
Under Voltage Protection	Present
Over Load Protection	Present
No Load Protection	Present
Short Circuit Protection	Present
Thermal Monitoring System	Present NTC Based
Battery Charge-Discharge Cycles	500
Battery Charging Type Recommended	CC/CV (Constant Current, Constant Voltage)
IP Rating	IP65
Operating Temperature	-10°C to +60°C
Application	Indoor / Outdoor (needs enclosure)
Mileage Meter	Present-Additional
Battery Level Indicator	Present-Additional
GPS Tracking System	Present-Additional
Communication	CAN BUS/SM Bus/RS232/RS485-Additional
Dimension (Tolerance: +/- 10%)	250mm x 250mm x 250mm

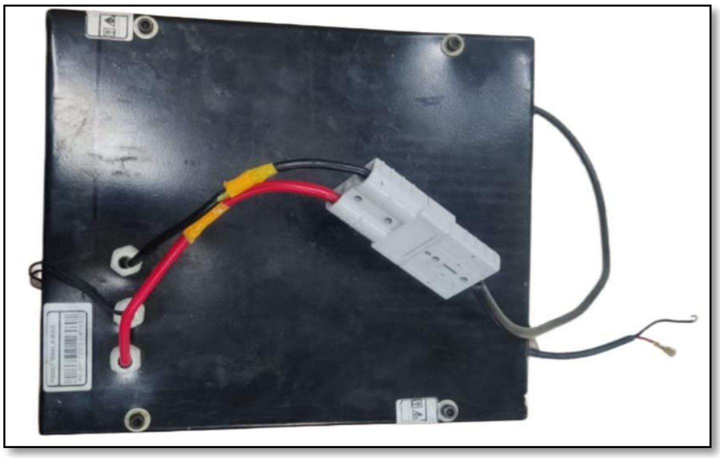

Fig. 3. Battery

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TABLE II. BMS SPECIFICATION

Parameters	Ratings and Details
Product Type	Battery Management System (BMS)
Technology	Programmable With CAN Communication
Maximum Series Series	20
Cell Chemistry Supported	Programmable
Number of Cells in Series	Up to 20
Full Charge Voltage per Cell	Programmable
Lower Cutoff Voltage per Cell	Programmable
Full Charge Battery Pack Voltage	Programmable
Lower Cutoff Voltage	Programmable
BMS Rating	Upto 20 Series 40A continuous
BMS Speak Current Sustainability	80A (≤10 seconds)
Continuous Current Sustainability	40A
Under Voltage Protection	Present
Over Load Protection	Present
No Load Protection	Present
Short Circuit Protection	Present
Thermal Monitoring System	Present - NTC Based
Switching Components	MOSFETS
Operating Temperature	-10°C to +50°C
Communication	CANBUS
Display	LCD
Keypad	Present
Dimensions	139mm x 99mm x 24.5mm
Weight	250g

D. Controller

TABLE III. CONTROLLER SPECIFICATION

Parameter	Rating
Anti-theft electric door lock	Present
Anti-theft power supply	Present

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Anti-theft signal low	Present
Anti-theft wheel running signal	Present
Hall U yellow	Present
Hall V green	Present
Hall W blue	Present
High-level brake	Present
ISDN meter	Present
Learn	Present
Low-level brake	Present
Meter (common meter)	Present
Parking	Present
Throttle signal	Present
Three speed slow	Present
Three speed fast	Present
+5V	Present
Ground	Present

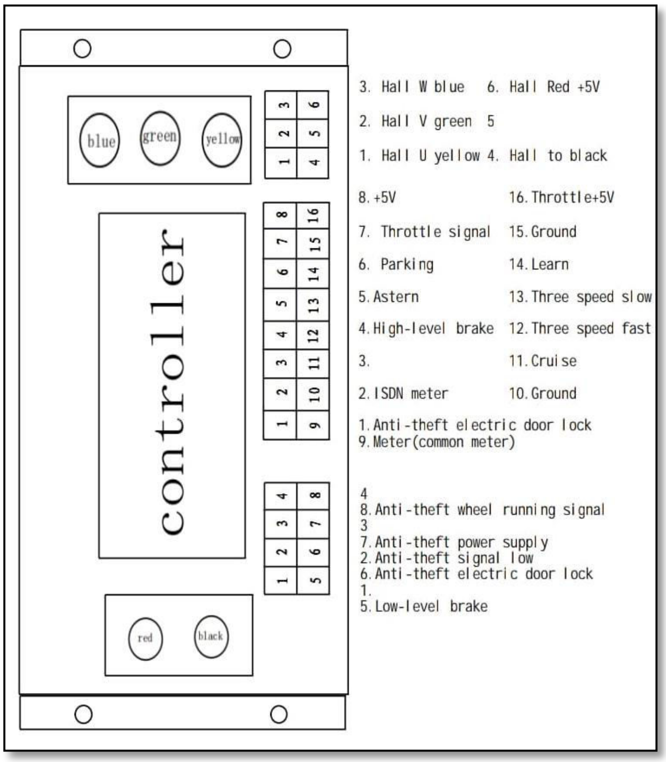

Fig. 4. Controller

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A. *CALCULATION*

B. *Calculation for Selection of Battery*

1) *Rolling Resistance Frolling = Crr * M * g*
   Where, Crr = coefficient of rolling resistance

