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Exploring the State-of-the-art in Plug-in Hybrid Electric Vehicle Design and Modeling: A Review

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Abstract

This document provides a thorough explanation of the process involved in designing and developing plug-in hybrid electric vehicles (PHEVs). A viable way to lessen greenhouse gas emissions and reliance on conventional internal combustion engine vehicles is through plug-in hybrid electric vehicles (PHEVs), which have gained popularity in response to growing concerns about environmental sustainability and the depletion of fossil fuels. The main elements, design factors, difficulties, and developments in the field of plug-in hybrid electric vehicles are covered in this paper. Additionally, it investigates how to improve the performance and efficiency of plug-in hybrid electric vehicles (PHEVs) by integrating smart grid systems, battery technology, and renewable energy sources. The purpose of this study is to offer insights that will aid in the continuous research and development related to sustainable transportation.

Keywords: Plug-in hybrid electric vehicles, design, development, renewable energy, battery technologies, smart grid, sustainability

INTRODUCTION

Plug-in hybrid electric cars, or PHEVs, are a major development in automotive technology that present a viable way to address the issues of fossil fuel dependency and greenhouse gas emissions reduction. Plug-in hybrid electric vehicles (PHEVs) are more fuel-efficient and produce less pollution than traditional gasoline-powered cars because they combine an internal combustion engine with an electric motor and a rechargeable battery. The design, development, importance, and uses of plug-in hybrid cars are examined in this article within the framework of environmentally friendly transportation.

Because fossil fuels are burned in cars, the transportation industry contributes significantly to both air pollution and climate change. Alternative propulsion technologies have been investigated by the car industry in response to environmental concerns and the need for energy security.

Different groups of people choose different cars for various kinds of travel-related arrangements, particularly when they are traveling alone, with family members, or with non-household members. This study creates people's short-term vehicle choice models for various travel scenarios in multicar families to close these gaps. In this work, three trip-based vehicle type choice models—traveling alone, traveling with household members, and traveling with non-household members—are constructed based on the accompanying persons present on an individual's journey. By combining

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the advantages of electric and conventional propulsion systems, plug-in hybrid electric cars, or PHEVs, have become a promising solution.

In plug-in hybrid electric vehicles (PHEVs), choosing the right drive train architecture and creating an effective power flow control method are equally crucial to lowering pollutants and fuel consumption. Many control techniques have been developed and presented; however, most of them are extensions of control strategies for hybrid electric vehicles (HEVs) and do not fully realize the potential that the plug-in hybrid electric vehicle (PHEV) offers due to its long-range electric-only operation.

Significance and Applications

As we move toward a more environmentally friendly transportation system, plug-in hybrid cars are essential. Their capacity to run in electric mode lowers emissions from tailpipes, improving public health and air quality. Furthermore, PHEVs give users the option to drive exclusively on electricity for brief distances while still having the convenience and range of a traditional car for larger trips. A recent study indicated that the size of the global market for EVs and PHEVs would be approximately USD 158401.38 million in 2022. The market is expected to develop significantly over the forecast period, reaching a value of USD.

Applications for plug-in hybrid electric vehicles (PHEVs) include long-distance driving, fleet operations, and urban commuting. They may be adjusted to various driving situations and user preferences thanks to their capacity to transition between electric and hybrid modes. Furthermore, by resolving issues with range anxiety and charging infrastructure, plug-in hybrids can act as a bridge technology, assisting in the wider adoption of fully electric vehicles. Plug-in hybrid cars are a major development in automotive technology that provide a workable way to address the issues of lowering greenhouse gas emissions and reliance on fossil fuels. PHEVs combine the advantages of conventional and electric powertrain systems to offer better driving performance, reduced emissions, and increased fuel efficiency. Plug-in hybrid technology is anticipated to be crucial in facilitating the shift to a more environmentally friendly and energy-efficient transportation system as the automobile industry innovates further.

Automakers are working on electric, hybrid, and plug-in hybrid electric vehicles in response to regulations aimed at lowering emissions and increasing fuel efficiency. The development of these greener cars and the application of sophisticated electrical architectures to satisfy the demands for higher electric loads are made possible by power electronics.

