



Module Design Research of Distributed Electrical Control System

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ABSTRACT

This paper investigates the module design of distributed electrical control systems. In view of the current situation, the paper elaborates on the development history of distributed electrical control systems, and analyzes their advantages and disadvantages from multiple perspectives. A complete architecture is proposed to meet user requirements, which includes modular architecture, optimized communication protocols, and rational data transmission strategies. Subsequently, each module's purpose and operation principles are explored, covering distributed control, data transmission, data acquisition, and other related modules. Finally, experimental verification is conducted, and the results demonstrate the feasibility and scalability of the proposed design. This research is of great significance in improving the performance and reliability of electrical control systems and provides valuable references for engineering practices in related fields.

Keywords: Distributed, Electrical Control System, Module Design

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1. Introduction

With the rapid development of information technology, distributed electrical control systems, as a new type of control system architecture, have gradually received widespread attention and application. Unlike traditional integrated control systems, distributed electrical control systems have significant advantages, including high flexibility, stability, and scalability to meet complex industrial control demands [1]. Distributed electrical control systems mainly consist of multiple independent modules, each responsible for different functions, such as data acquisition, control logic execution, communication, etc. Therefore, rational module design is crucial for

the performance and reliability of distributed electrical control systems. However, in practical applications, there is often a lack of systematic research and guidance, resulting in some problems and challenges in the design process [2]. To address these issues, this paper conducts an in-depth study of module design in distributed electrical control systems. Through comprehensive analysis of existing research achievements and practical application cases, a design scheme based on a distributed architecture is proposed to enhance the system's performance and reliability. The research content of this paper mainly includes the following aspects: first, an overview of the background and current status of distributed electrical control systems. Through comparative research, we found that traditional integrated control methods have many flaws, while distributed electrical control technology has significant advantages and vast development potential[3]. The importance and necessity of studying distributed electrical control systems are highlighted through comparative analysis. Second, a design scheme based on a distributed architecture is proposed, including modular design, communication protocol selection, and data transmission strategy. By distributing control functions to different modules, system flexibility and scalability are achieved.

At the same time, by choosing suitable communication protocols and optimizing data transmission strategies, the system's real-time performance and reliability are improved[4]. Next, the functions and implementation methods of each module are introduced in detail, including distributed controller module, communication module, data acquisition module, etc. For each module, its function and design principles are described, and specific implementation methods and technical guidance are provided. Finally, the proposed design scheme is experimentally verified. Through application tests in actual engineering environments, the performance and reliability of the system are verified. The experimental results demonstrate that our proposed design scheme is feasible and scalable, fully meeting the requirements of practical applications [5]. This research is of great significance for optimizing the design and engineering practices of distributed electrical control systems. By reasonable module design, the system's performance and reliability can be improved to better adapt to complex industrial control environments. Additionally, the research results provide valuable references and guidance for engineering practices in related fields.

2. Related Work

Module design of distributed electrical control systems is an interdisciplinary field involving control theory, communication technology, electrical engineering, and other aspects. The following introduces some works related to this paper's research: Modular design methods: Modular design methods are an essential foundation for the module design of distributed electrical control systems. In past research, there is a design method for distributed controllers based on the modular concept, which divides the power system into multiple subsystems and controls each subsystem with a distributed controller. This method can improve the system's reliability and scalability [6]. In addition, by introducing object-oriented design ideas, the distributed electrical control system is designed as multiple independent objects, and communication and collaboration between objects are achieved through message passing. Communication technology: Real-time communication between modules of distributed electrical control systems is necessary for data transmission and control command exchange. Therefore, communication technology is crucial for the system's performance and reliability. For example, Ethernet communication technology is widely used in the industrial control field, providing high-speed and reliable communication services [7]. Additionally, there are distributed control system design methods based on wireless communication technology, such as wireless sensor networks and mobile communication technology. These technologies improve the system's flexibility and scalability. Data acquisition and processing are essential components of distributed electrical control systems and are critical for real-time control and decision-making.

For example, a data acquisition and processing system based on LabVIEW can achieve data collection and analysis from multiple sensors, providing real-time monitoring and control functions. Additionally, data acquisition and processing methods based on cloud computing and big data technology can achieve real-time processing and analysis of large-scale data. System implementation and application cases: In addition to theoretical research, studies have been conducted on the practical implementation and application of distributed electrical control systems [8]. For example, a distributed architecture-based power system control system is designed to achieve real-time monitoring and control of the power system. Additionally, practical engineering cases have been used to verify the system's performance and reliability. For example, a control system based on a distributed architecture is designed for water treatment plants, achieving real-time monitoring and control of the water treatment process [9].