   M = mass in kg

   g = acceleration due to gravity = 9.81 m/s^2

   NOTE: For the application of scooter,

   Crr = 0.004,

   M = 180 kg

   Therefore,

   Frolling = 0.004 * 180 * 9.81 = 7.0632 N ... (Eq. No. 1)

2) *Gradient Resistance Fgradient = M * g * sin α*
   In this illustration, let us consider the electric scooter runs on a flat road. Therefore, the angle α = 0

   Fgradient = 180 * 9.81 * sin 0 = 0 ... (Eq. No. 2)

3) *Aerodynamic Drag*
   Faerodynamic drag = 0.5 * CA * Af * ρ * (V)^2
   Where,
   AF = Front surface area of vehicle including rider = 0.825
   *F*aero = 0.5 * 1.225 * 0.825 * 0.7 * (13.880)^2

   Faerodynamic drag = 68.1455 N ... (Eq. No. 3)

   Total Force for max speed 50 km/hr

   Ftotal = Frolling + Fgradient + Faerodynamic drag

   = 7.0632 + 0 + 68.1455 = 75.2087 N

   Pdemand = 75.2087 * 13.88

   Pdemand = 1043.8967 W

C. *Battery Calculation*

Range = 100 km

Velocity = 35 km/hr = 35 * (1000/3600)

= 9.72 rev/min

Total force require for avg speed of 35 km/h is

Ft = Crr * M * g + 0.5 * CA * Af * ρ * (V)^2 + 0 + 0

= 180 * 9.81 * 0.004 + ½ * 1.225 * 0.82 * 0.7 * (9.72)^2

Ft = 40.27 N

Pdemand = Ft * V = 40.27 * 9.72

Pdemand = 391.5 W

Power at wheel = 391.5 W

Time to drive 100 km = 100/35 = 2.85 h

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Energy to drive for 2.85 hour = 391.5 * 2.85 = 1115.7 Wh Energy requirement for battery = 1115.7/0.8 = 1394.6

Battery Capacity = 1394.6/0.8 = 1.7 * 1000/48

Battery Capacity = 36.32 Ah

D. Calculation for Selection of Motor

1) *Tire Details:*
Diameter = 30.5 cm (12 inch)
Radius = 15.25 cm = 0.1525 m

Distance / revolution = $2\pi r = 2\pi \times 0.1525 = 0.958$ m

2) *Wheel RPM:*
Maximum Speed = 50 km/hr

RPM of the wheel = Velocity / distance per revolution

= 13.88/0.958 rev/min = 14.48 rev/min

3) *BLDC Motor:*
Voltage = 72 V

Power = 1000 W

4) *Power Equation:*
$P = I \times V$

$I = P/V = 1000/72 = 13.88$ A

5) *Speed of the motor in RPM*
$N = K / (d \times 0.001885)$

$= 35 / (30.5 \times 0.001885)$

N = 609 RPM

Where,

N = speed in RPM

K = speed in Kmph

d = wheel diameter in cm

6) *Torque of the motor (T)*
$T = (P \times 60) / (2\pi N)$

$= (1000 \times 60) / (2 \times 3.14 \times 609)$

T = 15.68 Nm

Torque of the wheel hub motor, T = 15.68 Nm

IV. CONCLUSION

There are so many advancements happening in every direction in the current world. We find it impossible to believe that there will ever be an energy crisis on Earth or that other solutions will be required in light of these forward-thinking developments in industrialised nations. In light of the events, it appears that everything is proceeding according to plan and that the energy crisis is unreal. There are a plethora of developments occurring in every direction in the modern world. We find it impossible to believe that there will ever be an energy crisis on Earth or that other solutions will be required in light of these forward-thinking developments in industrialised nations. In light of the events, it appears that everything is proceeding according to plan and that the energy crisis is unreal.

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It is clear from the case study used to better understand how hub motors operate that a lithium ion battery bank, which produces voltage output in multiples of 4.2V basic battery output, can be used to drive a 72V, 1000 W hub motor. On the other hand, studies on battery banks and their components are moving towards smaller, more compact designs or just rougher construction. Any kind of e-vehicle's cost-related problems are based on the total cost of the battery bank [5].

Combination of every component required for the vehicle's flawless operation, ergonomics, and good efficiency. All of the work was done to make sure that an electric motorbike could handle large loads and still function properly after a severe crash. The vehicle's efficiency was attained with an ideal speed of 50 km/h and a range of more than 90 km on a single charge. It requires less maintenance and is far more dependable and efficient than a motorbike with a conventional internal combustion engine. With advancements in battery technology, vehicles can now travel farther on a single charge and charge more quickly. It will help reduce transportation-related pollution and be better for the environment. After a few years of advancements, everyone will have access to the current electric motorcycle technology.

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