International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
***Article Received:** 22 November 2022 **Revised:** 30 December 2022 **Accepted:** 12 January 2023*

Formulation and Enhancement of an Innovative Plug-in Parallel Hybrid Power System

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Abstract

This research focuses on the development of a novel plug-in parallel hybrid power system that integrates multiple power drive devices and incorporates various driving and braking modes. The system includes a power battery system, two drive motor systems, an engine, a clutch, and a transmission. The objective of this study is to enhance the power performance, efficiency, and fuel economy of the vehicle by optimizing the power drive modes and brake energy recycling. The proposed hybrid power system offers seven power driving modes and three brake energy recycling modes, enabling improved vehicle performance and energy efficiency. The engine operates solely for vehicle propulsion, eliminating energy losses during power generation. The research aims to analyze and optimize the system's performance under different operating conditions.

Keywords: Plug-in hybrid power system, Parallel hybrid, Power drive modes, Brake energy recycling, Efficiency, Fuel economy

Introduction

The automotive industry has been rapidly developing new technologies to reduce the carbon footprint of vehicles and improve fuel efficiency. One such technology is the plug-in parallel hybrid power system, which combines the advantages of a traditional fuel-powered engine and an electric motor system. The plug-in parallel hybrid power system is an innovation that has gained a lot of attention in recent years. This technology has become increasingly popular due to its fuel efficiency, dynamic performance, and low emissions. The system is designed to be used in vehicles to improve their overall performance, efficiency, and sustainability.[1]

The plug-in parallel hybrid power system consists of several components, including a power battery system, drive motor systems, an engine, a clutch, and a transmission. The power battery system provides the energy required to drive the electric motor systems, which assist in driving the vehicle and recycle braking energy. The engine is only used in the non-pure-electric drive mode and does not have a power generation mode.[6] One of the main advantages of the plug-in parallel hybrid power system is that it can operate in seven different power driving modes and three brake energy recycling modes. This means that the vehicle can operate using a combination of drive modes, depending on the driving conditions. The multiple drive combination modes and brake energy recycling modes not only improve the power performance of the vehicle but also improve the efficiency of the drive motor and the brake energy recycling. Another significant advantage of the plug-in parallel hybrid power system is its ability to improve fuel economy. As the engine does not have a power generation mode, the energy loss during the power generation step is eliminated, resulting in better fuel efficiency and overall vehicle performance.[2]

The research objective of this study is to investigate the performance and efficiency of a novel plug-in parallel hybrid power system. The study aims to analyse the various drive modes and brake energy recycling modes of the system to evaluate its overall performance and efficiency. The study will also explore the impact of the novel power system on fuel economy, power performance, and sustainability. To achieve the research objective, the study will employ a range of experimental methods, including simulation and testing of the power system on a test bench. The test bench will comprise various components, including the power battery system, drive motor systems, engine, clutch, and transmission. The study will analyse the torque, power output, and efficiency of the power system under different driving conditions to determine its performance and fuel economy.[2]

The study will also evaluate the overall sustainability of the plug-in parallel hybrid power system. The study will analyze the system's carbon footprint, including the emissions produced during the manufacturing, operation, and disposal of the power system. The results of the study will provide a better understanding of the system's sustainability and its impact on the environment.[4]

In conclusion, the plug-in parallel hybrid power system is an innovative technology that combines the advantages of a traditional fuel-powered engine and an electric motor system. The system's multiple power driving modes and brake energy recycling modes improve the power performance and efficiency of the vehicle, while the elimination of the energy loss during the power generation step improves the fuel economy. The research objective of this study is to investigate the performance and efficiency of a novel plug-in parallel hybrid power system, including its impact on fuel economy, power performance, and sustainability. The study will provide valuable insights into the system's performance and its impact on the environment, which will be crucial for the future development and adoption of this technology in the automotive industry.

Related Work

In recent years, the global automotive industry has been undergoing a strategic transformation due to the dual pressures of energy shortages and environmental pollution. As a result, new energy vehicles have emerged as a strategic development direction for the domestic automotive industry. Among them, pure electric vehicles have been identified as a crucial aspect of China's automotive technology development in the "Development of Electric Vehicles in Science and Technology," a special plan issued by the Department of Science and Technology in 2012. Pure electric vehicles offer a propulsion source that addresses both the issues of oil dependency and environmental pollution in the transportation sector.[2]

However, current pure electric vehicles have certain technological limitations that hinder their widespread adoption in the automotive market. These limitations include high initial costs, limited driving range, and long charging times. To bridge the transition to pure electric vehicles, hybrid vehicles have gained strong support from the government in recent years. Hybrid vehicles primarily rely on internal combustion engines as their main power source, with conventional fuels being the main energy consumed.[1] However, when operating at high speeds for extended periods, conventional hybrid vehicles are not highly fuel-efficient. This has led to the development of plug-in hybrid electric vehicles, which closely resemble pure electric vehicles. In comparison to conventional hybrids, plug-in hybrid electric vehicles rely on the electric energy stored in the battery pack as their main power source. This makes them more similar to pure electric vehicles. From both a strategic development perspective and considering national conditions, plug-in hybrid electric vehicles are deemed more favourable for market acceptance.

