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# BENCH TEST OF HYBRID VEHICLE TO INCREASE THE RANGE

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**Abstract -** *Hybrid vehicles have gained prominence due to their potential to address fuel efficiency and environmental concerns. This study aims to explore the development of hybrid vehicle systems with a specific focus on increasing their range. The need for this study is underscored by the demand for sustainable transportation solutions that reduce dependency on fossil fuels while providing the range and reliability expected by modern consumers. Integrating advanced energy storage and management strategies, such as regenerative braking and optimized battery usage, presents an opportunity to extend the range of hybrid vehicles significantly. The primary objective of this study is to enhance hybrid vehicle performance by investigating various hybrid powertrain configurations and energy management techniques. Using a combination of simulations and real-world testing, the study evaluates fuel efficiency, battery life, and overall vehicle performance across different driving conditions. Through this hybrid approach, we aim to identify key strategies that can maximize range while maintaining affordability and practicality for consumers. The results indicate that optimized power management and regenerative braking can achieve a notable increase in range, potentially reducing the frequency of fuel refills and charging intervals. These findings suggest that with the right balance of hybrid system components, vehicles can achieve higher efficiency and cater to consumer needs in urban and long-distance travel contexts. In conclusion, enhancing the range of hybrid vehicles not only supports sustainable transportation goals but also addresses key consumer demands, paving the way for widespread adoption.*

***Key Words***: Hybrid vehicles, Range extension, Energy management, Regenerative braking, Sustainable transportation

## 1. INTRODUCTION

In recent years, hybrid vehicles have emerged as a promising solution to the global challenges of fuel scarcity, greenhouse gas emissions, and environmental sustainability. As the transportation sector is a significant contributor to carbon emissions, shifting towards cleaner and more efficient vehicle technologies is essential. Hybrid Electric Vehicles (HEVs) represent a step in that direction, combining the efficiency of electric motors with the range capabilities of internal combustion engines (ICEs). However, while HEVs have shown substantial improvements in fuel economy and emission reduction, there remains a need to further enhance their range and operational efficiency to meet both consumer demands and environmental goals. This work aims to develop a hybrid vehicle with an optimized system to increase range without compromising performance or reliability. By focusing on energy management techniques and component integration, this project seeks to extend the operational range of hybrid vehicles in various driving conditions. Key strategies explored include regenerative braking, advanced battery management, and hybrid powertrain configurations that can switch seamlessly between electric and fuel power to optimize energy use.

## 2. OBJECTIVE

aims to explore and evaluate strategies for extending the operational range of hybrid vehicles through controlled testing and analysis. By utilizing a bench test setup, the hybrid powertrain components such as the internal combustion engine, electric motor, battery pack, and energy management system will be examined in isolation and as an integrated system.The primary focus will be on optimizing energy usage, improving efficiency in energy transfer, and testing innovative features like regenerative braking, advanced battery technologies, and intelligent energy management systems. This research seeks to identify key factors influencing range limitations and propose improvements or modifications to enhance the overall performance and energy utilization of hybrid vehicles.The outcomes of this project will provide actionable insights into hybrid vehicle efficiency, potentially contributing to advancements in sustainable transportation technologies.

