

Intelligent Design and Control Strategy Research for New Energy Vehicle Drive Systems

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Abstract: With the rapid development of new energy vehicles today, intelligent drive systems have become one of the key technologies for improving vehicle performance. This paper analyzes the importance of intelligent drive systems in new energy vehicles and proposes design principles, including balancing efficiency and economy, integrated and modular design of intelligent drive systems, considerations of reliability and safety, as well as environmental adaptability and durability. It also discusses control strategies for intelligent drive systems in new energy vehicles, aiming to enhance both vehicle performance and market competitiveness.

Keywords: new energy vehicles; intelligent drive system; system control strategy

1 Introduction

The intelligent drive system of new energy vehicles not only affects vehicle efficiency and economy, but also directly influences performance, safety, and user experience. This paper discusses the importance of intelligent drive systems in new energy vehicles, explains their design principles, and analyzes methods for implementing control strategies, aiming to provide theoretical support and practical guidance for the intelligent development of new energy vehicles, thereby promoting technological advancement and industrial upgrading in the automotive sector.

2 Importance of Intelligent Drive Systems for New Energy Vehicles

Against the backdrop of growing global environmental awareness and continuous adjustments in energy structures, new-energy vehicles have emerged as a new trend in the automotive industry, thanks to their advantages such as low emissions and high efficiency. Intelligent drive systems integrate advanced electronic control technologies, information and communication technologies, and artificial intelligence algorithms, enhancing energy utilization efficiency while also optimizing vehicle handling performance and driving experience.

3 Design Principles for Intelligent Drive Systems of New Energy Vehicles

3.1 Balancing Efficiency and Economy

Efficiency refers to the ability of an intelligent drive system to achieve optimal performance with minimal energy consumption, thereby maximizing battery range and enhancing overall vehicle performance. From an economic standpoint, cost-effectiveness should be prioritized throughout both the design and manufacturing stages of new-energy vehicles, ensuring that the intelligent drive system meets performance requirements while minimizing production and maintenance costs, thus strengthening the competitiveness of automotive products in the market. To balance efficiency and economy, design teams must carefully consider the architecture, electrical design, and control strategies of intelligent drive systems for new-energy vehicles. When selecting key components such as motors, batteries, and electronic control units, factors including performance, cost, and reliability must be taken into account to ensure the system operates economically without compromising performance. In developing control strategies for intelligent drive systems, energy management and power distribution under various operating conditions must be

thoroughly considered to optimize power output and energy utilization efficiency [1]. Furthermore, the application of advanced simulation tools and testing technologies is crucial for achieving a balance between efficiency and economy during the design process. Simulation analysis enables early identification and resolution of potential issues, facilitating optimized design and reducing development costs and time. Additionally, leveraging the advantages of modular design can reduce the complexity of integrating intelligent drive systems, improving production efficiency and quality control in vehicle manufacturing.

3.2 Intelligent Drive System Integration and Modular Design

The integration of intelligent drive systems for new energy vehicles refers to the organic combination of various subsystems, components, and functional modules to optimize overall vehicle performance. At the same time, modular design emphasizes dividing the intelligent drive system into independent and reusable modules, thereby reducing design and manufacturing complexity while enhancing flexibility and maintainability. In terms of integrating intelligent drive systems, design teams must carefully consider the mutual influences and coupling relationships among subsystems, and achieve efficient communication and coordination among functional modules through rational system architecture design and interface definition. For instance, accurate and coordinated information exchange between the motor, battery management system, and vehicle control unit is essential to ensure stable and reliable overall performance of the intelligent drive system. Modular design enables high levels of decoupling among different functional modules, thus reducing the complexity and interdependence of the intelligent drive system. By defining clear interfaces and standardizing module designs, individual modules can be independently tested and upgraded, improving system maintainability and scalability. Moreover, modular design facilitates collaboration and division of labor among team members, enabling parallel development of different modules and ultimately integrated testing, thereby enhancing both development efficiency and quality control in intelligent drive systems for new energy vehicles.

