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Vehicle Control Unit and Battery Management System for Range Extended Electric Vehicle (REEV)

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Abstract: **To ensure reliable performance and maintain the battery's health, the Battery Management System (BMS) constantly tracks key parameters such as voltage, temperature, state of charge, and fault conditions.**
At the same time, the Vehicle Control Unit (VCU) manages overall vehicle operations by efficiently distributing power between the internal combustion engine and the electric motor, regulating torque and vehicle speed, implementing regenerative braking, and ensuring smooth transitions between different driving modes.

Keywords: **Hybrid Electric Vehicles, Battery Management System, Vehicle Control Unit, Power Distribution, Regenerative Braking.**

INTRODUCTION

Range-Extended Electric Vehicles (REEVs) integrate an internal combustion engine (ICE) as a backup power source, complementing the primary electric drivetrain to enhance overall vehicle performance.This combination effectively addresses the range limitations of fully electric vehicles, enabling extended travel distances while maintaining high levels of efficiency and environmental friendliness.

At the heart of this system, the Vehicle Control Unit (VCU) orchestrates the distribution of power between the electric motors, battery, and internal combustion engine.By intelligently managing torque delivery, optimizing energy flow, regulating speed, enabling regenerative braking, and coordinating seamless transitions between drive modes, the VCU enhances both the performance and overall efficiency of the vehicle.

Working closely with the VCU, the Battery Management System (BMS) monitors key electrical parameters, ensures thermal stability, estimates remaining driving range, and protects against electrical faults, enhancing battery longevity and vehicle safety.

The coordinated operation of these systems greatly improves REEV reliability, enhances energy management, and supports environmental sustainability, fostering progress in next-generation eco-friendly vehicle technologies.

LITERATURE REVIEW

1. Gheorghe Livinţ et al. (2011) discussed how the adoption of regenerative braking systems, CAN-based communication networks, and reduced dependence on fossil fuels play a crucial role in enhancing energy efficiency and lowering environmental impact.

2. Mulugeta Gebrehiwot and Alex Van den Bossche (2015) noted that innovations like the use of lightweight engine designs and high-efficiency BLDC motors play a key role in enhancing the performance of REEVs by increasing energy density, reducing emissions, and minimizing noise, which is particularly advantageous for urban and specialized vehicular applications.
3. Priyanka et al. (2020) emphasized the vital role of the Battery Management System (BMS) in prolonging battery lifespan and ensuring safe operation. By effectively managing battery performance, the BMS not only increases the vehicle's driving range and reduces maintenance costs but also plays an essential role in advancing the development of a more sustainable and environmentally friendly transportation system.

NEED OF PROJECT

1. The BMS is fundamental in REEVs for overseeing the high-voltage battery system to ensure safe, efficient operations and to maximize the vehicle's driving range.
2. Through its ability to control charging and discharging cycles, maintain cell voltage balance, and adapt to varying operational conditions, the BMS safeguards both battery health and system reliability.
3 A tightly coordinated relationship between the BMS and VCU enables efficient power distribution, strengthens system robustness, and fosters the development of environmentally sustainable automotive technologies consistent with the latest HEV innovations.

PROPOSED METHODOLOGY

The proposed system features a smart Battery Management System (BMS) that actively oversees battery operations, employing real-time algorithms to estimate state of charge, manage temperature, and perform proactive cell balancing for optimal performance.

Moreover, the implementation of advanced motor control techniques—including regenerative braking and Field-Oriented Control (FOC)—optimizes energy recovery, extends driving range, and refines vehicle responsiveness.

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Such enhancements lead to improved internal energy circulation, helping maintain battery health and ensuring efficient, long-term vehicle operation.

The Vehicle Control Unit (VCU) interprets signals from multiple vehicle sensors and switches through its embedded microcontroller, facilitating accurate and real-time operational The vehicle's onboard interface dynamically communicates essential performance statistics, system alerts, and operational parameters to the driver, promoting an intuitive and informative user experience.

