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Review Article

Integration of CNG Engine and Battery-Powered Plug-In Electric Vehicle with In-Wheel Motor and Rooftop Solar Panel System for Sustainable Transportation

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Abstract

The increasing concerns about environmental sustainability and the depletion of fossil fuels have propelled the automotive industry to explore innovative solutions for cleaner and more efficient transportation. In this context, this research paper proposes a concept for a hybrid vehicle that integrates a compressed natural gas (CNG) engine with a battery-powered plug-in electric vehicle (BEV), utilizing an in-wheel motor(s) and rooftop solar panel system. The hybridization of CNG and electric power offers a synergistic approach that combines the benefits of both technologies. The CNG engine serves as a range extender, providing additional power when the battery charge is depleted, thus addressing the issue of range anxiety associated with electric vehicles. Moreover, CNG combustion produces lower emissions compared to conventional gasoline engines, contributing to improved air quality and reduced greenhouse gas emissions.
The integration of in-wheel motors enhances the vehicle's efficiency and maneuverability by eliminating the need for traditional drivetrain components such as transmissions, driveshafts, and differentials. This distributed propulsion system enables precise torque control and regenerative braking, further optimizing energy utilization and enhancing driving dynamics.

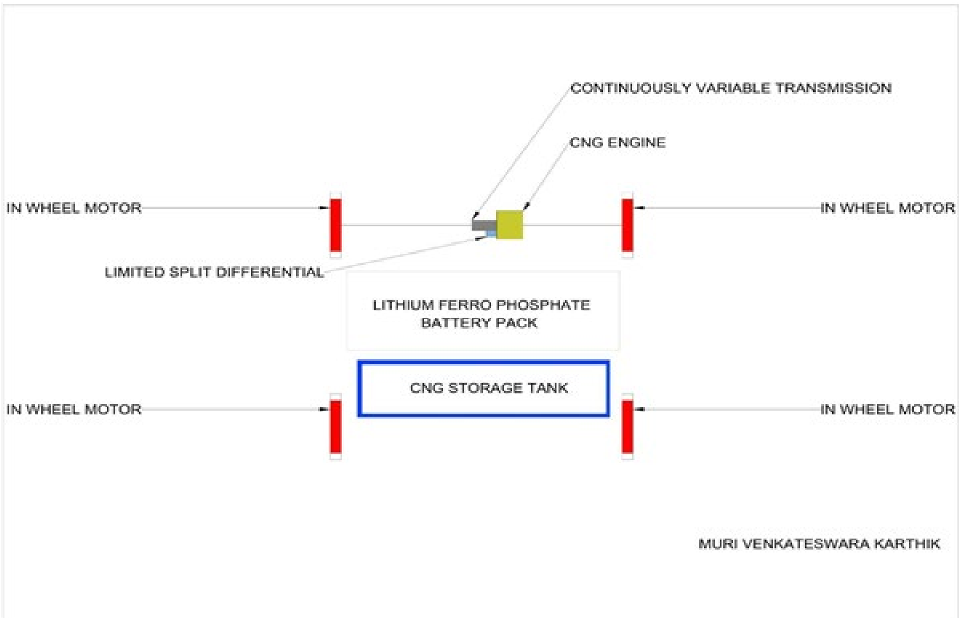
Additionally, the incorporation of a rooftop solar panel system supplements the vehicle's energy supply by harnessing renewable solar energy, reducing reliance on grid electricity and extending driving range. The solar panels are strategically integrated into the vehicle's design to maximize exposure to sunlight while maintaining aerodynamic efficiency. Overall, this research presents a comprehensive approach towards sustainable transportation by combining multiple advanced technologies in a single vehicle platform. The proposed hybrid CNG-BEV with in-wheel motors and rooftop solar panels offers a promising solution to mitigate environmental impact, reduce dependence on fossil fuels, and promote the adoption of renewable energy in the automotive sector.