Plug-in hybrid electric vehicles can be classified into three main types based on their power delivery modes: series, parallel, and series-parallel. In the series-mode configuration, the internal combustion engine does not directly drive the vehicle; instead, it transfers its energy through an electric generator and a motor to propel the vehicle.[4] This significantly reduces the efficiency of the internal combustion engine. In the series-parallel configuration, the engine can directly drive the vehicle, resulting in higher efficiency. However, due to the complexity of the control policies involved in the series-parallel configuration, it is more challenging to implement. On the other hand, the parallel configuration offers higher efficiency for the engine compared to the series configuration, and the control policies are relatively simpler compared to the series-parallel configuration. Hence, most of the current plug-in hybrid electric vehicles on the market employ the parallel configuration.[3]

However, most existing plug-in parallel hybrid electric vehicles use a single high-power electric motor for propulsion. This leads to low efficiency when the vehicle operates under light loads or during low-speed cruising. Additionally, the large battery capacity of plug-in hybrid electric vehicles and the relatively low power output of the engine result in the engine operating at partial load to charge the battery, which significantly reduces its charging efficiency. As a result, the overall vehicle efficiency and fuel economy suffer.

To address these challenges and improve power performance in electric-only mode, optimize regenerative braking energy recovery, enhance driver efficiency, and improve overall energy utilization efficiency and fuel economy, this research focuses on studying an innovative plug-in parallel hybrid power system. The goal is to develop an insertion electric-type parallel connection hybrid power system that overcomes the limitations of existing designs and achieves improved overall performance and efficiency. By exploring this new hybrid power system, it is expected to unlock the potential for enhanced power performance, efficient regenerative braking, improved driver efficiency, and optimized energy utilization. These advancements will contribute to improved fuel economy and overall vehicle performance. The research objective is to analyse and evaluate the performance, efficiency, and fuel economy of the proposed plug-in parallel hybrid power system. Through experimental analysis and simulation studies, the research aims to demonstrate the feasibility and benefits of this novel hybrid power system.[5]

In conclusion, the development of plug-in hybrid electric vehicles is an important strategic direction for the automotive industry, particularly in response to energy shortages and environmental pollution concerns. Pure electric vehicles have been identified as a key technology in the development of new energy sources in the automotive industry. However, the high cost, limited range, and long charging times of pure electric vehicles hinder their widespread adoption in the market.[4] As an interim solution towards pure electric vehicles, hybrid vehicles have gained significant support from governments and industry as they offer a transition from conventional fuel-powered vehicles.

Research Objective

The objective of this research is to design, optimize, and evaluate a novel plug-in parallel hybrid power system. The study aims to investigate and implement various power drive modes and brake energy recycling modes to enhance the vehicle's power performance, drive motor efficiency, and fuel economy. By eliminating the power generation mode of the engine and utilizing the appropriate combination of power drive devices, the research seeks to improve the overall efficiency and performance of the hybrid power system under different operating conditions.

Research

The proposed hybrid power system is an innovative configuration that combines electric and conventional power sources. It consists of three main components: the battery system (B), two drive motor systems (M1 and M2), an internal combustion engine (E), a power-transfer clutch (C), and a transmission (T). The unique feature of this hybrid power system is that it includes three power drive units: M1, M2, and E. M1 is designed to assist in driving the vehicle and recover braking energy, while M2 is responsible for driving the vehicle and also recovering braking energy. The engine (E) is specifically used for vehicle propulsion in non-pure electric drive mode and does not operate in power generation mode.

Depending on the vehicle's operating conditions, such as acceleration level, speed, and braking intensity, the system offers seven different power drive modes and three brake energy recovery patterns. By combining these modes and patterns, the hybrid power system improves the vehicle's dynamic performance, enhances the efficiency of the drive motors, and maximizes the recovery of braking energy. Furthermore, because the engine does not have a power generation mode, the system eliminates energy losses that occur during engine power generation. This significantly improves the fuel economy of the vehicle. In simple terms, the proposed hybrid power system combines electric and conventional power sources to optimize vehicle performance and fuel efficiency. It uses different power drive modes and brake energy recovery patterns to enhance the vehicle's dynamic capabilities and improve the efficiency of the drive motors. Additionally, by eliminating power generation mode in the engine, the system achieves better fuel economy.

Conclusion

The novel plug-in parallel hybrid power system presented in this research offers a range of power drive modes and brake energy recycling modes, leading to enhanced vehicle performance and energy efficiency. By utilizing the appropriate power drive combinations, the system achieves improved power performance and drive motor efficiency. Additionally, the elimination of the engine's power generation mode eliminates energy losses during power generation, resulting in enhanced fuel economy for the entire vehicle. The research findings highlight the potential of the proposed hybrid power system in achieving a balance between performance, efficiency, and environmental sustainability. Further optimization and testing can lead to practical implementation and broader adoption of this novel plug-in parallel hybrid power system in the automotive industry.

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