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Design Hybrid Electric Vehicle Using Intelligent Battery Management System

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Abstract
With the increasing adoption of Hybrid Electric Vehicles (HEVs), the need for a sophisticated and intelligent Battery Management System (BMS) has become crucial for enhancing battery performance, safety, and longevity. This study introduces an innovative Intelligent Battery Management System (IBMS) that improves battery efficiency, monitoring, and control within HEVs. The system leverages real-time monitoring, advanced data-driven algorithms, and predictive analytics to precisely determine the State of Charge (SoC) and State of Health (SoH) of the battery. These capabilities optimize energy utilization and extend battery lifespan. The IBMS utilizes machine learning techniques and adaptive control strategies to reduce battery degradation and enhance overall performance. Additionally, it incorporates advanced fault diagnosis and thermal management functions to ensure safety and reliability. The effectiveness of this system has been validated through comprehensive simulations and experimental evaluations, demonstrating notable improvements over traditional BMS. The proposed IBMS represents a significant step forward in advancing next-generation HEVs by promoting efficient and intelligent energy management. We have converted normal Petrol Bike to Hybrid Bike by using Hub motor on backside wheel of bike. The Intelligent BMS is playing important role in monitoring all the parameters of the LiFePO4 Battery.

Keywords: *BMS (Battery Management System), EV (Electric Vehicle), SoC (State of Charge), SoH (State of Health), Intelligent Battery Management System (IBMS).*

1. Introduction
Vehicles that combine an internal combustion engine (ICE) with an electric motor and battery to generate propulsion are known as hybrid electric vehicles [5]. HEVs. HEVs' primary objectives are to increase fuel economy, lower emissions, and provide a more environmentally friendly substitute for conventional gasoline-powered automobiles [7]. HEVs can recharge their batteries without a plug, unlike fully electric vehicles (EVs) [3]. Rather, the engine and regenerative braking are used to charge the electric motor [1]. Vehicles known as hybrid electric vehicles (HEVs) use an internal combustion engine (ICE) in conjunction with an electric motor and battery to provide propulsion [2]. Enhancing fuel efficiency, cutting emissions, and providing a more environmentally friendly option to conventional gasoline-powered vehicles are the primary objectives of HEVs [6]. In contrast to fully electric vehicles (EVs), hybrid electric vehicles (HEVs) do not require a plug to replenish their batteries [4].

2. Literature Review
Hybrid electric vehicles (HEVs) use a variety of battery technologies to preserve and manage energy efficiency [3]. Initially, lead batteries were used for low cost and recyclability, but due to their low energy density, heavy goods vehicles and short lifespan, they were not suitable for modern applications [7]. Previous research into battery optimization in hybrid electric vehicles (HEVs) focused on improving energy efficiency, extending battery life, and

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increasing overall vehicle productivity [5]. Various studies have explored optimization methods such as intellectual energy management strategies, battery management, and advanced methods for assessing modern health care (SOH) [2].

3. HEV Architecture

3.1. Types of HEVs

- **Series Hybrid:** The hybrid series electric car (HEV) is a type of hybrid, where the internal combustion engine (ice) is not connected directly to the wheels, but operates exclusively as an electricity generator. In this configuration, the vehicle depends entirely on the engine, which does it more like an electric car with an increase in the engine. ICE generates power.
- **Parallel Hybrid:** In a parallel hybrid system, an internal combustion engine and an electric motor are connected to the transmission, allowing them to cooperate or operate independently to supply the vehicle. This configuration allows the engine and electric motor to share propulsion loads, making it more effective than traditional gasoline vehicles. The battery is recharged by regenerative braking and engine if necessary.

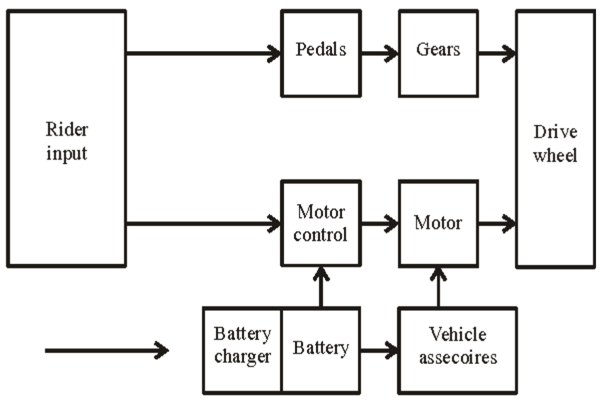

Figure 1 Block Diagram of Parallel Hybrid Vehicle

- **Plug in Hybrid:** In parallel hybrid systems, internal combustion engines and electric motors are connected to the transmission, allowing them to cooperate and function independently of the vehicle's supply. This configuration allows the engine and electric motor to exchange load movements, making it more effective than traditional gasoline vehicles

4. Intelligent Battery Management System (IBMS)

4.1. Features of an Intelligent BMS

Battery monitoring in real time and diagnosis, Improvement of thermal control to regulate the temperature, Cell balancing to ensure uniform tension distribution, Protection against re -evaluation, deep discharges and short circuits, Possibility of remote monitoring and predictive service, Integration with Cloud Analytics and IoT platforms.