Objectives of the Study

Just as conventional combustion engine vehicles require fossil fuels for refueling, electric vehicles must have their own energy source in order to operate. The primary resource in electric vehicles is electric energy, which is kept in batteries. A public or domestic electric charging station is the most popular source of electric energy for electric vehicles (or some types of hybrid vehicles). Before discussing the advantages of driving electric cars, it is essential to examine the method of generating electric energy. Electric vehicles cannot be seen as an environmentally beneficial alternative to internal combustion vehicles since the great majority of power is produced in less environmentally favorable ways that burden and pollute the environment. In addition, there are problems with infrastructure development, battery recycling, charging alternatives, and a host of other challenges that will affect future transportation possibilities.

Numerous alternative energy sources are being researched for hybrid cars to supplement the world's depleting petroleum supply. Because fossil fuels have negative consequences on the environment, there is growing concern over their usage in automobiles. Researchers are looking into sources including batteries, fuel cells (FC), super capacitors (SC), and photovoltaic cells, sometimes known as solar cells, for use in automobiles. The next generation of transportation, the hybrid electric vehicle (HEV), can be powered by combinations of various renewable energy sources.

The study's goal is to talk about the issues raised.

1. Comparable to BEVs, or battery electric vehicles
2. Plug-in hybrids can use centralized renewable energy generators.
3. Mostly emission-free, or a fossil fuel plant, in which case they replace greenhouse gas emissions from vehicle exhaust to the power plant.
4. such as hydropower, wind, or solar

Related Studies

A succinct overview of future electric vehicle methods, existing trends, and the role of power electronic subsystems is provided by Emadi et al. There was also a presentation on the power electronic components and electric motor drive requirements for the successful development of these vehicles [1].

The most recent control strategies are thoroughly evaluated and categorized in the work of Weerasinghe et al. Most PHEV controllers use either an optimization-based algorithm or a rule-based approach, each with pros and cons of their own. A synopsis of the controllers presented, along with an examination of the best strategies to optimize plug-in hybrid electric vehicle (PHEV) performance under various driving cycle scenarios. A novel categorization system for plug-in hybrid electric vehicle control techniques showcased and validated by means of simulation outcomes [2]. The design and control approaches of a plug-in hybrid electric vehicle (PHEV) were extensively discussed by Gao et al. The electrical power and potential of batteries is the main consideration in the design procedure. Furthermore, a limited engine on/off control approach for charge-sustained running was covered. For a sample passenger car, a simulation has been run. According to the modeling results, electric energy can replace a sizable portion of fuel in regular urban driving [3].

Hannan et al examined several HEV-related topics and methodologies related to the propulsion system, power conditioning, and energy management system (EMS). Included are further HEV-related fields including DC machines and vehicle systems. Details were provided on a variety of type algorithms and frameworks that were developed through experimentation and simulation. They offered a thorough analysis of hybrid electric vehicles, including models, source combinations, energy management systems (EMS), etc. created by different researchers. From the rigorous review, it is observed that the existing technologies can be capable of performing HEV well; however, the reliability and the intelligent systems are still not up to the mark [4]. Dižo et al examined the current state of the infrastructure for charging electric or plug-in hybrid cars, with a focus mostly on the Central and Eastern regions [5]. Soroush Shafiee et al. suggested a thorough model to investigate the effects of PHEVs on residential distribution systems. By doing this, basic PHEV features such as battery capacity, state of charge (SOC), and energy consumption during daily travels are precisely modelled [6]. The National Household Travel Survey was used by Darabi et al. to extract the data. It is simpler to research the effects of coordinated charging through charging policies and incentives if the technique for extracting the profile of plug-in car power demand is established [7]. The electrical motor and combustion engine in a plug-in hybrid electrical automobile work together seamlessly to power the vehicle. One huge battery or several Li-ion batteries are possible configurations [8]. Gonder et al. provided an overview of three possible energy management techniques and compared the effects of choosing one over the other considering the degree of aggression and duration of the duty cycle that the vehicle will probably operate across [9]. The issue of dividing the driver power requirement of a plug-in hybrid electric vehicle (PHEV) optimally among its various actuators—that is, its engine and electric machines—was studied by Moura et al. [10].