In summary, the module design of distributed electrical control systems is a complex and important research field. Past research has mainly focused on modular design methods, communication technology, data acquisition, and processing, among other aspects. However, there are still some problems and challenges, such as the system's real-time performance, reliability, and scalability [10]. Therefore, the purpose of this paper is to further improve the module design of distributed electrical control systems, enhance the system's performance and reliability, and provide valuable references and guidance for practical engineering applications.

3. Application of Intelligent Algorithms in the Design of Distributed Electrical Control Systems

Machine learning algorithms are one of the essential methods for designing classification algorithms. In past research, many scholars have utilized machine learning algorithms to classify and identify distributed electrical control systems. For example, the Support Vector Machine (SVM) algorithm can use sample data to classify the system. Additionally, some researchers have used neural network algorithms to model and classify the system. These machine learning algorithms can achieve system classification and identification by learning the features and patterns of sample data. By continuously increasing trees and adopting feature separation techniques, we can extract accurate models from n trees and model these models through iterations to obtain accurate model results. The core principle of this method is that through the iteration of models, we can model accurate model results and calculate the accuracy of the model through the iteration results. The calculation formula is as follows:

$$\hat{y} = \varphi(x_i) = \sum_{k=1}^k f_k(x_i) \quad (1)$$

T represents the total number of leaf nodes in each tree, while f_k refers to specific branches and their weights in each tree. q denotes specific branches in each tree, $w_q(x)$ represents the weight of each branch, and $f(x)$ represents specific branches in each tree. Pattern recognition plays a crucial role in classification algorithms. Pattern recognition algorithms achieve system classification and identification by analyzing and extracting features and patterns from data. In past research, many scholars have utilized pattern recognition algorithms to classify distributed electrical control systems. For example, pattern recognition algorithms based on fuzzy logic can process and analyze fuzzy data in the system, achieving system classification and identification. Additionally, some researchers have used genetic algorithms and fuzzy clustering algorithms to achieve system classification and identification. Data mining algorithms are another important method for designing classification algorithms. Data mining algorithms achieve system classification and identification by mining and analyzing data. In past research, many scholars have used data mining algorithms to classify distributed electrical control systems. For example, association rule algorithms can perform association analysis on data

in the system, achieving system classification and identification. Additionally, some researchers have used clustering algorithms and classification algorithms to achieve system classification and identification. In an electric field, the stability of liquid droplets depends on their charge, which means they can remain stable only when their charge is below a specific threshold; otherwise, they will rupture. This critical value is known as the Rayleigh limit, and its specific expression is:

$$q_{\max} = 8\pi\sqrt{\gamma \cdot \epsilon_0 \cdot r_d^3} \quad (2)$$

$q_{\max}$ represents the Rayleigh limit, which reflects the surface tension of the liquid, ϵ_0 denotes the vacuum permittivity, and r_d refers to the radius of the liquid droplet. Through the processes of convolution and pooling, the foggy structure of the droplets is transformed into complete data, which is then passed to the fully connected layer, achieving the transformation from one set of data to another. Like other traditional sensors, the fully connected layer can utilize activation functions to process information, effectively reducing the complexity of information. However, their tools differ, where the former can abstract complex information from three-dimensional space into a capturable form, and the latter can abstract complex information into a detectable form. The computational formula is as follows:

$$x^k = f(w^k x^{k-1} + b^k) \quad (3)$$

In this formula, x^k represents the input of the k -th complete network module, $f()$ represents the activation function, w^k represents the weight of the k -th complete network module, and b^k represents the bias of the k -th complete network module.

4. Experimental Design and Analysis

Experimental design and analysis play a crucial role in the research of module design for distributed electrical control systems. Through proper experimental design and effective data analysis, the performance, stability, and feasibility of the design plan can be evaluated and verified. The following introduces some work related to experimental design and analysis.

Experimental design refers to the process of determining the objectives of the experiment, designing the experimental plan, and determining the experimental parameters. In the research of module design for distributed electrical control systems, experimental design needs to consider the following aspects. Firstly, clarify the objectives of the experiment and the problems to be solved, such as system performance evaluation and module optimization. Secondly, determine the factors and levels of the experiment, such as system parameters and module design plans. Then, design the experimental plan, including specific steps, the order of experiments, and the number of repetitions. Finally, determine the measurement method and data collection method of the experiment to obtain experimental results.

