Energy Control Method for Hybrid Electric Automobile Based on Minimum Energy Consumption Rate

Dr.J.Maalmarugan1, D.Palanivel2, K.Rajeshkumar2, G. Mariya Sundari2
1Professor, Department of Electrical and Electronics Engineering, Sri Ranganathar Institute of Engineering and Technology, Athipalayam, Coimbatore 641 110
2Assistant Professor, Department of Electrical and Electronics Engineering, Sri Ranganathar Institute of Engineering and Technology, Athipalayam, Coimbatore 641 110
Corresponding Author: D.Palanivel
Mail ID :palanivel@sriet.ac.in

Abstract

This research proposes an energy control method for hybrid electric automobiles with the objective of minimizing energy consumption rate. The method involves three main steps: (1) measuring energy source parameters under various driving conditions in a real automobile, (2) optimizing the efficiency of three energy sources based on power and energy consumption rate using a self-adaptive genetic algorithm, and (3) implementing an energy switching system to distribute energy during real-world driving based on State of Charge (SOC) and power demands of the hybrid system. The proposed method allows for rapid adaptation to real-world conditions, ensuring optimal operation of the multi-energy automobile and offering significant practical engineering value.

Keywords: Hybrid electric automobile, Energy control, Minimum energy consumption rate, Energy source parameters, Self-adaptive genetic algorithm, Energy switching system.
DOI Number: 10.48047/nq.2021.19.2.NQ21047 NeuroQuantology 2021; 19(2): 278-284

Introduction

The increasing concern for environmental sustainability and the growing demand for energy-efficient transportation have spurred significant advancements in the development of hybrid electric automobiles. These vehicles combine the benefits of internal combustion engines and electric motors, offering improved fuel efficiency, reduced emissions, and enhanced overall performance. However, achieving optimal energy control and management in hybrid electric automobiles remains a complex challenge.One crucial aspect of energy control in hybrid electric automobiles is the distribution and utilization of energy from different sources, such as the internal combustion engine, battery, and regenerative braking system. The efficient allocation of power among these sources plays a pivotal role in minimizing energy consumption and maximizing the vehicle's overall performance. Therefore, developing an effective energy control method that can optimize the energy distribution in real-time is of paramount importance(Castellazzi 2017).

The objective of this research is to propose an energy control method for hybrid electric automobiles based on the minimum energy consumption rate(Hu et al. 2018). The method aims to optimize the power distribution proportion of the power system in the electric automobile, considering the efficiency characteristics of different energy sources and the energy consumption rate of the system.

By achieving an optimal power distribution, the method can significantly reduce energy waste and enhance the overall energy efficiency of the vehicle.To accomplish this objective, the research follows a systematic approach. In the initial step, various energy source parameters are measured under different driving conditions in a real automobile. These parameters provide valuable insights into the characteristics and performance of each energy source, allowing for a comprehensive analysis of their efficiency.

In the next step, the research focuses on optimizing the efficiency of the three energy sources: the internal combustion engine, battery, and regenerative braking system. This optimization is conducted by utilizing a self-adaptive genetic algorithm, which iteratively adjusts and fine-tunes the power distribution proportions based on the energy consumption rate of the power system. The algorithm seeks to identify the optimal balance between the energy sources to minimize overall energy consumption.The proposed energy control method goes beyond static optimization and incorporates real-time adaptability. By continuously monitoring the actual driving conditions and power demands of the hybrid system, the method ensures that the energy distribution remains responsive and adaptable to the dynamic requirements of the vehicle. This real-time adjustment enables the system to operate in an optimal state, thereby enhancing energy efficiency and performance(Lin et al. 2015).