PHEV elements include:

Internal Combustion Engine (ICE): In a plug-in hybrid electric vehicle (PHEV), the internal combustion engine (ICE) is essential for supplying power and expanding the car's range beyond what the electric motor and battery can accomplish on their own. The main purpose of an ICE in a plug-in hybrid electric vehicle (PHEV) is to produce electricity that can be used to power the electric motor directly or to recharge the battery as necessary as shown in Figure 1. The electric motor is powered by the electricity generated by the internal combustion engine (ICE) when the battery is low on charge or when more power is needed.

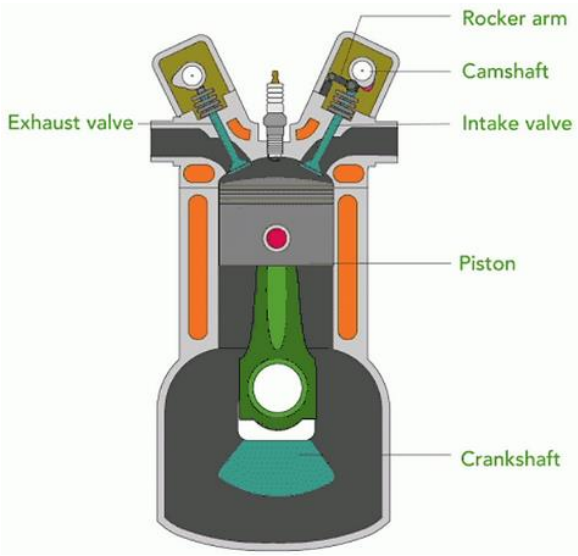

Figure 1. Internal Combustion Engine
Source: *https://www.energy.gov/eere/vehicles/articles/internal-combustion-engine-basics*

Electric Motor: Using only electric power for propulsion is one of the main purposes of the electric motor in a plug-in hybrid electric vehicle. When traveling at modest speeds, in urban areas, or when the battery is fully charged, the electric motor can drive the car without the assistance of the internal combustion engine. This helps to enhance air quality and lessen environmental impact by enabling plug-in hybrid electric vehicles (PHEVs) to run silently and produce no exhaust emissions when driving solely on electricity. To enable hybrid operation, PHEV's electric motor collaborates with the ICE. The internal combustion engine's (ICE) performance is increased by the electrical motor to enhance performance when additional torque is required, such as during accelerating or fast riding. When compared to conventional vehicles, PHEVs' hybrid operation optimizes power delivery, increases fuel efficiency, and lowers pollutants.

Power Electronics: The process of transforming the battery's stored direct current (DC) electricity into the alternating current (AC) electricity needed to run the electric motor is handled by power electronics. Furthermore, power electronics can do reverse conversion, which is the process of converting DC electricity for battery storage from AC electricity produced by the ICE or by regenerative braking. Power electronics govern the electric motor's speed, torque, and rotational direction by managing the energy supply to it. Power electronics provide smooth and efficient operation over a wide range of driving circumstances by varying the voltage and frequency of the electrical impulses sent to the motor.

Regenerative Braking

When it comes to operation, PHEVs make use of both an electric motor and an ICE. The torque needed to propel the car is produced solely by the electric motor. The battery is exhausted in this phase, which is known as charge depletion mode. The internal combustion engine takes over and the car operates on fuel when the battery is no longer able to power the motor. To meet the need, an ICE and an electric motor can operate in tandem. The battery is charged during this entire process using the kinetic energy generated while moving. We refer to this as regenerative braking. Regenerative braking, which captures kinetic energy while coasting or braking and transforms it into electricity to replenish the battery, is one of the main characteristics of plug-in hybrid electric vehicles. In addition to increasing the vehicle's electric range, this method increases overall efficiency by lowering the energy waste that conventional braking systems are known to produce.

Battery Pack: There is discussion of two common battery types: NiMH and Li-ion. Control strategies are centred on all electric stretch and charging depletion range procedures. The electrical generator and combustion engine in a plug-in hybrid electrical automobile work together seamlessly to power the vehicle. One huge battery or several Li-ion batteries are possible configurations. The Li-ion battery series guarantees a longer lifespan and boosts the electric motor's overall efficiency.