4.2. Algorithms for State of Charge (SoC) and State of Health (SoH)

State of Charge (SoC) estimation algorithms determine the remaining energy in the battery relative to its full capacity. Common methods include the Coulomb Counting method, which integrates current flow over time, and the Open Circuit Voltage (OCV) method, which estimates SoC based on the resting voltage of the battery. The Health Status (SOH) Estimation Algorithm evaluates the overall condition of the battery and remaining lifespan.

5. Hybrid Vehicle by Using IBMS

5.1. LiPeO4 Battery

The use of LiFePO4 batteries in HEVs also contributes to lower maintenance costs and improved reliability compared to traditional lead-acid batteries. The compact size and lightweight nature of LiFePO4 batteries make them ideal for integration into HEVs without compromising vehicle performance or interior space.

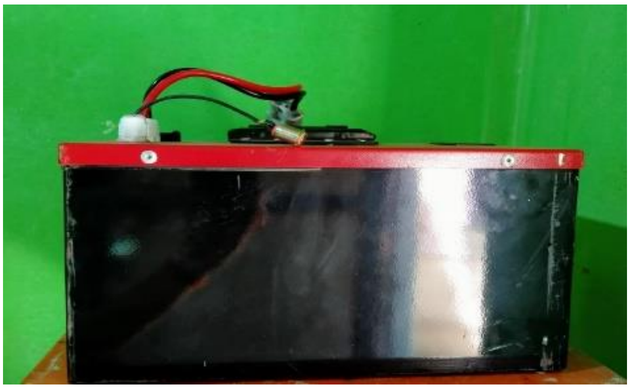

Figure 1 LiPeo4 Battery

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5.2. Hub Motor

1. Weight of vehicle=120.00kg
2. Weight of vehicle +Approx. weight of 1 person=120.00+60=180.00kg.
3. Weight of battery=12 kg.
4. Weight of vehicle + battery=132Kg.
5. Weight of vehicle+battery+1person=132+60.00=192.00 Kg.
6. Coefficient of Rolling = 0.015
7. Coefficient of drag = 0.5
8. Air Density = 1.27 kg/m3
9. Frontal Area = 0.6m2
10. Rolling Resistance (Rr) = $0.015\times$ Gwgt$\times 9.81$
    a. $= 0.015\times 192\times 9.81$
    b. $=28.373$ N
11. Air Drag (Ra) $=12\times \rho \times A \times V^2\times Cd$
    a. $=12\times 1.27 \times 0.6 \times 19.44^2\times 0.05$
    b. $= 71.99$ N
12. Total Resistance = Rr + Ra = 72 + 28.373 = 100.37 N
13. Torque N = $38.25 * 60 * 10^3/\pi*254$
    a. N= 2876.06 RPM
14. Gradient Force (Rg) = w*9.81*Sin $\propto$
    a. Rg = 374.76 N
15. Gradient Angle ($\propto$) =10°
16. Total Resistance = Rr + Ra + Rg
    a. = 374.76 + 9.186 + 28.373
    b. = 412.32 N
17. Torque Required = 412.32 * 0.127 = 52.36 N.m

5.3. Design Process

Figure 2 Wheel Setup for Hub Motor

Wheel Design Setup: In this vehicle changed the actual design of chassis because the shaft of hub motor is not suitable for existing fitment. Hence by using welding machine original design of bike was modified by extending actual chassis. In this as chassis was extended some of the factors became easy to remove tire and install it again.

Figure 3 Battery Rack and Battery Box

Battery Rack and Battery Box: The battery rack supports the battery box. In the battery box the LiFePO4 battery is been fitted. The rack got support with the accessories of the vehicle. Rod is of 37 inch with diameter of 0.9 inch the box vertically is 11.7 inch and horizontally 13 inch, Figure 2.

