

Hybrid Electric Vehicle (HEV)

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ABSTRACT

Hybrid Electric Vehicles (HEVs) combine an internal combustion engine (ICE) with an electric propulsion system to improve fuel efficiency, reduce emissions, and enhance overall vehicle performance. The hybrid EV car utilizes energy from conventional fuel and electrical sources, intelligently switching or combining power modes based on driving conditions. During low-speed or stop-and-go traffic, the electric motor operates independently, minimizing fuel consumption and exhaust emissions. At higher speeds or under heavy load, the internal combustion engine supports or takes over propulsion to ensure sufficient power output. Regenerative braking technology is employed to recover kinetic energy during deceleration and convert it into electrical energy, which is stored in the battery for later use. This dual-energy approach significantly reduces greenhouse gas emissions and dependency on fossil fuels compared to traditional vehicles. Hybrid EV cars offer a practical and transitional solution toward sustainable transportation by balancing environmental benefits, driving range, and cost-effectiveness without the need for extensive charging infrastructure.

Keywords: - Hybrid Electric Vehicle, Internal Combustion Engine, Electric Motor, Regenerative Braking, Fuel, Efficiency, Low Emissions, Sustainable Transportation etc.

1. INTRODUCTION

Hybrid Electric Vehicles (HEVs) represent a significant advancement in modern automotive technology by integrating an internal combustion engine (ICE) with an electric motor and energy storage system. Unlike conventional vehicles that rely solely on fossil fuels, HEVs utilize a combination of fuel and electrical energy to achieve improved efficiency, reduced emissions, and enhanced driving performance. The concept of hybridization allows the vehicle to intelligently manage power flow between the engine and the electric motor depending on driving conditions such as speed, load, and battery state of charge. In an HEV, the electric motor assists the internal combustion engine during acceleration and low-speed driving, where fuel engines are typically less efficient. At idle or during slow traffic conditions, the vehicle can operate in electric-only mode, thereby reducing fuel consumption and tailpipe emissions. When higher power is required, both the engine and motor work together to provide optimal performance. Additionally, HEVs are equipped with regenerative braking systems that capture energy normally lost during braking and convert it into electrical energy to recharge the battery. This feature further improves energy efficiency and reduces overall energy wastage. Hybrid Electric Vehicles do not require external charging infrastructure, as the battery is charged through regenerative braking and engine operation. This makes HEVs a practical and accessible solution for reducing environmental impact while maintaining the driving range and convenience of traditional vehicles.

With increasing concerns over fuel scarcity, rising pollution levels, and climate change, HEVs serve as a crucial transitional technology toward fully electric and sustainable transportation systems..

1.1 OBJECTIVE

- To improve fuel efficiency
- To reduce exhaust emissions
- To utilize regenerative braking
- To optimize power management
- To decrease dependency on fossil fuels.
- To enhance vehicle performance
- To develop a cost-effective and practical solution
- To promote sustainable transportation

2. LITERATURE SURVEY

- **Viswanath, M., Arunraja, K. M., & Lakshan Raaj, K. et al. (2018)** A Literature Review on Hybrid Electric Vehicles This paper provides an overview of hybrid vehicle technology, highlighting the evolution, advantages, and role of HEVs in reducing fuel consumption and emissions compared with conventional vehicles.
- **Singh, K. V., Bansal, H. O., & Singh, D. et al. (2019)** A Comprehensive Review on Hybrid Electric Vehicles: Architectures and Components Discusses various hybrid architectures and key components such as power electronics, energy storage systems, and traction motors, emphasizing design challenges and efficiency improvements.
- **Talari Krishnaiah et al. (2022)** A Review on Hybrid Electrical Vehicles This work surveys HEV technology with an emphasis on emissions reduction, energy conservation, and the necessity of HEVs due to environmental challenges posed by internal combustion engine vehicles.
- **D. Upadhaya, G. Roy, P. Das, S. Ghosh, et al. (2024)** A Review on Hybrid Electric Vehicles Using Various Energy Storage Reviews the use of different energy storage technologies in HEVs, reflecting more recent developments in renewable energy integration and storage methods.
- **Parveen Kumar & Deepak Kumar et al. (2021)** A Review on the Development in Hybrid Electric Vehicle Focuses on the evolution and current developments in HEVs, including an examination of power splitting strategies between the electric motor and engine to improve fuel efficiency.
- **Sushil Kumar Tripathi & Ajay Agrawal et al. (2021)** Hybrid Electric Vehicles and Their Challenges: A Review Investigates various aspects of HEVs including alternative energy sources (battery, fuel cells, supercapacitors), challenges in implementation, and future prospects.
- **Rogelio León, Christian Montaleza, José Luis Maldonado et al. (2021)** Hybrid Electric Vehicles: A Review of Existing Configurations and Thermodynamic Cycles Reviews different configurations and thermodynamic operating cycles of HEVs, offering insight into system efficiency and performance.

3. HARDWARE PARTS OF SYSTEM

A Hybrid Electric Vehicle (HEV) consists of mechanical, electrical, and electronic hardware components that work together to deliver efficient and low-emission transportation. The major hardware parts are listed below:

- **INTERNAL COMBUSTION ENGINE (ICE):**

The ICE is the conventional fuel-powered engine (petrol or diesel) used in HEVs. It provides power during high-speed driving, heavy load conditions, and also assists in charging the battery when required. An internal combustion engine (ICE or IC engine) is a heat engine in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to components of the engine. The force is typically applied to pistons (piston engine), turbine blades (gas turbine), a rotor (Wankel engine), or a nozzle (jet engine). This force moves the component over a distance. This process transforms chemical energy into kinetic energy which is used to propel, move or power whatever the engine is attached to.