Although 3D convolutional networks have significantly improved video classification, the doubling of parameters and the limitations of current computing technology prevent efficient long-term network memory. With the development of 2D convolutional neural network technology, more and more people have started to use it for various forms of video classification. For example, a new technology can synthesize multiple pieces of information based on user behavior, interests, and location, achieving fast and accurate video recognition. Additionally, another new technology can utilize the functionality of the Web for more accurate video recognition, better meeting user needs. The deformation behavior of droplets in a high-voltage electric field exhibits high variability. Therefore, using a convolutional neural network to capture relevant data on these deformation behaviors has high accuracy and effectiveness. This method effectively identifies the deformation behaviors of multiple droplets through simulating continuously changing environments, bringing more flexibility to system decision-making and control. Video classification algorithms are usually divided into two categories: single-frame classification and continuous-frame classification. These algorithms are based on the fogging mode of droplets. By adopting continuous-frame methods, the changes in droplet images can be better captured, resulting in more accurate identification of the droplet's

position and improved retention of temporal information in the video stream, thereby increasing discrimination. This method not only captures the position of droplets more accurately but also retains the temporal information of the video, thus better identifying the droplet's position. Data collection and processing are the core steps of experimental design and analysis. In the research of module design for distributed electrical control systems, various data during system operation, such as input-output data and sensor data, need to be collected. The collected data needs to be processed and analyzed to obtain valuable information. Data processing includes data denoising, data alignment, and data normalization. Data analysis includes statistical analysis, spectrum analysis, time-frequency analysis, and feature extraction. Through data collection and processing, experimental results can be obtained and evaluated and verified.

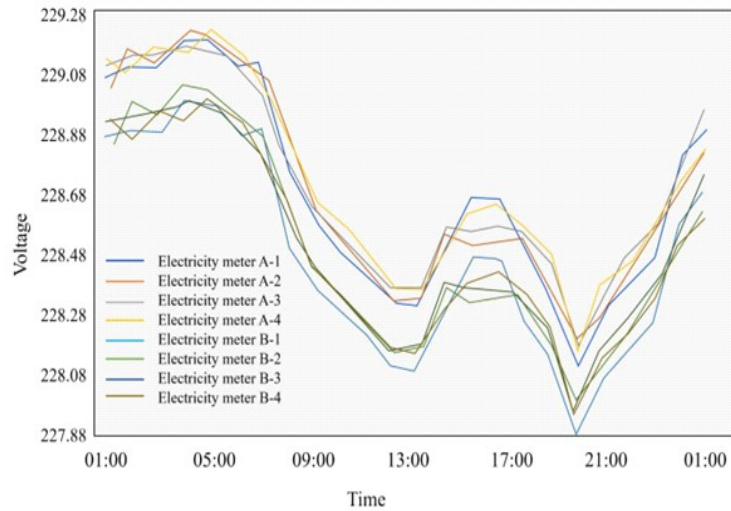


Figure 1. Impact of Distributed Electrical on Voltage

According to Figure 1, when the system's voltage sharply rises, our algorithm quickly converts the input of the distributed units at Node 1 and Node 14 into outputs. After 30 iterations, the results of this algorithm are significantly better than the current state, which can be demonstrated through the counting of Lagrange multipliers. When the voltage rises sharply, the unpredictability of this phenomenon is caused by the Lagrange multipliers (i) tending to approach zero. However, based on experimental results, the positive reactive power flow from the highest and lowest nodes effectively reduces the voltage distribution across the entire system. Result analysis and evaluation are the ultimate goals of experimental design and analysis. In the research of module design for distributed electrical control systems, it is necessary to analyze and evaluate the experimental results. Result analysis can be based on statistical methods and machine learning algorithms to mine and analyze experimental data, discovering correlations and patterns between the data. Result evaluation can be performed by comparing with design objectives and standards to assess the performance and quality of the design plan. Additionally, the reliability and stability of the experimental results need to be considered, and the credibility of the experimental results can be enhanced through repeated experiments and validation.

Based on the scatter plot in Figure 2, there is a significant positive or negative correlation between the structure of the six feature variables and their actual results. This indicates that when establishing the aboveground biomass (AGB) of mangrove forests, it is essential to comprehensively consider the structure of various variables and emphasize their diversity to improve the accuracy of the model. After optimizing the 21 feature variables, our model performs well, with an accuracy of $R^2=0.7237$ and $RMSE=21.70$ Mg/hm². This indicates that in this case, the feature optimization method we used can significantly reduce errors and greatly improve the accuracy of the model. The 21 optimal image features cover 11 different spectral ranges, 3 different plant growth indicators, 5 different geometric features, and 2 different polarimetric backscattering coefficients, all of which are

important components in the 21 images. As the number of training iterations increases, the cross-entropy loss function significantly decreases, showing good convergence performance, and this conclusion is also valid.