To facilitate the energy distribution during real-world driving, an energy switching system is integrated into the hybrid electric automobile. This system takes into account the State of Charge (SOC) parameter, which indicates the energy level of the battery, and the power demands of the hybrid system.[2] By intelligently distributing the energy among the sources, the energy switching system optimizes energy utilization and ensures smooth and efficient operation of the vehicle.The proposed energy control method offers several advantages over existing approaches. Firstly, it allows for rapid adaptation to the actual situation of the real automobile system, enabling online self-adjustment based on real-time driving conditions. This adaptability ensures that the multi-energy automobile remains in an optimal operational state, maximizing energy efficiency and performance.Furthermore, the method's reliance on a self-adaptive genetic algorithm provides a robust and efficient optimization framework. The algorithm's ability to iteratively refine the power distribution proportions based on the energy consumption rate allows for continuous improvement in energy control and management.In conclusion, this research proposes an energy control method for hybrid electric automobiles based on the minimum energy consumption rate. By optimizing the power distribution proportions of different energy sources and incorporating real-time adaptability, the method offers significant potential for enhancing the energy efficiency and overall performance of hybrid electric vehicles(YU, Mukai, and Kawabe 2014). The integration of an energy switching system and the consideration of SOC and power demands further contribute to efficient energy utilization. The proposed method holds considerable promise and practical engineering value in advancing the development of energy-efficient transportation systems.

Related Work

The energy is a driving force behind social development, while the environment serves as the foundation for the survival of mankind. The rapid growth of the automotive industry has brought about material progress in modern times. However, it has also given rise to significant problems such as exhaust emissions, noise pollution, and high fuel consumption(Xie et al. 2019). Electric vehicles, with their zero-emission capabilities, low noise levels, and comprehensive energy utilization, offer a promising solution to address these environmental challenges and achieve energy efficiency. They hold immense potential for future development.However, electric vehicles face limitations in energy storage capacity, low-capacity utilization rates, and insufficient driving range, which directly impact their development. To overcome these challenges, hybrid energy electric vehicles have emerged as a solution. These vehicles draw power from three primary energy sources: fuel cells, batteries, and supercapacitors. Fuel cells provide stable, long-term power output, but they have limited adaptability to frequent and wide variations in power demands.[1] Batteries, on the other hand, offer high-power discharge capabilities, making them suitable for supplying complex electric power demands.[3]Supercapacitors serve as auxiliary power sources, particularly during high-power requirements.This paper investigates a parallel hybrid energy storage electric vehicle with controller, motor, and HESS, which includes ultracapacitor, battery, and DC/DC, as shown in Figure 1.

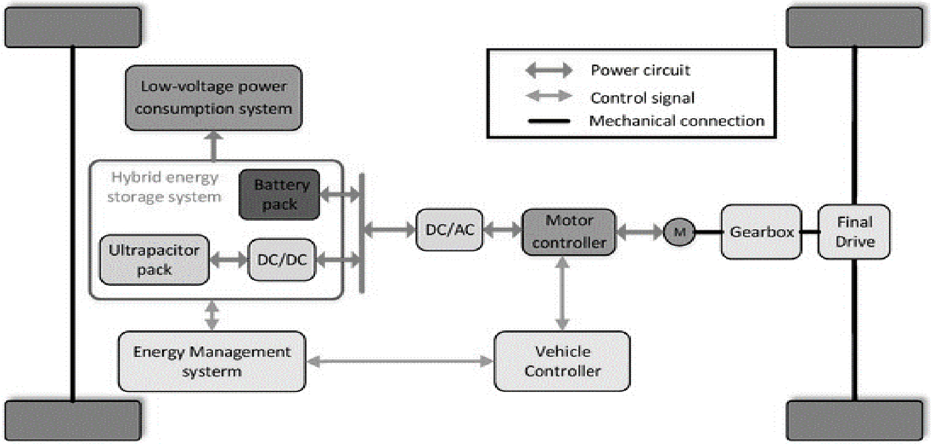

Figure 1. The configuration and detailed structure of a parallel hybrid electric vehicle.

By combining fuel cells, batteries, and supercapacitors in a hybrid energy storage system, the overall energy utilization rate can be increased, resulting in improved driving range. Additionally, this approach helps mitigate the negative impact of high-load currents and idle currents on the batteries, leading to an extended battery life and improved power output of the system(YU et al. 2014).However, current research on the energy management strategy of electric vehicles primarily relies on offline methods and control rules. These approaches fail to account for the changes that occur over the service life of an electric vehicle. As the performance of the main power sources degrades over time, the energy management strategies need to adapt accordingly to achieve optimal control effectiveness. Furthermore, these strategies often do not consider factors such as road conditions, driving modes, and the state of electrical energy storage.[4]The motor configuration defines the power needs of the hybrid energy storage system (HESS), therefore the charts displaying the motor's operating and regenerative conditions are obtained through experimental trials for modeling purposes(Castellazzi 2017).The motor's efficiency diagram can be observed in Figure 2.