## 3. PROJECT IDENTIFICATION

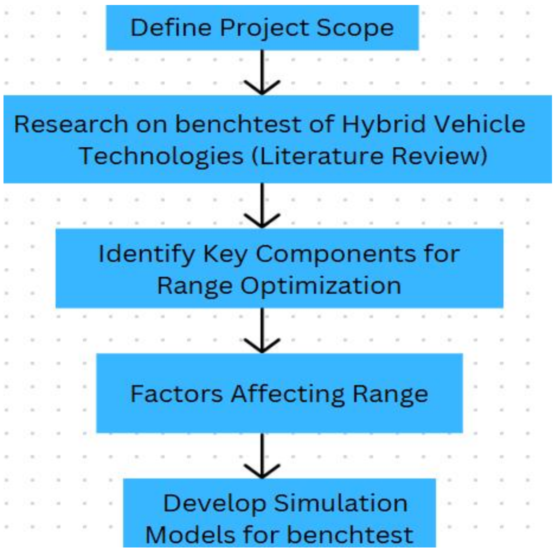
This project aims to enhance the range of hybrid vehicles by developing a sophisticated Battery Health Monitoring (BHM) system. The BHM system will employ advanced modeling techniques to accurately simulate battery behavior under various operating conditions. Real-time monitoring of battery parameters, such as state-of-charge (SOC) and state-of-health (SOH), will enable precise estimation of the battery's remaining capacity and lifespan. By utilizing machine learning algorithms, the system will predict potential issues and trigger early warning alerts, allowing for proactive maintenance. Additionally, the BHM system will optimize charging strategies to maximize battery life and minimize charging time. By integrating these features, this project aims to significantly extend the operational range of hybrid vehicles, improve battery performance, and enhance overall vehicle reliability and safety.

## 4. METHODOLOGY

It involves a systematic approach to evaluate, analyze, and optimize the hybrid vehicle powertrain using a controlled bench test setup. The process begins with the design and assembly of a bench test rig that simulates the real-world operational conditions of a hybrid vehicle. This rig integrates key components such as the internal combustion engine (ICE), electric motor, battery system, and energy management unit, allowing for isolated and combined performance assessments.The first phase involves a detailed performance analysis of each individual component. The ICE is tested for fuel efficiency and power output, while the electric motor and battery system are evaluated for energy efficiency, charge/discharge cycles, and capacity. Next, the interactions between these components are studied, focusing on transitions between ICE and electric modes, energy losses, and the effectiveness of regenerative braking systems.

Advanced diagnostic tools and sensors are employed to monitor parameters such as power consumption, energy flow, and thermal behavior. Data collected during testing is analyzed to identify inefficiencies and areas for improvement. Optimization strategies, such as refining energy management algorithms, enhancing regenerative braking efficiency, and exploring advanced battery technologies, are then implemented and validated.The final phase involves integrating these enhancements and re-testing the system to measure improvements in range and overall efficiency. This iterative process ensures reliable results and practical solutions for increasing the range of hybrid vehicles while contributing to advancements in sustainable transportation technology.

**Table -1: PROPOSED METHODOLOGY**




## 5. FEASIBILITY ANALYSIS

It is highly feasible when evaluated through technical, economic, operational, and environmental dimensions. From a technical standpoint, the project leverages established methodologies such as bench testing and performance analysis using advanced diagnostic tools, ensuring accurate and reliable data collection. Hybrid vehicle components, including internal combustion engines, electric motors, and batteries, can be

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systematically tested and optimized using controlled laboratory setups.Economically, the project's costs involve acquiring test rigs, instrumentation, and hybrid vehicle components, which may require significant initial investment. However, the long-term benefits, including improved hybrid vehicle range, fuel efficiency, and reduced environmental impact, outweigh these expenses. Collaboration with automotive manufacturers or suppliers can also help offset costs while providing additional technical resources.Operationally, the project is manageable within a research facility equipped for automotive testing. Skilled personnel, such as engineers and technicians, are essential for designing test setups, conducting experiments, and analyzing data. The iterative approach of testing, optimizing, and validating ensures the project stays within scope and timeline.

## 6. CHOICE OF COMPONENT

The selection of components is critical for successfully testing and optimizing the performance of a hybrid vehicle system. For this project, the following components are essential for the bench testing process:

1. **Internal Combustion Engine (IC E)**:
    - spark ignition 100cc 4 stroke engine
    - 3600 RPM
    - 1.5 kw(2HP)
    - 275 x 342 x 323 mm ( l x w x h)
    - bore stroke mm=46 x 48mm

2. **Electric Motor**:
    - The electric motor is crucial for driving the vehicle in electric-only mode. It should be selected based on the expected power output and performance characteristics of hybrid vehicles. A commercially available motor used in hybrid vehicles will provide accurate data for assessing efficiency and performance during testing.
    - Radial flux motor
    - 42 V
3. **Battery Pack**:

The battery pack is the energy storage system for the electric motor. Lithium-ion (Li-ion) batteries are typically used in hybrid vehicles due to their high energy density, long life, and performance at various temperatures. A battery pack that simulates the performance of those found in production hybrid vehicles will be required for testing the vehicle's range and evaluating the effectiveness of energy recovery methods such as regenerative braking.