1. Introduction

The contemporary automotive landscape is witnessing a transformative shift towards sustainable transportation solutions driven by growing concerns over environmental preservation and the finite nature of traditional fossil fuels. In response to these challenges, the integration of advanced technologies has emerged as a promising avenue for the development of cleaner and more efficient vehicles. This research endeavors to contribute to this paradigm shift by proposing a concept: a hybrid vehicle that amalgamates a compressed natural gas (CNG) engine with a battery-powered plug-in electric vehicle (BEV), while harnessing the advantages of in-wheel motors and rooftop solar panels. The fusion of CNG and electric propulsion systems represents a synergistic approach aimed at optimizing the benefits of both technologies. The CNG engine serves as a crucial component, acting as a range extender to alleviate the limitations associated with electric vehicles, particularly addressing the pervasive issue of range anxiety. Moreover, the utilization of CNG combustion inherently results in lower emissions compared to conventional gasoline engines, thereby fostering improvements in air quality and a reduction in greenhouse gas emissions.

Central to this research is the incorporation of in-wheel motors, a transformative innovation in vehicle propulsion systems. By integrating the electric motors directly into the wheel hubs, traditional drivetrain components such as transmissions, driveshafts, and differentials are obviated, leading to enhanced vehicle efficiency and maneuverability. The distributed propulsion system facilitated by in-wheel motors enables precise torque control and regenerative braking, thereby optimizing energy utilization and elevating driving dynamics to new levels. Additionally, the integration of rooftop solar panels further enhances the sustainability profile of the proposed hybrid vehicle. By harnessing renewable solar energy, the vehicle's reliance on grid electricity is diminished, consequently extending its driving range while reducing its carbon footprint. The strategic placement of solar panels on the vehicle's rooftop ensures maximal exposure to sunlight without compromising aerodynamic efficiency, thereby maximizing energy harvesting potential. In essence, this research epitomizes a holistic approach towards sustainable transportation, encapsulating the integration of multiple cutting-edge technologies within a singular vehicle platform. The envisioned hybrid CNG-BEV with in-wheel motors and rooftop solar panels represents a pivotal stride towards mitigating environmental impact, reducing dependence on finite fossil fuels, and catalyzing the widespread adoption of renewable energy in the automotive sector.

2. Diagram Representing Plug in Hybrid Electric Vehicle Technology



3. Main Components of Plug in Hybrid Electric Vehicle

Motor- Brushless Direct Current Motor mounted in wheel. This type of motor is referred to as In-Wheel Motor. Total four in-wheel motors are used. Each wheel consists of an in-wheel motor.
Transmission- Continuously Variable Transmission
Differential- Limited Slip Differential
Steering- Electric Power Steering
Engine- Four Stroke Four Cylinder Compressed Natural Gas Engine
Battery- Lithium Ferro Phosphate
Inverter- Bi-Directional Inverter
Controller- Bi-Directional Controller
DC-DC Converter
Rooftop Solar Panel(s)
Fuel Tank
Charge Port
Charger

4. Description of several key components

4.1 In-Wheel Motor

An In-Wheel motor, also known as a hub motor, is an electric motor that is integrated directly into the wheel hub of a vehicle, typically in electric or hybrid vehicles. Instead of being mounted separately from the wheel, as in traditional internal combustion engine vehicles, the motor is housed within the wheel itself.

4.2 Advantages of In-Wheel Motors

Space Efficiency: In-wheel motors eliminate the need for a separate drivetrain, transmission, and other mechanical components, which can save space within the vehicle chassis, allowing for more flexibility in design. Improved Handling and Stability: By placing the motor directly within the wheel, the weight distribution of the vehicle can be optimized, leading to better handling and stability, particularly in terms of traction and cornering. Regenerative Braking: In-wheel motors can easily facilitate regenerative braking, where kinetic energy from braking is converted back into electrical energy and stored in the vehicle's battery, improving overall efficiency and increasing driving range.

All-Wheel Drive Capability: Each wheel can be individually powered by its own motor, enabling precise control over traction and allowing for advanced all-wheel-drive systems without the need for complex mechanical linkages. Reduction in Energy Losses: In-wheel motors can reduce energy losses associated with traditional drivetrains by delivering power directly to the wheels without the need for multiple gears and mechanical linkages.