BLOCK DIAGRAM

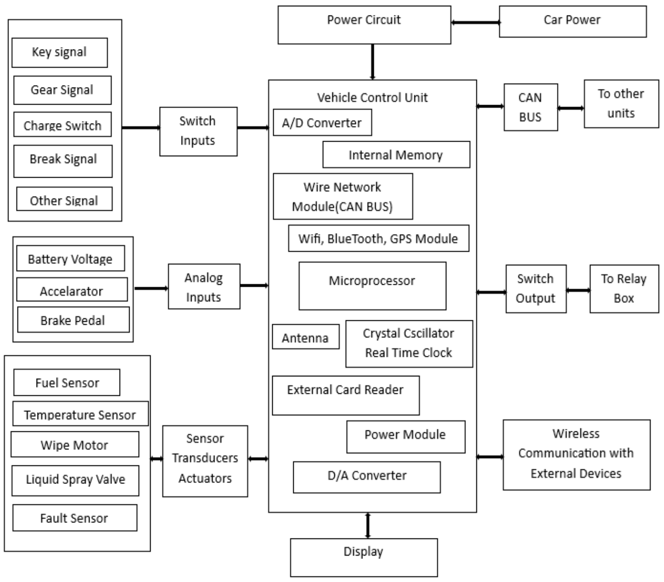

Fig.1: Block Diagram of The System

1. After activation, the Vehicle Control Unit (VCU) oversees the regulation and coordination of all major vehicle systems.
2. The VCU interprets input signals through its embedded processing unit, enabling real-time decision-making and system control.
3. The VCU utilizes its onboard microcontroller or processor to interpret incoming signals and determine the appropriate system responses.
4. Based on the processed data, the VCU controls actuators, electric motors, and other critical components of the vehicle.
5. Communication between the VCU and other onboard systems is managed through wireless technologies and the Controller Area Network (CAN) bus.
6. The vehicle's user interface or display panel provides real-time information and system status to the driver.

EQUATIONS FOR MOTOR AND BATTERY

1. Motor Equations:

$$P\ total = (m*g*u)*v + (0.5*c*a*d*v2)*v + (m*g*sin\ Q)*v$$

Where

P total= Total Power

m: mass of vehicle= 340kg

g: acceleration due to gravity= 9.81m/s2

u: rolling resistance= 0.01

a: frontal area= 1.1475m2

d: density of air= 1.2kg/m3

v: velocity=74kmph= 20.55m/s

Q: inclined angle= 3

$$Torque = 1000*60*P/2\pi*n$$

2. Battery Equations

*Total force =(m*g*u) +(0.5*c*a*d*v2) + (m*g*sin Q)*

*Battery capacity = Force(N) *range(km)/3600*

Force = Total force-gradient force

Energy consumption= P total(kw)/vehicle speed(miles/hr)

Electric range= Battery capacity/Energy consumption

ALGORITHM

algorithm of Hybrid Electric Vehicles

Step 1: Initialize system:

- Start HEV, set battery to 100%, generator OFF.

Step 2: Check Battery Percentage:

- Continuously check the battery percentage.
  - If battery SOC drop, note current battery Percentage.

Step 3: Battery Below 40 % (Trigger Generator ON)

- If the battery state of charge drops below 40%, the generator is automatically activated to recharge the battery.
- **Battery drops to 35% Example**

  For instance, if SOC reaches 35%, the generator starts supplying power.

Step 4: Generator Power Generation:

- Generator generates electricity at a certain rate.

Generator Output Calculation (basic idea):

$$P_{gen} = V_{charging} \times I_{charging}$$

Where:

$V_{charging}$ = Battery charging voltage

$I_{charging}$ = Charging current

Example:

- Charging voltage is approximately 54V, and current depends on system settings.
  - Current = 50A (Max charge current)

Thus,

$$P_{gen} = 54V \times 50A = 2700W = 2.7kWP$$

Step 5: Battery Charging Complete (80%)

- Monitor battery charging until SOC ≥ 80%.

Charging Time Calculation:

Time=Energy Needed (kWh) / Power Supplied (kW)

Suppose:

- Battery capacity = 4.6 kWh
- 40% to 80% = 40% of 4.6kWh = 1.84 kWh to be charged.

Thus,

Time=1.84/2.7=0.68 hours ≈ 41 minutes (approx.)

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Step 6*:* Motor Power Check

- Motor requires power for propulsion.