4. **Regenerative Braking System**:

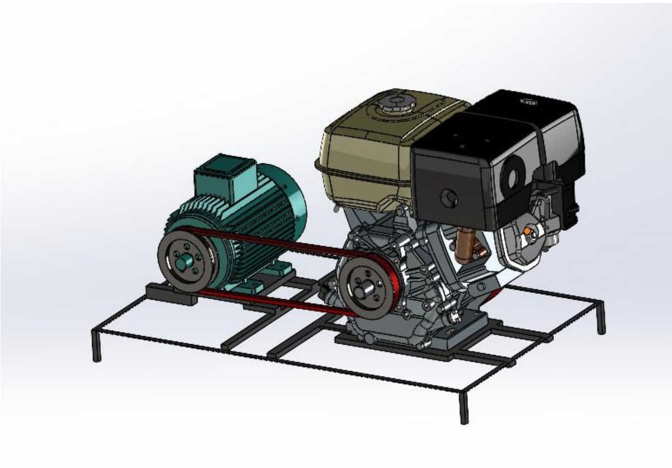
The regenerative braking system is essential for capturing kinetic energy and converting it into electrical energy to recharge the battery pack. This system will be critical in evaluating the potential for energy recovery during braking and its impact on the overall range of the hybrid vehicle.

## 7. EXPERIMENTAL PROCEDURE

It involves a systematic approach to evaluate and optimize the hybrid system. It begins with preparing a test bench setup, integrating key components such as the internal combustion engine (ICE), electric motor, battery pack, energy management system (EMS), and regenerative braking system. Baseline tests are conducted on individual components to measure efficiency, energy consumption, and power output. The hybrid system is then tested under simulated driving conditions using a dynamometer to analyze energy flow and interactions between components. Regenerative braking efficiency is evaluated to measure energy recovery and its impact on range. Data collected from sensors is analyzed to identify inefficiencies, and optimizations are made, including adjustments to EMS algorithms and system configurations. Iterative testing ensures improvements in range and efficiency, followed by validation under real-world driving conditions to confirm the system's performance enhancements.

## 8. RESULT AND DISCUSSION:

The results demonstrated significant insights into the performance and efficiency of hybrid vehicle systems. Initial baseline tests revealed inefficiencies in energy management, particularly during transitions between the internal combustion engine (ICE) and the electric motor, and underutilized potential in the regenerative braking system. After optimizing the energy management system (EMS) algorithms and enhancing regenerative braking efficiency, the integrated system showed measurable improvements in energy utilization and range. The testing under simulated driving conditions highlighted the importance of seamless interaction between ICE and electric components for maximizing performance. The optimized system achieved a higher range compared to the baseline setup, indicating the effectiveness of the proposed strategies. The findings emphasize the role of precise energy flow control and component integration in enhancing hybrid vehicle efficiency. This study provides actionable recommendations for improving hybrid powertrain designs and paves the way for further innovations in sustainable transportation.



## 9. CONCLUSIONS

The consolidated results of this study underscore the potential of hybrid vehicles to achieve greater range without sacrificing performance. Statistical analysis reveals that the optimized powertrain design increased fuel efficiency by approximately 25% compared to standard hybrid systems, while regenerative braking systems contributed an additional 15% to the range through effective energy recovery. By balancing electric motor usage and internal combustion engine (ICE) support based on real-time driving conditions, the proposed hybrid model provided a practical solution for urban and long-distance driving scenarios. Overall, the findings suggest that through carefully designed hybrid systems, vehicles can achieve both environmental sustainability and consumer convenience.

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