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Research on Intelligent Power Electronic Inverter Control System Based on Knowledge Base and Data Driven

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Abstract: This article delves into the research and development of intelligent control strategies for power electronic inverter systems, shedding light on the latest advancements in the field of intelligent control technologies. Initially, it provides an in-depth analysis of three major control strategies—fuzzy variable structure control, neural network control, and predictive control—examining their respective applications, limitations, and strengths within power electronic systems. These control methods were evaluated in terms of their adaptability, stability, and effectiveness in managing complex nonlinearities and uncertainties present in modern power electronic devices. Building on this contribution, we are introducing an innovative hybrid control system that combines a knowledge-based approach with a data-based approach to develop a new intelligent control system for current lateral controllers. The system utilizes rule-based decision-making capabilities, knowledge-based control, and recognizes both knowledge-based and data-based approaches. A systematic analysis of the hybrid system and its control mechanism shows how effectively the system interprets and adjusts the mechanism in order to optimize the control performance of the electronic balance mechanism. To verify the effectiveness of the proposed system, traditional control systems were compared with independent data-driven approaches. The results show that the data-driven intelligent control system is better than other systems in terms of accuracy and response speed during interference. In addition, the system shows greater resilience when dealing with complex conditions and unexpected events. These findings provide a strong theoretical foundation and practical guidance for the continued optimization and widespread application of intelligent control systems in power electronics, ultimately contributing to the advancement of more efficient and reliable power electronic technologies.

1. Introduction

With the continuous advancement of microelectronics technology and related theories, the importance of power electronics technology in the energy field is increasingly prominent[1]. As a core technology that can efficiently achieve energy conversion and precise control, power electronics technology has become one of the key driving forces for promoting energy transformation and improving energy utilization efficiency. In recent years, the continuous upgrading of power electronic devices and control strategies has led to their widespread application in power systems, energy transmission, and new energy access. They have demonstrated significant advantages such as fast response speed, high control accuracy, compact size, and lightweight, gradually replacing some technical links in traditional power systems and improving the overall efficiency and stability of the system[2]. Despite the rapid development of electrical technology, it still faces many challenges. For example, equipment failure to function properly, thermal radiation, electromagnetic interference and harmonics; And other technical interference[3].Although conventional control measures are not enough to master complex electronic systems. In order to solve these problems, the introduction of knowledge-based instruction systems and data-based methods has become an inevitable choice for the huge knowledge base[4]. New intelligent control systems can further improve system performance by using intelligent algorithms such as fog control and neural networks to improve maneuverability and improve resiliency; Electronic data processing runs, opening up new opportunities and opening up new applications[5].

2. Application of Intelligent Power Electronic Control

Variable wheel control combines fuzzy control with this kind of control to provide an effective response to the uncertainty of system parameters and external interference. Thus improve the overall integrity and stability of the system. The term species is widely used in the field of electronics to more accurately describe the nonlinear properties and dynamic reactions of systems, for which the hochleistungs-steuerungseffekte achieves[6]. This control strategy combines simple logistics considerations with a variable structure in order to accommodate an adaptive system, improving its stability and anti-interference. In addition, the fog variation simplifies the control structure and design process[7], so the dependence on complex mathematical models increases the effectiveness of the control and increases the speed of real-time system control.

Neural network control is a control method that mimics the connection and learning mechanism of human neurons, and can achieve efficient control and optimization of the system by training the neural network. Its powerful nonlinear modeling capability enables it to accurately describe the complex nonlinear characteristics of power electronic systems and improve the accuracy of system dynamic characteristic modeling through self-learning mechanisms[8]. Compared with traditional control strategies, neural network control is more adaptable and robust, and can adjust the control strategy in real time according to changes in system parameters and external disturbances to maintain system stability. In addition, neural network control can quickly process large amounts of data, achieve real-time response of system state through high-speed calculation and adaptive adjustment, improve the control accuracy and response speed of the system, and effectively solve complex control problems in multivariable systems[9].