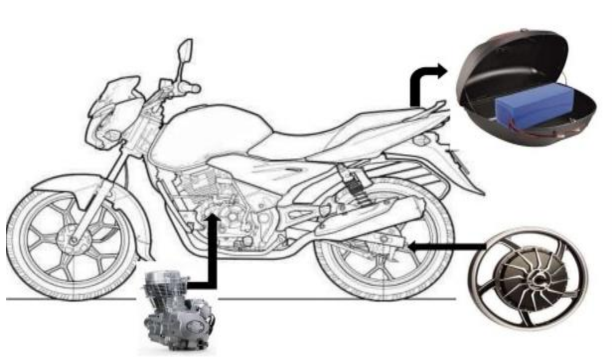

Figure 4 Imagine Design of the Vehicle

Setup: The main aim of this paper is to structure and manufacture a hybrid two wheelers such as scotty. bikes which can be operated by means of fuel and battery. The integration of both the battery and the fuel makes the vehicle dynamic, Fig 3 to Fig 5.

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Figure 5 **Actual Design of The Vehicle**

6. Simulation Setup and Scenarios

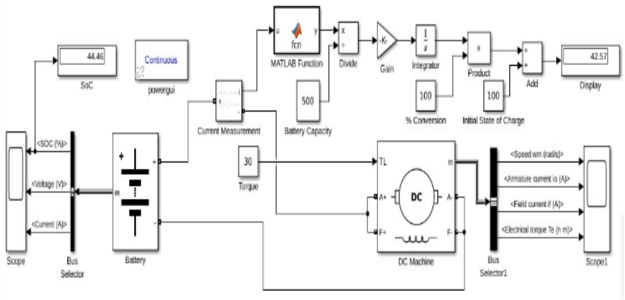

Figure 6 **Detail Design of BMS with SoC Estimation**

1. **Battery:** The battery is one of the primary components that provides electricity to the DC machine.
2. **DC Machine:** This device operates electrically on battery power.
3. **Blocks of Measurement:** Current Measurement: The current of the system is monitored for control and feedback reasons. The SoC, Voltage, and Current blocks are used to keep track of battery conditions.
4. **MATLAB Function Block:** It appears that this function computes both the torque and the battery capacity. It calculates a value using torque and battery information, which is subsequently processed by other blocks.
5. **Control Loop:** A division and multiplication operation is performed based on the battery capacity and system status. This signal is sent to an output after going through an integrator and a gain to ascertain the percentage conversion.
6. **Display Block:** Displays a calculated value (possibly the current SoC) along with relevant outputs, which include the state of charge (SoC).
7. **Initial Conditions**: Focusing on the battery's State of Charge (SoC) and the motor's operational efficiency under load, this simulation demonstrates the connectivity between a battery system and a DC motor. The battery, which supports the DC motor, has a capacity of 500 Ah and an initial state of charge of 16. 92%, Shown in Figure 6.

7. Results

7.1. State of Charge (SoC)

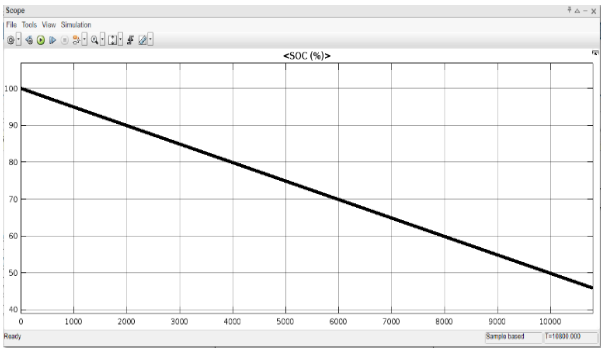

Figure 7 **SoC Output by using MATLAB Simulation**

It is essential for figuring out how much battery energy is left. State of Charge (SoC) % over time during a MATLAB Simulink simulation. Time is represented by the X-axis, which runs from 0 to 10,800 seconds, or around three hours, while the SoC is displayed as a percentage on the Y-axis, which starts at 100% and gradually drops to about 10, as shown in Figure 7.

7.2. Battery Voltage (V)

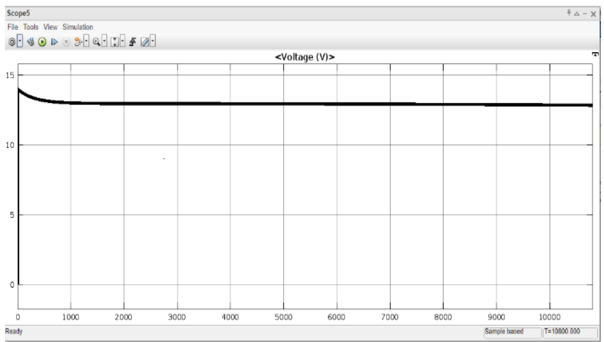

Figure 8 **Voltage Output by using MATLAB Simulation**

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The battery's voltage behaviours during the simulation are depicted in this graph. An early load or current surge may be the cause of the initial slight voltage drop. With just a very slight decrease over time, the voltage then stabilizes at 14–15 volts, representing the battery's discharge., as shown in Figure 8.