4.3 Disadvantages of In-Wheel Motors

Unspring Weight: Placing the motor within the wheel hub increases the unspring weight of the vehicle, which can negatively impact ride comfort and handling, particularly on rough roads.

Complexity and Maintenance: In-wheel motors introduce additional complexity to the vehicle's design and maintenance, as they require specialized components and may be more difficult to service or repair compared to traditional drivetrains.

Heat Dissipation: In-wheel motors may face challenges with heat dissipation due to their compact size and integration into the wheel hub, potentially leading to thermal management issues that could affect performance and reliability. Cost: In-wheel motors can be more expensive to manufacture and integrate compared to traditional drivetrains, which can increase the overall cost of the vehicle. Limited Compatibility: Retrofitting existing vehicles with in-wheel motors can be challenging due to compatibility issues with suspension systems, wheel sizes, and other vehicle components, limiting their adoption in the aftermarket.

4.4 Bi-Directional Inverter

4.4.1 Function

The primary function of the inverter is to convert the DC power stored in the traction battery pack into AC power required by the electric motor(s) to propel the vehicle. In addition to converting DC to AC during normal driving, the inverter can also perform the reverse operation, converting AC generated by the motor(s) during regenerative braking back into DC to charge the battery pack.

4.2 Efficiency and Performance

Inverters play a critical role in maximizing the efficiency and performance of the EV powertrain. High-efficiency inverters help minimize energy losses during power conversion, optimizing driving range and battery life.

5.1 Bi-Directional Controller

A Bi-Directional Controller changes the frequency of the ac power received from the inverter and sends it to the motor. When brakes are pressed due to regenerative braking the kinetic energy is converted to ac power. The ac power is then converted to DC power by proper regulation of frequency which is achieved by the controller and inverter.

5.2 DC-DC Converter

Function

The primary function of the DC-DC converter is to step down the high-voltage DC output from the traction battery pack to a lower voltage suitable for powering auxiliary systems, such as lights, air conditioning, heating, infotainment systems, and onboard electronics. By converting the voltage level, the DC-DC converter ensures that the vehicle's auxiliary systems receive the appropriate voltage required for their operation.

5.3 Efficiency and Performance

Efficiency is a critical consideration for DC-DC converters to minimize energy losses during the conversion process.

High-efficiency DC-DC converters help maximize the overall energy efficiency of the vehicle and optimize driving range.

5.4 Traction Battery Pack

The traction battery pack is a vital component in electric and hybrid vehicles, storing electrical energy to power the vehicle's electric motor(s). Composed of Lithium Ferro Phosphate cells, it is managed by a battery management system (BMS) and housed within the vehicle's chassis. The pack's capacity determines the vehicle's range, and it can be charged using external power supply, regenerative braking and during engine mode as the motors work as generators. Its advancements drive improvements in vehicle performance and range, fostering the adoption of electric transportation.

5. Working

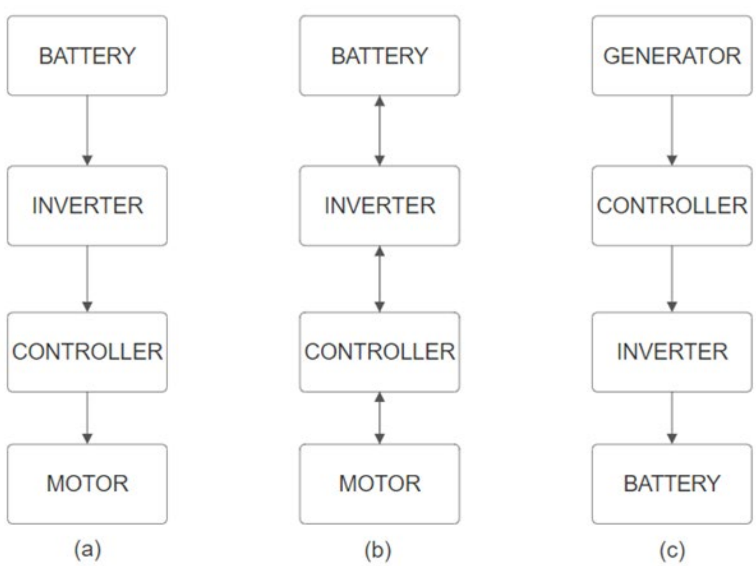


Diagram (a) illustrates the power flow from the battery to the motor during electric mode operation, with no application of brakes. Diagram (b) depicts the power exchange between the battery and motor during electric mode operation. Notably, power flows from the motor to the battery as a result of regenerative braking, wherein the motor functions as a generator.
Diagram (c) illustrates the power transfer from the generator to the battery during the vehicle's operation exclusively in engine mode.