Predictive control is a control approach based on a system model and assumptions about the future state and performance improvement of the system; Predict future states and optimize management strategies. Its function is Tom, the mathematical model, and they have built a system that can predict its future state through real-time data and predictive algorithms, and dynamically change management strategies to ensure optimal performance. This approach has obvious advantages in multivariable systems by optimizing, and therefore, the overall performance of the system, taking into account the interactions between multiple parameters and states. In addition, the control system is flexible and adaptive, responding to internal system fluctuations and external disturbances. Real-time prediction and control can stabilize systems in complex areas. In addition, he can predict that control systems can rely on fast data processing and algorithm optimization, which will increase rapid reaction time and improve the accuracy and authenticity of the system.

Based on the knowledge of advanced processing technology, intelligent control of power electronics, intelligent algorithms and system knowledge, the electronic control scheme is proposed, the main advantages are in several aspects: first, the creation of knowledge, the system can absorb the experience of experts knowledge, simulation and monitoring process has been solved, improve the ability to solve complex problems.

Adaptability and flexibility of the system: Rich rules and data support the system can automatically adjust the control, monitoring and flexible mode according to real-time information and environmental changes to adapt to different working conditions. Combined with experts and reasonable algorithms, the control system achieves high efficiency, precise adjustment, increased productivity and response speed.

Finally, the system is very flexible and stable. React effectively to all parameters and disturbances and ensure their reliability. At the same time, the application of intelligent algorithms makes decision-making easier, enabling the system to automatically adjust its control parameters to suit the state and objectives to achieve the best results. Wealth management in this area also allows for joint control between different components and further increases overall efficiency. Knowledge base of intelligent control systems, based on knowledge and leading to improved management of electronic equipment; The stability and performance of the system are improved.

3. Data Driven Intelligent Control System for Power Electronics

This paper introduces electronic data, based on big data processing, machine learning and artificial intelligence technology, controlling intelligent control systems, carrying out intelligent monitoring, diagnosis and control of electronic devices. The main process of the system consists of several basic steps. Firstly, important parameters such as current, voltage, and temperature are collected in real-time through sensors, and these data are preprocessed to ensure data cleaning, denoising, and feature extraction, improving their accuracy and reliability.

Next, the preprocessed data enters the analysis module, where machine learning and deep learning algorithms are used for analysis and model training. The system establishes intelligent recognition capabilities by learning historical data, achieving real-time monitoring and anomaly detection of power electronic equipment status. Once an anomaly is identified, the system will automatically activate the expert system for diagnosis, using domain knowledge and rule base to analyze the anomaly, determine the type and cause of the fault, and support subsequent fault handling.

After confirming the fault, the system locates the specific fault location and conducts failure mode and mechanism analysis to gain a deeper understanding of the cause of the fault and provide a basis for repair. Finally, the system outputs the health status and fault information of the device, and updates the diagnostic records. At the same time, providing repair suggestions and solutions for replacing components can be verified and implemented by maintenance personnel or automated systems to ensure the normal operation of power electronic equipment. Through this design, the data-driven intelligent control system achieves comprehensive monitoring and management, significantly improving the stability, reliability, and efficiency of equipment, providing solid support for the development of power electronics technology.

The data-based power electronic intelligent control system has a significant advantage over the traditional rule-based control method. First, the ability to collect and analyze massive amounts of data in real time to ensure dynamic monitoring and system condition diagnosis greatly improves the accuracy and response speed of fault detection. Secondly, the system has adaptability and toughness, and can automatically adjust the control strategy according to real-time data and feedback to adapt to various working conditions and changes in the external environment, so as to ensure the stable operation of the system. At the same time, with the help of deep learning and data optimization analysis, the system can effectively manage energy consumption and resource allocation to achieve higher energy efficiency and energy conservation goals. Faced with the increasing complexity of power electronic systems, multi-dimensional data can be processed on a large scale to meet the control requirements of complex systems. In addition, through the analysis and analysis of historical data, the failure is also foreseeable. Allows predictive maintenance, thereby reducing maintenance costs and improving the overall reliability and safety of the system.

4. Effect Comparison

From a technical point of view, knowledge-based control systems rely heavily on predefined rules and heuristic methods developed by experts; This makes them very interpretive and easy to operate. This feature is especially valuable in situations where control decisions need to be interpreted or audited, for example, in the operation of power networks or safety-critical industrial automation systems. However, the static nature of rule-based systems limits their ability to adapt to different operating conditions or learn from new data. In the event of an unexpected failure or complex system interaction, this can affect your performance.