Motor Power Requirement (From Vehicle Motion Equations):

$$P_{total} = (m \times g \times u) \times v + (0.5 \times c \times A \times d \times v2) \times v + (m \times g \times \sin(\theta)) \times v$$

Given Values:

m=340 kg
g=9.81 m/s^2
u=0.01u
c=0.30
A=1.1475 m^2
d=1.2 kg/m^3
v=20.55 m/s (74 km/h)
θ=3∘

Calculating:

1. Rolling resistance power:

$$P_{roll} = (340 \times 9.81 \times 0.01) \times 20.55 = 685.77W$$

2. Aerodynamic drag power:

$$P_{aero} = (0.5 \times 0.30 \times 1.1475 \times 1.2 \times (20.55)^2) \times 20.55 = 4640.3W$$

3. Gradient resistance power:

$$P_{grad} = (340 \times 9.81 \times \sin(3^0)) \times 20.55$$

First, sin (3^0) ≈ 0.05234, thus

$$P_{grad} = (340 \times 9.81 \times 0.05234) \times 20.55 = 3597.2\ W$$

4.Total Power:

$$P_{total} = 685.77 + 4640.3 + 3597.2 = 8923.27\ W \approx 8.92\ Kw$$

Step 7: Power Source Selection:

- If generator ON, motor uses generator.
- If generator OFF, motor uses battery.

Step 8: Motor Propulsion:

- Motor input=selected power source output.

Example:

- If battery is supplying: pulling~8.92kWfrom battery

Energy consumption:

$$\text{Energy consumption} = P_{total}(kW) / \text{vehicle speed (mile/hr)}$$

Convert 74 km/h = 46 mph.

Thus:

$$\text{Energy consumption} = 8.92 / 46 = 0.194kWh/mile$$

Step 9: Repeat Until Operational:

Keep monitoring and updating the power source selection.

Step 10: Shutdown:

- When vehicle is OFF:
  Stop generator and motor propulsion

FLOW CHART

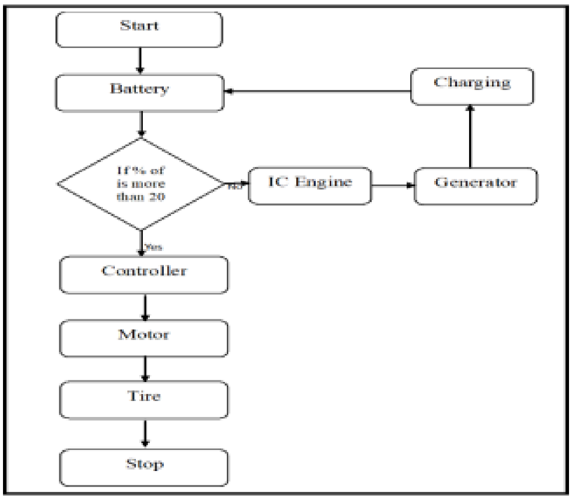

Fig.2: Flow Chart of the system

VCU TOPOLOGY: VEHICLE CAN BUS EXPLAINED

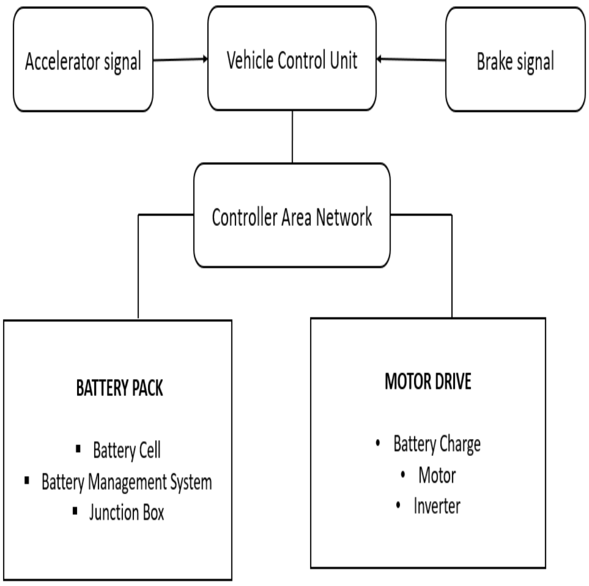

Fig.3: VCU TOPOLOGY

The main controller that oversees an electric vehicle's overall operation is called the Vehicle Control Unit (VCU). The VCU processes input from the accelerator and brake pedals and communicates with the Battery Pack and Motor Drive via the Controller Area Network (CAN).

It regulates the operation of the motors, manages battery usage, and ensures the efficient delivery of power in response to the driver's commands.