NeuroQuantology| February2021 | Volume19 | Issue2 | Page 278-284|doi:10.48047/nq.2021.19.2.NQ21047
Dr.J.Maalmarugan et al/ Energy Control Method for Hybrid Electric Automobile Based on Minimum Energy Consumption Rate

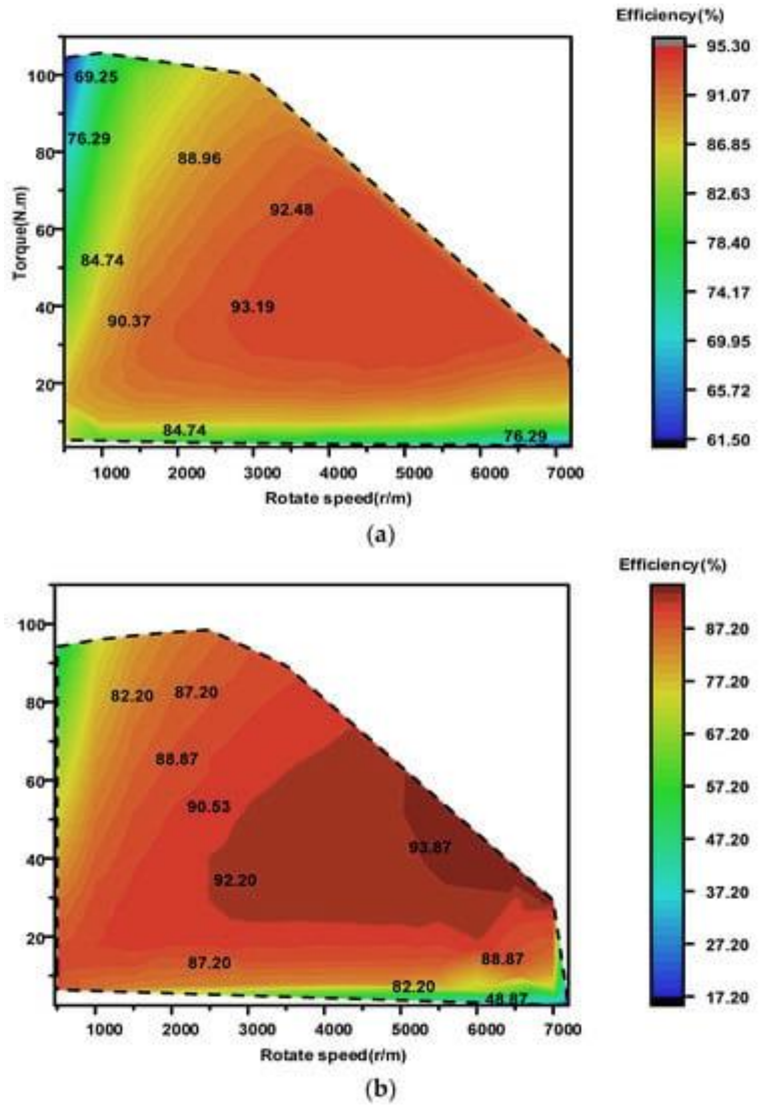

Figure 2. (a) Map of motor driving. (b) Map of motor braking.

To address these issues and enable control strategies that can automatically update based on the characteristics of all components (battery, fuel cell, supercapacitor), a real-time measurement and computation of their parameters is necessary. This entails studying the energy distribution control system for hybrid energy electric vehicles. However, there is a lack of relevant research in the existing literature(Lin et al. 2015).Therefore, this research aims to develop an energy distribution control system for hybrid energy electric vehicles that can automatically update its control strategies based on real-time measurements and computation of the parameters of the battery, fuel cell, and supercapacitor. By achieving this, the energy distribution effects can be aligned with the actual characteristics of the onboard power sources, leading to more efficient energy management. This research addresses a critical gap in the existing literature and holds significant promise for advancing the field of hybrid energy electric vehicles(Xie et al. 2019). The energy landscape plays a crucial role in driving social development, while the preservation of the environment is essential for the survival of humanity. The rapid growth of the automobile industry has undoubtedly brought about significant advancements in modern times. However, this progress has also given rise to several pressing issues, including exhaust emissions, noise pollution, and excessive fuel consumption(Lin et al. 2015). These challenges necessitate the development of innovative solutions that prioritize environmental protection and energy efficiency. Electric vehicles have emerged as a promising alternative, offering numerous advantages such as zero emissions, reduced noise levels, and efficientenergy utilization. Consequently, electric vehicles have vast potential for future growth and adoption.