Developing and Designing

The process of creating a plug-in hybrid car entail combining an electric motor, a high-capacity rechargeable battery pack, and an internal combustion engine. The engine's ability to run on gasoline, diesel, or other fuels increases the vehicle's versatility and range. The battery pack, which can be charged by connecting into an electrical outlet or charging station, powers the electric motor. To maximize efficiency and performance, complex control systems regulate the power flow between the engine, motor, and battery. Improvements in battery technology, electric drivetrains, and vehicle integration have propelled the development of plug-in hybrid technology. To increase battery energy density, lower costs, and improve durability, manufacturers have made research and development investments. Because of this, contemporary PHEVs provide a remarkable range on electricity alone, smooth hybrid functioning, and performance that is on par with traditional automobiles.

This study aims to be a useful resource for researchers, engineers, policymakers, and industry stakeholders working towards the growth of sustainable transportation solutions by offering a thorough overview of the design and development process of plug-in hybrid electric vehicles (PHEVs). A set of Li-ion batteries guarantees a longer lifespan and boosts the electric motor's total efficiency. When it comes to operation, PHEVs make use of both an electric motor and an ICE. The electric motor is the only source of torque required to move the car forward. This stage, referred to as charge depletion mode, ends when the battery is completely depleted. When the battery is unable to continue powering the motor, the internal combustion engine takes over and the vehicle runs on fuel. To meet the need, an ICE and an electric motor can operate in tandem. The battery is charged during this entire process using the kinetic energy generated while moving. This is known as regenerative braking. PHEVs are affordable and good for the natural world. Compared to traditional hybrids, they are an improvement. The battery can be charged by the power supply. The current high starting cost may be a drawback, but as the industry expands, costs will gradually decrease. For now, think of this as an everyday LED that is expensive at first but useful, economical, and efficient in the long run.

Table 1. Table of Specification.

Electrical Parts	Mechanical parts	Fabrication parts
Motor 60v 1250w	100cc engine	Square Pipe 1.5 inches and 0.75 inch
Controller 60v 1500w	Chain And Sprocket	Welding Material for Welding
Battery	Brake	
Accelerator	Gear Shifting Mechanism	
Headlight And Horn	Steering	
	Rack and pinion	
	Wheels and Hubs	

Electric Propulsion: To power an electric motor, plug-in hybrid electric vehicles (PHEVs) are outfitted with large capacity rechargeable batteries. When running on electricity alone, the car uses the battery pack to provide all of the power for the electric motor. In situations when there is little demand for power, such as short commutes and city driving, this mode is especially effective.

Engine Management: The advanced engine management systems used by plug-in hybrid electric vehicles (PHEVs) control how the petrol engine operates to maximize efficiency and reduce pollution. These systems could have features like variable valve timing, which maximizes engine performance under various driving circumstances, and start-stop technology, which turns off the engine when the car is stationary.

Methodology

The project started with extensive research on existing hybrid car technologies and the design considerations for low-speed operation. A low-speed plug-in hybrid vehicle prototype was developed based on the research findings. Energy efficiency and emissions of pollutants are hot problems these days, and hybrid electric vehicles (HEVs) offer the best immediate solution to address this issue. Hybrid electric vehicles combine the strong reliability of internal combustion engines with the high efficiency of electric motors to provide the best possible outcomes in terms of fuel economy and pollution. The architecture selection is greatly influenced by the vehicle and path elements. Longer routes and faster speeds are better suited for a parallel architecture's more flexible structure and higher motor power, while urban cycling is better suited for the series architecture's ability to transition to a pure electric mode.