3.3 Reliability and Safety Considerations

Reliability refers to the ability of an intelligent drive system in new energy vehicles to perform its intended functions under specified conditions over a certain period. Safety, on the other hand, focuses on the system's capability to avoid causing harm to personnel, equipment, or the environment under various operating conditions. To ensure reliable operation of the intelligent drive system, design teams must conduct thorough reliability assessments and failure mode and effects analysis (FMEA) on both critical components and the overall system. This enables accurate identification of potential failure modes and their root causes, allowing for targeted design improvements that enhance the system's stability and reliability. Incorporating redundancy design and fault detection mechanisms into the intelligent drive system helps reduce the impact of single-point failures on overall system performance and strengthens the system's fault tolerance during malfunctions [2]. Meanwhile, safety considerations are an essential part of the design process for intelligent drive systems in new energy vehicles. As a core component of these vehicles, the safety of the intelligent drive system directly affects the life and property safety of drivers and pedestrians. Therefore, designers must fully account for safety requirements across diverse driving scenarios—such as crash safety, fire protection, and electrical safety—to ensure the system can promptly activate self-protection measures in various accident situations and guarantee safe vehicle operation.

3.4 Environmental Adaptability and Durability Design

In terms of environmental adaptability design, intelligent drive systems for new energy vehicles must be capable of adapting to various climatic and road conditions. To ensure reliable operation under extreme climates, materials resistant to high and low temperatures should be used in the intelligent drive system, along with an efficient heat dissipation system and a well-sealed structure to prevent moisture and dust from entering. Additionally, for applications in high-altitude regions, the impact of thin air on the performance of intelligent drive systems must be considered to guarantee stable operation at elevated altitudes. Regarding durability design, potential wear, aging, and

failure over long-term operation must be taken into account. For battery components, factors such as battery cycle life, degradation in charge-discharge performance, and the use of advanced battery management systems and charging technologies should be comprehensively evaluated to extend battery lifespan. For motors and control systems, regular life testing and simulation analysis are required to verify reliability and stability during prolonged operation. Based on this, maintenance and servicing considerations must be integrated into environmental adaptability and durability design. Design teams can combine remote diagnostic technology with intelligent health management systems to enable real-time monitoring and remote maintenance, allowing early detection of potential issues, preventive repairs, extended system lifespan, and reduced maintenance costs [3].

4 Intelligent Control Strategy for New Energy Vehicle Powertrain

4.1 Power Distribution and Coordinated Control

The power distribution in intelligent drive systems for new energy vehicles involves effectively allocating the vehicle's overall power resources to achieve optimal performance and energy efficiency. New energy vehicles feature diverse and adjustable power sources, and their intelligent drive systems can perceive vehicle conditions, road situations, and driver intentions, then use advanced control algorithms to precisely distribute power [4]. For example, in hybrid electric vehicles, the drive system dynamically adjusts the operating modes of the motor and engine based on factors such as battery state, engine load, and driving mode, thereby optimizing fuel efficiency and vehicle performance. Additionally, during power distribution, the safety and reliability of the entire vehicle system must be considered to prevent abnormal conditions such as overloading. Coordinated control refers to the synchronization and optimization of power output from multiple power sources. Since different power sources may exhibit inconsistent response speeds and power characteristics, intelligent control systems are required to ensure effective coordination.

4.2 Energy Management Strategy Based on Model Predictive Control

Model predictive control-based energy management strategies are a crucial component of intelligent drive systems in new energy vehicles. Model predictive control is an advanced control strategy that optimizes system performance by predicting the system's behavior over a future time horizon and adjusting control inputs accordingly. In new energy vehicles, the effectiveness of energy management significantly impacts driving range and overall performance. By accounting for the nonlinear characteristics and dynamic variables of vehicle powertrains, model predictive control optimizes energy distribution to improve overall energy efficiency and enhance driving performance. Through the establishment of system models combined with real-time sensor data, this approach can forecast the vehicle's future operating conditions and dynamically adjust power allocation to maximize energy utilization [5]. This strategy not only considers the vehicle's current state but also integrates anticipated driving conditions and energy consumption patterns in the near future, enabling precise energy management. In practical applications, model predictive control effectively coordinates the drive system with the energy system, ensuring high energy efficiency and superior driving performance under various operating conditions.