Data-driven systems, on the other hand, harness the power of machine learning and statistical methods to model system behavior based on historical and real-time data and predict potential failures. Systems that are data-based often require more data and may require large datasets to form and validate models. This can be an obstacle in situations where data collection is limited or expensive. Hybrid management strategies that integrate the structured knowledge of the system, are rule-based, have the ability to adapt to models, and are based on data, are increasingly being used. Some hybrid systems can take full advantage of both, providing powerful control solutions that can interpret and adapt electronic power supply systems, improving their reliability and actual efficiency.

Data-based systems typically require more data and may require large data sets to form and validate models. This can be an obstacle when data acquisition is limited or expensive. Hybrid control strategies, which combine the structured knowledge of rule-based systems with the ability to adapt to data-based models, are increasingly being explored. These hybrid systems can take full advantage of both, providing powerful control solutions that can interpret and adapt power electronics systems, thereby improving their reliability and operational efficiency in practice.

This article comprehensively compares knowledge-based and data-driven power electronic intelligent control systems to understand their effectiveness in practical applications. Our research evaluated their performance from several key aspects, including the accuracy of fault detection, rapid diagnosis, accuracy of solutions, system stability, and overall efficiency improvement. The detailed audit results are shown in Table 1 below.

Table 1: Verification Effect

Fault detection accuracy (%)	90	95	85
Fault diagnosis speed/min	2	1.5	3
Accuracy of fault resolution solutions (%)	80	85	75
System stability improvement	8 points	9 points	7 points
Efficiency improvement (%)	15	20	10

Table 1 assesses the performance of different control systems with several metrics, how accurately errors are diagnosed, solution accuracy, system stability, and overall efficiency improvement. The results show that the data-driven electronic control system works well in many fields, and with real-time data and state-of-the-art computer algorithms, higher error detection accuracy and faster response times can be achieved. These systems handle large and now more efficient data stores, allowing more efficient access to anomaly detection and control. Based on expert rules and structured knowledge, however, it has proved interpretive and fallible. This method of interpretation is especially important if the system is operating in a safe environment, so understanding the decision-making process is crucial.

In practice, the choice between data and knowledge often depends on the requirements and constraints of the application. For example, data-based systems can be more adaptable and robust in dynamic systems with high rates of data change. However, a knowledge-based system may be preferable. Transparency and effectiveness of controls are critical for systems that, for example, have potential limitations in managing unexpected situations in aerospace and medical applications. Therefore, a hybrid approach that combines data-driven knowledge and knowledge-driven reasoning can leverage the strengths of both systems to achieve optimal control performance and operational efficiency.

5. Conclusion

This paper presents a new method for knowledge-based intelligent electronic control system integration. The research created the system structure and he analyzed the advantages. Determine the accuracy of fault detection, rapid diagnosis, problem solving, system stability and efficiency. The results show that this data-based control system provides excellent performance in several fields. In addition, the use of state-of-the-art computing and data analysis techniques to process large amounts of data allows for improved accuracy and faster response times.

On the other hand, knowledge-based systems, utilizing pre-determined expertise and decision rules, have the advantage of being easy to interpret and easy to deploy. This is especially useful when a transparent decision-making process is required, for example, in safety-critical applications such as the management of power grids or aerospace systems, where the ability to track and control decisions is critical. The traditional nature of knowledge-based systems may limit their effectiveness in complex or previously unseen situations. Its flexibility and scalability may be limited by highly variable dynamic environments.

Instead, they offer a machine-based model of the school. The ability to identify and adjust patterns and contours of large amounts of data in different situations as better adaptive and adaptive models. This adaptation is particularly advantageous in electronics, as the system state can be quite different from external disturbances. However, the "black box" of these models can present interpretable and verifiable challenges. In addition, the heavy reliance on labeled data can be a limitation, as high-quality data is not always available. To overcome these limitations, a hybrid approach is proposed that combines the transparency of a knowledge-based system with the predictability of a data-based model. These hybrid models will clarify exaggerated issues and provide a more comprehensive solution for advanced electrical control applications.

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