However, electric vehicles face inherent limitations in terms of energy storage capacity and overall efficiency. The utilization rate of their energy storage systems is often suboptimal, resulting in limited driving range and inadequate performance. To overcome these challenges, hybrid energy electric vehicles have been introduced as a potential solution. These vehicles employ a combination of three primary energy sources: fuel cells, batteries, and supercapacitors(Yang et al. 2019). Fuel cells provide a stable and continuous power supply over extended periods, but they are less adaptable to frequent and substantial variations in power demand. Batteries, on the other hand, offer high-power discharge capabilities and are capable of meeting complex electric power requirements. Supercapacitors serve as auxiliary power sources, particularly during instances of high-power demand.

The integration of fuel cells, batteries, and supercapacitors in a hybrid energy storage system enables improved energy utilization rates and enhanced driving range. Furthermore, this approach mitigates the adverse effects of high-load currents and idle currents on battery performance, resulting in extended battery life and improved power output. The ability to combine these energy sources effectively is critical for the optimal operation of hybrid energy electric vehicles.Presently, the research conducted on the energy management strategies of electric vehicles primarily relies on offline methods and predetermined control rules. However, these strategies fail to account for the dynamic nature of electric vehicle systems over their operational lifespan. As the performance of the main power sources gradually degrades over time, it becomes necessary to adapt the energy management strategies accordingly to achieve optimal control effectiveness. Additionally, existing strategies often overlook important factors such as road conditions, driving modes, and the state of electrical energy storage(Li et al. 2016).

To address these limitations, it is imperative to develop an energy distribution control system for hybrid energy electric vehicles that can dynamically update its control strategies based on real-time measurements and computations of battery, fuel cell, and supercapacitorparameters. This approach would ensure that the energy distribution aligns with the actual characteristics and conditions of the onboard power sources, resulting in efficient energy management and optimal vehicle performance. However, there is currently a lack of comprehensive research in this area.

Therefore, the objective of this research is to bridge this gap by designing and implementing an energy control method for hybrid energy electric vehicles that minimizes energy consumption rates.[6] The proposed method involves several key steps, including measuring energy source parameters under various operating conditions, analysing the efficiency of the three energy sources in relation to power, optimizing the power distribution proportions through a self-adaptive genetic algorithm, and utilizing an energy switching system for real-time energy distribution based on system demands and state of charge (SOC) parameters. By achieving rapid online self-adjustment and maintaining the vehicle in an optimal operational state, this method offers significant practical engineering value. In summary, this research focuses on developing an energy control method for hybrid energy electric vehicles based on minimum energy consumption rates.[1] By effectively integrating the three energy sources and implementing dynamic control strategies, this method aims to enhance the overall performance, energy efficiency, and practicality of hybrid energy electric vehicles(Li et al. 2016).

Research Objective

The objective of this research is to develop an energy control method for hybrid electric automobiles that minimizes the overall energy consumption rate. By optimizing the efficiency of different energy sources and implementing an adaptive energy distribution system, the research aims to achieve an optimal power distribution proportion for the power system of the electric automobile. The method seeks to enable real-time adjustments based on the actual driving conditions of the vehicle, ensuring efficient and optimal operation of the hybrid system.

Energy Control Method for Hybrid Electric Automobile

This research proposes an energy control method for hybrid energy electric vehicles that aims to minimize energy consumption rates. The method consists of the following steps:

Step 1: While the actual vehicle is being driven, the parameters of each energy source are measured under different driving conditions.