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ADVANTAGES

1) The VCU's unified control enhances the vehicle's performance, ensuring better stability and safety in diverse driving environments.
2) CAN facilitates effective communication between all major systems.
3) permits energy management, braking, and smooth acceleration.
4) Encourages the combination of hybrid and electric car technologies.
5) Supports improved motor efficiency and better battery utilization.

DISADVANTAGES

1) The intricate nature of the system may lead to longer design timelines, higher development costs, and more complex integration processes.
2) A major vehicle malfunction may result from a VCU failure.
3) VCU reliability demands detailed testing and strict quality checks.
4) Maintaining and troubleshooting the system requires the involvement of skilled and qualified professionals.

APPLICATIONS

1) Hybrid electric vehicles (HEVs) and electric vehicles (EVs).
2) Commercial electric buses and trucks.
3) Vehicles that are fully or partially autonomous.
4) Robotics and industrial electric machinery.
5) Used in next-generation electric vehicles designed with extended-range capabilities, such as Range-Extended Electric Vehicles (REEVs).

SPECIFICATIONS

1.Vehicle Control Unit: SECM70

Pin platform	70-Pin platform
Microprocessor	ST SPC5642A, 120 MHz
Memory	2 MB flash, 128 KB RAM, 16 KB serial EEPROM
Operating Voltage	8–32 V DC, 36 V (jump start), 5.5 V (crank)
Operating Temperature	–40 to +105 °C

Table 1: VCU technical specifications

2. CONNECTING KIT: GCM70 General Control Module

Component	Specification	Quantity
Terminals	0.63 mm, 18–20 AWG	80
Terminals	1.5 mm, 18–20 AWG	8
Female Connector	70-pin	1
Plugs	0.63 mm	15
Plugs	1.5 mm	5
Cover	For connector assembly	1

Table 2: Connecting Kit technical specifications

3. Battery: Lithium ion Battery Pack

Battery pack configuration	16S 6p
Battery nominal voltage	51.2 V
Battery capacity	90 Ah
Battery operating voltage	44.8V to 58V
Life cycle	2000
Casing type	Metal
Battery operating temperature	0ºC - 65ºC
Continuous discharge current	200A (can be change as per Rating)
Pulse discharge current	300A

Table 3: Battery pack technical specifications

FUTURE SCOPE

1. Create cutting-edge solid-state batteries to increase hybrid vehicles' driving range, lower their weight, and improve their energy density.
2. To facilitate recharging and promote the broad use of hybrid vehicles, increase the number of wireless charging stations in the network.
3. Incorporate autonomous driving capabilities into hybrid cars to improve consumer appeal, safety, and efficiency.
4. Use Vehicle-To-Grid (V2G) technology to enable hybrid cars to store extra energy and return it to the grid when demand is at its highest.

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RESULT

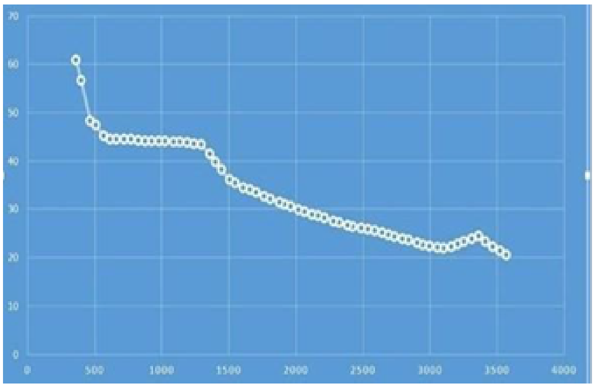

Fig 4: RPM VS Torque

Fig 5: Power Vs Torque

The graph presents the variation of torque across different power ratings.

By analyzing this graph, we can determine the specific power requirements corresponding to various torque outputs. This relationship is crucial for understanding the performance characteristics of the motor, helping in the selection of appropriate motor specifications to meet the desired torque and power demands at different operating conditions.

CONCLUSION

Hybrid Electric Vehicles (HEVs) offer an effective way to reduce fuel consumption and lower emissions. This project demonstrated how integrating electric motors with internal combustion engines improves overall efficiency and lessens environmental impact. The results support the idea that hybrid vehicles are a sustainable and practical transportation solution. Ongoing innovation and research will continue to make HEVs more efficient and eco-friendly. Embracing hybrid technology is crucial for balancing environmental responsibility with consumer convenience, paving the way for a cleaner and greener future in mobility.

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