- **BATTERY BANK**

A rechargeable battery stores the energy generated by the solar panel. This stored energy ensures uninterrupted operation during nighttime or cloudy conditions. The battery acts as a backup power source for continuous system functionality. A rechargeable battery, storage battery, or secondary cell (formally a type of energy accumulator) is a type of electric battery which can be charged, discharged into a load, and recharged many times, as opposed to a disposable or primary battery, which is supplied fully charged and discarded after use. It is composed of one or more electrochemical cells.



The term "accumulator" is used as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–acid, zinc–air, nickel–cadmium (NiCd), nickel–

metal hydride (NiMH), lithium-ion (Li-ion), lithium iron phosphate (LiFePO₄), and lithium-ion polymer (Li-ion polymer)

- **CHARGE CONTROLLER:**

The charge controller regulates the voltage and current coming from the solar panel to the battery. It prevents overcharging, deep discharging, and improves battery life while maintaining safe power levels for the system.



- **MOTOR (DC MOTOR / SERVO MOTOR)**

A Direct Current (DC) motor is a motor that turns energy from a direct current and turns this into mechanical energy. The first DC motor was developed around the 1830's-1840s. They were commercially unsuccessful, because these motors were battery powered and batteries were still very expensive and the quality was low.

- **LCD (LIQUID CRYSTAL DISPLAY)**

LCD (Liquid Crystal Display) is an electronic display device widely used in applications such as mobile phones, calculators, computers, televisions, and embedded systems. LCDs are preferred over multi-segment LEDs and seven-segment displays due to their low cost, ease of programming, ability to display custom characters, and support for simple animations. Compared to CRT displays, LCDs are thinner, lighter, and consume significantly less power. A 16×2 LCD operates by blocking light rather than emitting it, making it energy efficient and suitable for compact electronic devices.



- **TRANSMISSION SYSTEM**

The transmission transfers power from the engine and/or electric motor to the wheels. HEVs commonly use automatic, continuously variable transmission (CVT), or power-split transmission systems for smooth operation. A transmission system is a mechanism that transfers power, most commonly from an engine to wheels in vehicles, by changing speed and torque using gears, clutches, and shafts, allowing for different driving conditions like starting, accelerating, and cruising. In telecommunications, it's a system (cables, wireless, optical) that sends signals (electrical, light, radio) from one point to another, like the internet or phone networks. Both types focus on efficiently moving energy or data from a source to a destination.

- **REGENERATIVE BRAKING SYSTEM**

This system captures energy during braking and deceleration, converting it into electrical energy that is stored in the battery. It significantly improves energy efficiency and reduces brake wear. A regenerative braking system captures kinetic energy (motion) that's usually lost as heat during traditional braking, converting it into electricity to recharge a vehicle's battery, thus improving efficiency and range, especially in electric (EVs) and hybrid vehicles. When braking, the electric motor reverses its function, acting as a generator to create electrical energy from the wheels' rotation, which is then stored for later use in propulsion. It works alongside conventional brakes, providing a smoother deceleration and enabling "one-pedal driving" in some EVs by slowing the car as the driver lifts off the accelerator.

4. WORKING & IMPLEMENTATION

A Hybrid Electric Vehicle (HEV) operates by intelligently combining the power of an internal combustion engine (ICE) and an electric motor to achieve high efficiency, reduced emissions, and smooth vehicle performance. At the start of the vehicle or during low-speed driving conditions such as city traffic, the electric motor primarily powers the vehicle using energy stored in the battery pack. This eliminates fuel consumption and exhaust emissions during idle and slow movement. When the driver accelerates or when higher power is required, the hybrid control unit activates the internal combustion engine to work alongside the electric motor, providing additional torque and improved acceleration. During steady cruising at moderate to high speeds, the vehicle mainly relies on the internal combustion engine, as it operates more efficiently under such conditions. Simultaneously, excess engine power may be used to recharge the battery through the motor acting as a generator. When the vehicle decelerates or the brakes are applied, the regenerative braking system comes into

action. In this process, the electric motor operates in reverse mode as a generator, converting the vehicle's kinetic energy into electrical energy that is stored in the battery. This recovered energy is later reused for propulsion, reducing overall energy loss. The hybrid control unit continuously monitors vehicle speed, battery charge level, driver demand, and road conditions to determine the most efficient power source at any moment. Power electronics such as inverters and converters manage the energy flow between the battery, motor, and auxiliary systems. Through this coordinated operation, the HEV ensures optimal fuel economy, lower emissions, and reliable performance without the need for external battery charging.

5. CONCLUSIONS

The Hybrid Electric Vehicle (HEV) project demonstrates an effective and practical approach to improving fuel efficiency and reducing environmental impact by integrating an internal combustion engine with an electric propulsion system. Through intelligent power management, regenerative braking, and optimized energy utilization, HEVs significantly reduce fuel consumption and exhaust emissions compared to conventional vehicles. The system offers smooth performance, enhanced acceleration, and extended driving range without the need for external charging infrastructure. As a transitional technology between traditional fuel-powered vehicles and fully electric vehicles, Hybrid Electric Vehicles play a vital role in promoting sustainable transportation while maintaining reliability, affordability, and user convenience.

6. REFERENCES

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