Step 2: Based on the measured energy source parameters, the efficiency of the three energy sources is analysed in relation to power. Considering the energy consumption rate of the electric vehicle's power system, a self-adaptive genetic algorithm is used to optimize and adjust the power distribution proportions. This step ensures that the power system achieves an optimal sharing ratio, and the data is updated in real-time.

Step 3: During the actual vehicle's operation, the battery's state of charge (SOC1), the supercapacitor's state of charge (SOC2), and the power demand of the vehicle (P) are considered. With reference to the power distribution ratio obtained in Step 2, the energy distribution is effectively managed and implemented.

In simpler terms, this research focuses on finding the best way to control the energy usage in hybrid energy electric vehicles. The method involves three steps. First, the parameters of each energy source are measured while the vehicle is driven in different conditions. Second, the efficiency of the three energy sources is determined based on their power output. Using this information and considering the energy consumption rate of the electric vehicle's power system, a special algorithm is used to optimize the distribution of power between the sources. This helps achieve the best power sharing ratio for the vehicle. Lastly, when the vehicle is in operation, the method considers the remaining charge of the battery and supercapacitor, as well as the power demand of the vehicle. By referring to the optimized power distribution ratio, the energy is effectively distributed and managed in real-time.

Overall, this research aims to improve the energy efficiency and performance of hybrid energy electric vehicles by optimizing the way energy is distributed and utilized.

Conclusion

In this study, we proposed an energy control method for hybrid electric automobiles based on minimum energy consumption rate. By measuring energy source parameters and utilizing a self-adaptive genetic algorithm, we optimized the efficiency of three energy sources in relation to power and energy consumption rate. The results were then used to determine an optimal power distribution proportion for the electric automobile's power system. The integration of an energy switching system and consideration of SOC and power demands allowed for efficient energy distribution during real-world driving. The proposed method offers the advantage of online self-adjustment and keeps the multi-energy automobile in an optimal operation state. It demonstrates promising practical engineering value for enhancing the energy efficiency of hybrid electric vehicles.

Reference

Castellazzi, Luca. 2017. “Mild Hybrid Electric Vehicles: Powertrain Optimization for Energy Consumption, Driveability and Vehicle Dynamics Enhancements.”

Hu, Yue, Weimin Li, Kun Xu, Taimoor Zahid, Feiyan Qin, and Chenming Li. 2018. “Energy Management Strategy for a Hybrid Electric Vehicle Based on Deep Reinforcement Learning.” *Applied Sciences* 8:187. doi: 10.3390/app8020187.

Li, Liang, Sixiong You, Chao Yang, Bingjie Yan, Jian Song, and Zheng Chen. 2016. “Driving-Behavior-Aware Stochastic Model Predictive Control for Plug-in Hybrid Electric Buses.”

Applied Energy 162:868–79. doi: 10.1016/j.apenergy.2015.10.152.

Lin, Xue, Yetang Wang, Paul Bogdan, Naehyuck Chang, and Massoud Pedram. 2015. "Reinforcement Learning Based Power Management for Hybrid Electric Vehicles." *IEEE/ACM International Conference on Computer-Aided Design, Digest of Technical Papers, ICCAD* 2015:33–38. doi: 10.1109/ICCAD.2014.7001326.

Xie, Shaobo, Xiaosong Hu, Shanwei Qi, Tang Xiaolin, Kun Lang, Zongke Xin, and James Brighton. 2019. "Model Predictive Energy Management for Plug-In Hybrid Electric Vehicles Considering Optimal Battery Depth of Discharge." *Energy* 173. doi: 10.1016/j.energy.2019.02.074.

Yang, Chao, Sixiong You, Weida Wang, Liang Li, and Changle Xiang. 2019. "A Stochastic Predictive Energy Management Strategy for Plug-in Hybrid Electric Vehicles Based on Fast Rolling Optimization." *IEEE Transactions on Industrial Electronics* PP:1. doi: 10.1109/TIE.2019.2955398.

YU, Kaijiang, Masakazu Mukai, and Taketoshi Kawabe. 2014. "Battery Management Using Model Predictive Control for a Plug-In Hybrid Electric Vehicle." *SICE Journal of Control, Measurement, and System Integration* 7:304–12. doi: 10.9746/jcmsi.7.304.