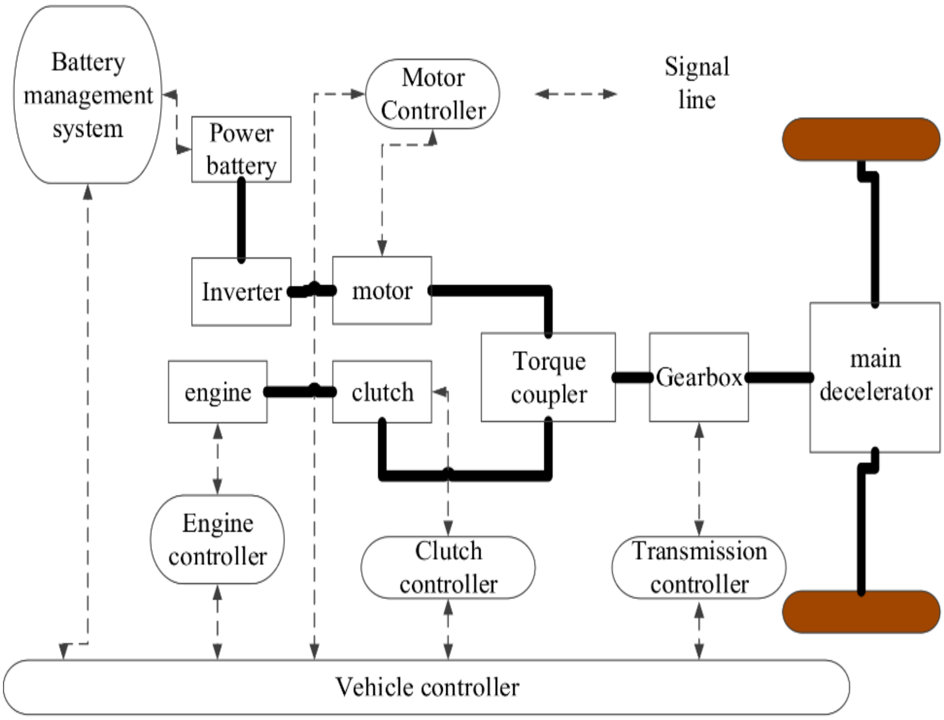

Figure 2. PHEV working Mechanism.

In addition, a parallel-series design is typically a wise decision. Determining an appropriate control method that can effectively manage the car's load distribution between the engine and motors as well as the regenerative braking is another critical step. Considering all these factors, the authors' goal in this study is to establish a thorough methodology that will make it easy to define an optimal powertrain layout, including the size of the devices and their design, as well as an effective control technique as shown in Figure 2. To achieve this, our research team has created an analytical code that mimics the power flows in a HEV engine and makes it possible to determine how well a particular vehicle performs under a variety of varied mission conditions.

The model's ability to calculate the necessary energy enables it to define a range of permissible states for each time step presented in Figure 3, which is the product of the engine power and the matching motor power, taking regenerative braking and limitations put in place by the engine, the motors, and the storage system into consideration. The Dijkstra shortest path optimization algorithm selects the configuration that allows for the least amount of fuel use, yielding the optimal solution out of all potential layouts.

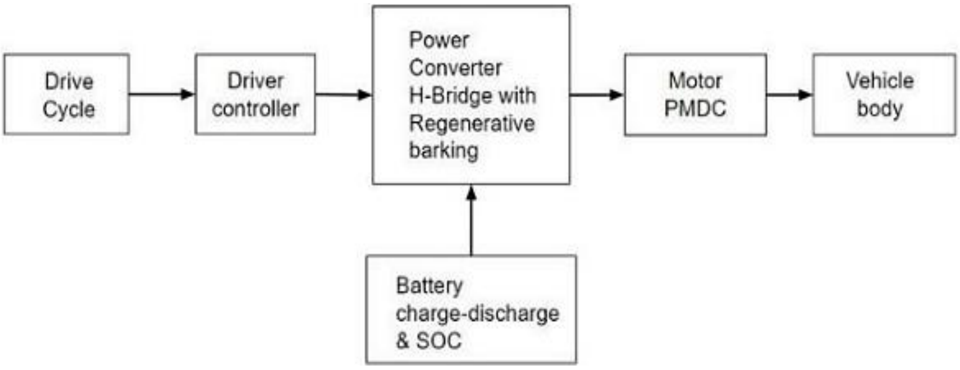

Figure 3. Block Representation of the proposed system.

CONCLUSION

In conclusion, electric cars are the way of the future for transportation since they are effective, affordable, and provide a fun driving experience. Hybrid electric vehicles are propelled by an internal combustion engine coupled with one or more battery-powered electric motors. An electric hybrid car cannot be plugged in to have its battery charged.

Future Scope

- Anticipate HEVs to be more environmentally friendly with cutting-edge electric powertrains and efficient internal combustion engines.
- They could be more efficient and offer an interesting pricing experience with improved battery technology.
- Given the volatile nature of gas prices and the higher expense of completely electric vehicles, which may not be within the means of all consumers, hybrid technology, which is often misunderstood, may be worth a closer examination.

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