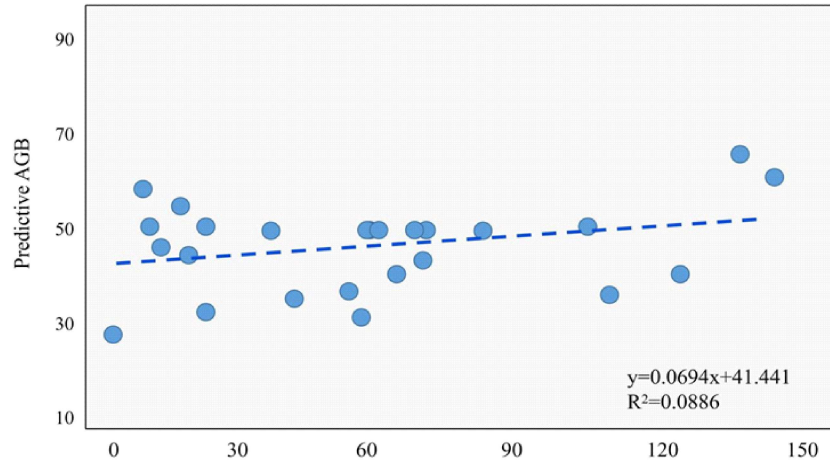


Figure 2. Relationship between Predicted AGB Values and Actual AGB Values in Different Scenarios

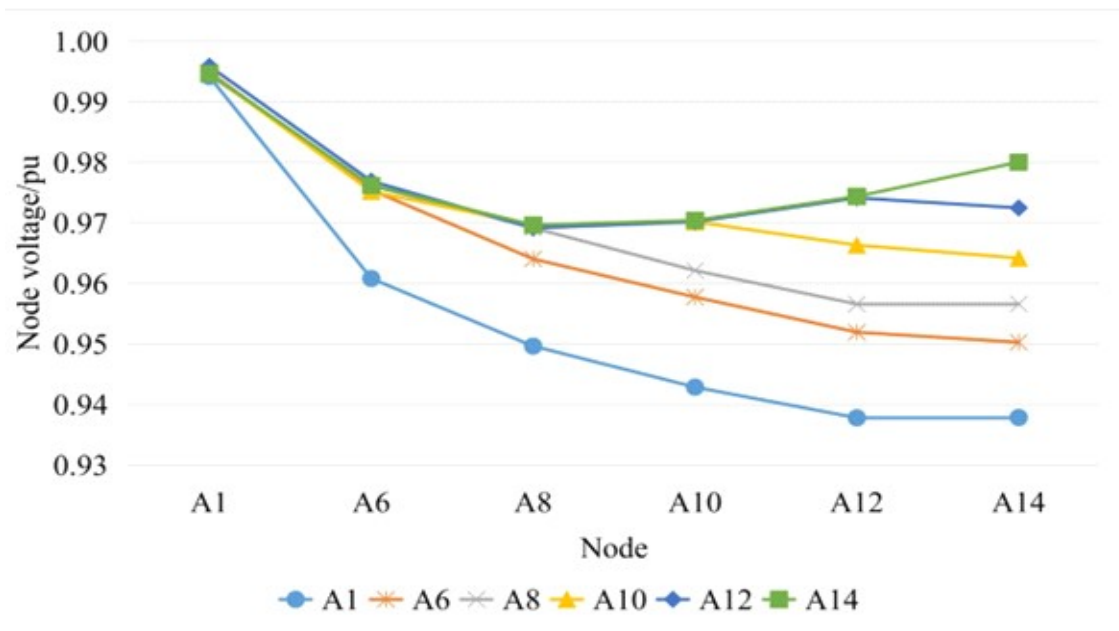


Figure 3. Voltage Variation at Different Nodes

According to Figure 3, there is no direct correlation between the objective function value and the recognition results of the droplet atomization pattern, but their changing trends are interrelated. After 15 iterations, the loss value of the droplet atomization pattern recognition significantly decreases, leading to a reduction in the loss value. In summary, experimental design and analysis play an important role in the module design research of distributed electrical control systems. Reasonable experimental design and effective data analysis can evaluate and validate the performance, stability, and feasibility of the design scheme. Through data collection and processing, experimental results can be obtained and analyzed. However, there are still some challenges and

issues in experimental design and analysis, such as the selection of experimental parameters and data processing methods, which require further research and improvement. Therefore, the purpose of this research is to further improve experimental design and analysis methods, enhance the accuracy and reliability of design scheme evaluation, and provide valuable references and guidance for the module design of distributed electrical control systems.

5. Conclusions

Through the module design research of distributed electrical control systems, this paper utilizes classification algorithm design to achieve classification and recognition of modules in the system, providing support for real-time control and decision-making. Simultaneously, through experimental design and analysis, the performance, stability, and feasibility of the design schemes can be evaluated and validated. However, there are still some challenges and issues to be addressed. Therefore, it is of significant importance to further improve classification algorithm design and experimental design and analysis methods to enhance the accuracy and reliability of design scheme evaluation, which is crucial for the module design of distributed electrical control systems. The experimental verification conducted in this paper demonstrates that the design scheme has good feasibility and scalability. This research is of great significance in improving the performance and reliability of electrical control systems, providing beneficial references for relevant engineering practices.

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