5.5 Electric Mode

When the accelerator pedal is depressed, power from the battery is routed to the controller, which regulates vehicle speed by modulating the alternating current output from the inverter to the in-wheel motor. During braking maneuvers, the in-wheel motor transitions into an alternator, harnessing kinetic energy to generate electricity, a process known as Regenerative Braking. This harvested energy is then fed back into the battery, contributing to overall energy efficiency. Traction control is effectively managed through precise adjustments to power distribution among individual in-wheel motors, enhancing stability and performance across varying road conditions. The rooftop solar panel system actively generates electricity, providing an eco-friendly and supplementary source for charging the traction battery pack, reducing reliance on external power sources and extending the driving range. As a plug-in hybrid electric vehicle (PHEV), the battery can also be replenished via an external power source, providing additional flexibility and convenience for recharging.

5.6 Engine Mode

While the vehicle is running under engine power, the rotation of the wheels drives the in-wheel motors to function as alternators, generating electrical power. This generated electricity is then utilized to recharge the traction battery pack, ensuring sustained power availability. Automatic transition to engine-based propulsion occurs once the traction battery pack reaches full charge, optimizing energy utilization and seamlessly transitioning between power sources.The utilization of Continuously Variable Transmission (CVT) is integral to the vehicle's design, offering advantages such as lightweight construction, the ability to achieve infinite gear ratios, and smooth operational characteristics. Additionally, its automatic functionality alleviates the burden on the driver, enhancing overall driving experience and efficiency. Furthermore, the incorporation of Limited Slip Differential enhances traction and stability, particularly during acceleration and cornering, contributing to enhanced performance and safety characteristics of the vehicle.

6. Results

Synergistic Approach: The integration of a compressed natural gas (CNG) engine with a battery-powered plug-in electric vehicle (BEV) demonstrates a synergistic approach that combines the benefits of both technologies. The CNG engine acts as a range extender, addressing range anxiety issues associated with electric vehicles, while also producing lower emissions compared to conventional gasoline engines. Efficiency and Maneuverability: Incorporating in-wheel motors enhances vehicle efficiency and maneuverability by eliminating the need for traditional drivetrain components. This distributed propulsion system enables precise torque control and regenerative braking, optimizing energy utilization and enhancing driving dynamics. Renewable Energy Integration: The addition of a rooftop solar panel system supplements the vehicle's energy supply by harnessing renewable solar energy. This reduces reliance on grid electricity and extends driving range, contributing to overall sustainability.

7. Conclusions

Comprehensive Approach to Sustainability: The proposed hybrid vehicle concept offers a comprehensive approach to sustainable transportation. By integrating multiple advanced technologies, including CNG engine, electric propulsion, in-wheel motors, and rooftop solar panels, the vehicle reduces environmental impact, decreases dependence on fossil fuels, and promotes the adoption of renewable energy in the automotive sector.

Environmental Benefits: The combination of CNG and electric power results in lower emissions and improved air quality, aligning with environmental sustainability goals. Additionally, the integration of renewable solar energy further enhances the vehicle's eco-friendly profile. Technological Advancements: The research underscores the importance of technological advancements in shaping the future of transportation. By leveraging innovations such as in-wheel motors and rooftop solar panels, the proposed hybrid vehicle exemplifies the potential for transformative change in the automotive industry.

In summary, the research paper highlights the viability and benefits of integrating CNG engine, electric propulsion, in-wheel motors, and rooftop solar panels in a hybrid vehicle platform. This holistic approach offers a promising solution for sustainable transportation, addressing environmental concerns and advancing the adoption of clean energy technologies in the automotive sector.

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