7.3. Battery Current (A)

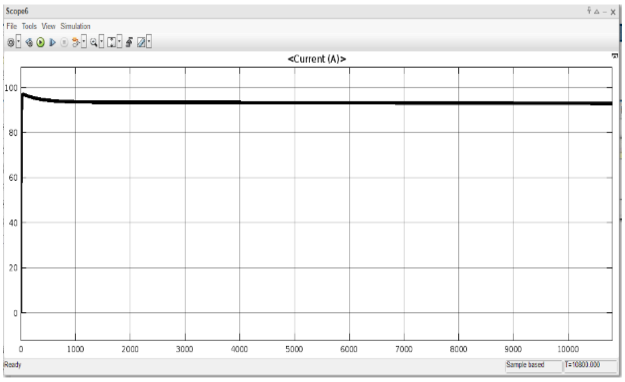

Figure 9 Current Output by using MATLAB Simulation

The constant current taken from the battery during the discharge process is seen in this graph. At first, there is a minor drop in current, which could be the result of initial load changes or system start up effects Minor load variations or changes in the battery's internal resistance could be the cause of the graph's slight oscillations, as shown in Figure 9.

7.4. Electrical Torque (Te)

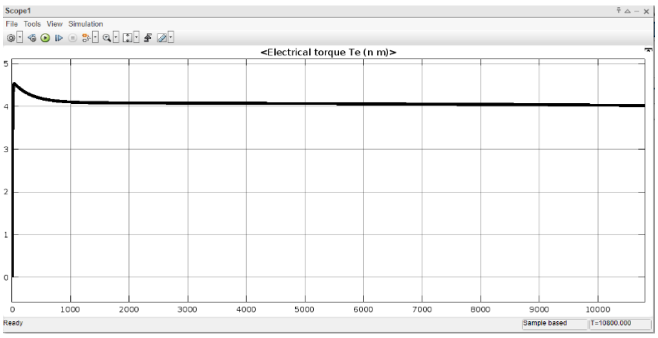

Figure 10 Electrical Torque Output by using MATLAB Simulation

The torque stabilizes at about 6 nm after this brief drop. It is largely consistent over the course of the simulation, suggesting that the electrical system is operating steadily and in balance, as shown in Figure 10.

7.5. Field Current (if)

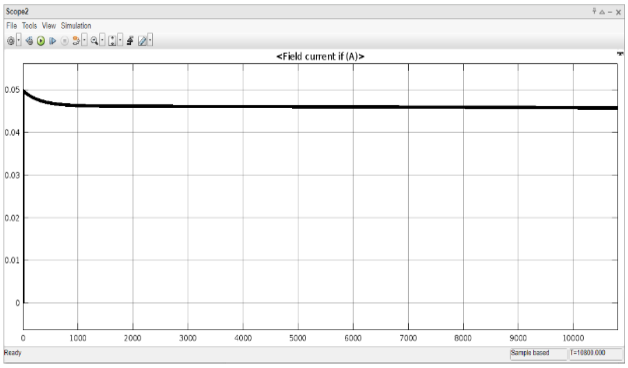

Figure 11 Field Current Output by using MATLAB Simulation

Current flowing through the DC machine's field winding affects the torque and speed control. The field current stabilizes over time, as the graph illustrates. As the system settles following start-up transients, there is a brief reduction in current at first. After that, the field current stays rather constant at around 0.045 A., as shown in Figure 11.

7.6. Armature Current (ia)

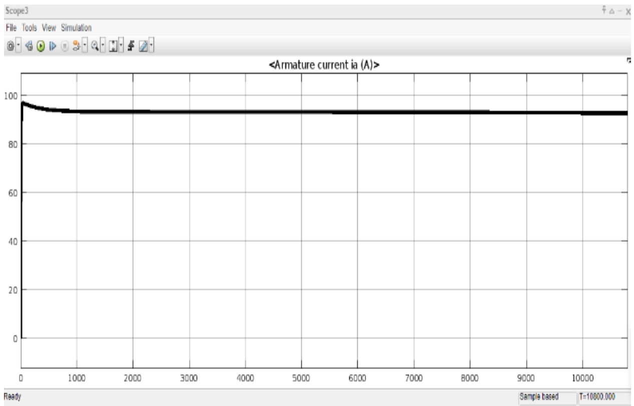

Figure 12 Armature Current Output by using MATLAB Simulation

The machine's electrical load is reflected in the current flowing through the armature winding. This graph illustrates how the armature current, expressed in amperes (A), changes over time. The plot suggests that the armature current first surges before levelling off at about 140, as shown in Figure 12.