4.3 Fault Diagnosis and Fault-Tolerant Control Strategy

As automotive electrification advances, modern vehicle drive systems have become increasingly complex, making fault diagnosis and fault-tolerant control strategies more critical than ever. In this context, fault diagnosis systems play a vital role by enabling new-energy vehicles to promptly detect potential issues within the drive system and take appropriate actions to prevent malfunctions that could lead to accidents or injuries. Typically, fault diagnosis systems identify abnormal behaviors in the drive system through monitoring various sensor data, performing self-check procedures, and exchanging information with other control modules across the vehicle network. When an issue is detected, the system immediately triggers alarms or takes corrective actions to restrict the operation of the affected drive system, thereby ensuring the safety of both the vehicle and its occupants. Meanwhile, the core objective of fault-tolerant control strategies is to ensure that, even when a drive system failure occurs, the vehicle can automatically

switch to a backup system or implement alternative measures to maintain essential functions. By proactively designing and implementing efficient fault-tolerant control strategies, establishing redundant systems, applying redundancy design principles, and setting up failover mechanisms, vehicles can swiftly and automatically transition to backup solutions upon failure, minimizing the impact of drive system faults on normal operation and significantly enhancing driving reliability and safety. To successfully achieve these goals, it is essential to conduct comprehensive analysis and design of the vehicle's drive system, thoroughly understand the interconnections among subsystems, clearly define the functions and roles of key components, and fully consider the requirements and design rationality of fault diagnosis and fault-tolerant control from the early stages of development. This ensures safe vehicle operation under various failure conditions. In modern vehicles, fault diagnosis and fault-tolerant control strategies have become crucial safeguards for the safe and reliable operation of intelligent drive systems in new-energy vehicles.

4.4 AI-Based Driving Behavior Prediction and Optimization Strategies

Artificial intelligence-based driving behavior prediction and optimization strategies play a crucial role in the intelligent drive systems of new energy vehicles. By leveraging AI technologies, the drive system can monitor and analyze driver behavior in real time, enabling it to predict driving intentions and actions, thereby optimizing vehicle control strategies. Specifically, AI techniques such as deep learning, machine learning, and pattern recognition can model and forecast drivers' habits, preferences, and behavioral patterns. By analyzing driver operation data, vehicle sensor information, and external environmental conditions, the drive system can identify driver characteristics in real time and anticipate future driving intentions, allowing it to adjust driving modes and energy management strategies accordingly. Through AI-driven prediction and optimization, new energy vehicles can respond more intelligently to driver inputs, delivering a more personalized driving experience. The drive system can automatically adapt power output and energy usage based on driver behavior and changing road conditions, improving fuel efficiency and overall performance. Furthermore, AI-based driving behavior prediction can help prevent potential risky behaviors or accidents by issuing timely warnings or initiating interventions, thus enhancing driving safety. This intelligent approach not only enhances the driving experience but also positively impacts energy conservation, emissions reduction, and safety performance. Through continuous learning and refinement, these AI-based strategies can progressively improve prediction accuracy and response speed, making interactions between driver and vehicle smoother and more efficient. In practical applications, such strategies can be integrated with other advanced driver assistance systems—such as adaptive cruise control and lane-keeping assist—to collectively enhance the vehicle's overall driving performance and safety level.

5 Conclusion

Analyzing the importance of intelligent drive systems in new energy vehicles, this paper elaborates on the design principles, including balancing efficiency and economy, integrated and modular design of intelligent drive systems, considerations for reliability and safety, as well as environmental adaptability and durability. It proposes control strategies for intelligent drive systems, such as power distribution and coordinated control, model predictive control-based energy management, fault diagnosis and fault-tolerant control, and AI-driven driver behavior prediction and optimization. Research into the design and control strategies of intelligent drive systems for new energy vehicles has profound implications for promoting sustainable development in the automotive industry. In the future, with continuous technological advancement and innovation, intelligent drive systems will become increasingly efficient, intelligent, and reliable, providing strong momentum for the growth of new energy vehicles and fostering the flourishing development of the new energy vehicle industry.

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