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7.7. Speed (ωm)

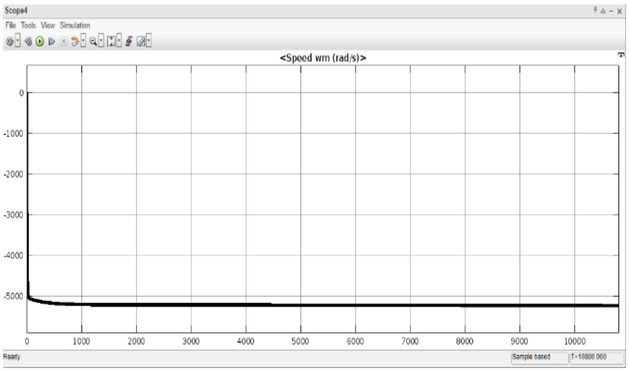

Figure 13 Speed Output by using MATLAB Simulation

Angular speed of the DC machine, usually in rad/s. This helps in evaluating the machine's rotational dynamics. This graph shows the Speed (ωm) in radians per second (rad/s) over time. The y-axis represents the rotational speed, ranging from -9000 to 1000 rad/s, while the x-axis represents time up to 10,800 units. The plot indicates that the speed starts at approximately -8000 rad/s and remains almost constant at that value throughout the time period., as shown in Figure 13.

7.8. SoC Parameters

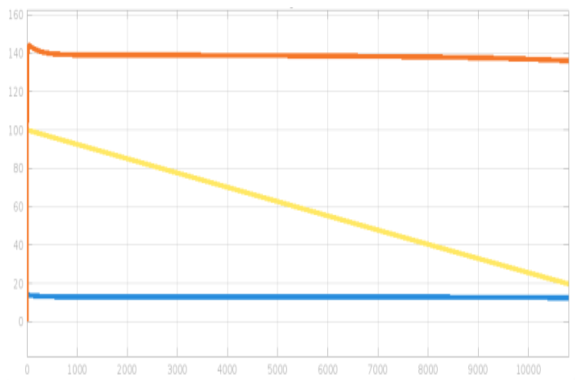

Figure 14 SoC Parameters

As the battery drains, the State of Charge (SoC) in yellow on the graph gradually drops. A regulated system is indicated by the voltage (blue) remaining comparatively constant throughout. As the battery drains, a lower load or adaptive current management may be indicated by the current (orange), which begins high and progressively drops. This illustrates how a managed power system would normally behave while under load, as shown in Figure 14.

7.9. DC Machine

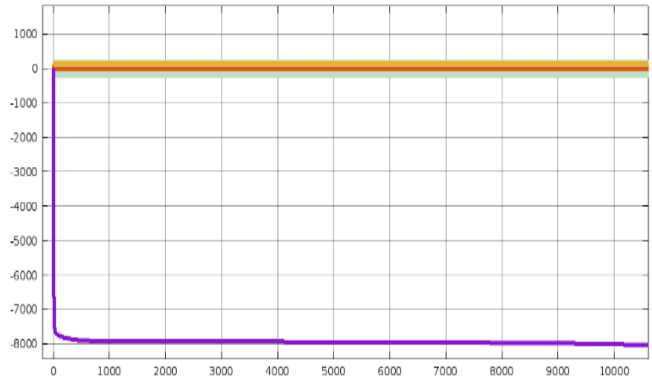

Figure 15 DC Machine Parameters

The graph shows how a DC motor's speed, electrical torque, field current, and armature current relate to one another. Field current is mostly constant as speed rises, although electrical torque and armature current fall. This trend is typical of DC motors, where the torque and current decrease at increasing speeds due to the back EMF produced by the revolving armature opposing the applied voltage, as shown in Figure 15.

Conclusion

The successful design and simulation of an Intelligent Battery Management System utilizing MATLAB Simulink in this work shows how battery performance may be effectively monitored and managed. To guarantee the best performance and longevity of batteries, the designed system effectively monitors vital factors like voltage, current, and temperature. In comparison to traditional BMS designs, the system offers a more dependable and robust solution by utilizing sophisticated algorithms, such as defect detection and state-of-charge calculation. According to the simulation results, the suggested method can improve battery operations' safety and efficiency, which qualifies it for use in electric cars, renewable energy systems, and other battery-powered gadgets.

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