DOI: 10.23977/jeeem.2024.070207
ISSN 2560-6697 Vol. 7 Num. 2

Research on Optimization Scheduling Technology Based on Distributed Power Cluster Model and Advanced Algorithms

Ziyuan Peng, Haibo Yuan, Heng Shen, Bowen Yang, Ziye Wang

State Grid Hubei Electric Power Co., Ltd., Xianning Power Supply Company, Xianning, 437100, China

Keywords: Distributed Power System, Renewable Energy, Optimization Scheduling Technology, Edge Cluster Model, Advanced Algorithms

Abstract: With the extensive grid connection of various new energy sources, the traditional centralized economic dispatching mode is facing challenges in the new power system. This paper presents an optimal scheduling technology based on distributed power cluster model and advanced algorithm. By constructing edge clustering models of some new energy sources and analyzing their fluctuation characteristics, an optimization method for distributed economic scheduling is proposed based on the traditional consistency algorithm. In addition, a two-layer optimal planning model of AC-DC hybrid microgrid cluster is established. In the upper layer model, node coupling and power balance are considered to realize the cluster division of regional nodes. The bottom optimization configuration model aims to minimize the total cost, and uses optimization software to analyze and obtain optimal configuration results. Simulation results show that the proposed optimization scheduling technology has significant advantages in the field energy consumption of distributed power supply, reducing system cost, improving scheduling efficiency, etc. It provides a new theory and technical support for the optimization scheduling of distributed power supply system.

1. Introduction

The aim of this study is to explore optimization scheduling techniques based on distributed power cluster models and advanced algorithms to address the challenges brought by clean energy integration into the power grid. With the widespread application of clean energy, the integration of high-density distributed power sources (DGs) into the power grid has caused a series of problems, such as disorderly access, decreased power quality, and insufficient power supply reliability. Hybrid AC/DC microgrid, as a solution, combines the advantages of AC and DC microgrids. However, a single hybrid microgrid has limitations in capacity and power supply range, making it difficult to meet the needs of renewable energy integration. Therefore, the combination of AC and DC microgrids has become a research focus. And by establishing a distributed power cluster model and adopting advanced algorithms, an optimization scheduling technology is developed to address the challenges of traditional centralized scheduling methods when facing distributed renewable energy clusters. Existing research mainly focuses on the design and scheduling of micro electric network clusters, while there is relatively little research on the planning of distributed power generation access. Therefore, this article proposes a two-layer AC/DC hybrid microgrid optimization planning model to achieve efficient scheduling of distributed power clusters. The upper level model aims to achieve cluster partitioning, considering node coupling and power balance; The lower level model aims to minimize investment, operation and maintenance, and purchasing and selling electricity costs, and uses CPLEX software to optimize the configuration of distributed power sources. Through simulation verification of actual systems, it has been proven that the model has significant advantages in reducing system costs and improving local consumption capacity. This study not only provides theoretical and technical support for the effective integration and optimization scheduling of high proportion renewable energy, but also promotes the intelligent development of new power systems, which has important academic and application value.

2. Related Literature

This study proposes a series of solutions to the frequency fluctuation problem of large-scale wind power cluster integration into the power system. The advanced frequency control strategy based on distributed model predictive control has achieved coordinated cooperation between wind power clusters and traditional power sources in frequency control. By adopting a multi temporal and spatial scale coordinated wind power cluster comprehensive frequency control strategy based on hierarchical distributed model predictive control, the system frequency regulation was achieved while balancing economic and safety objectives. Finally, the accuracy and reliability of system frequency regulation were improved through a chance constrained objective rolling planning method based on stochastic layered distributed model predictive control. The simulation results show that the proposed method effectively solves the frequency fluctuation problem of large-scale wind power cluster integration into the power system, and has practicality and robustness.[1]

China's new energy development ranks at the forefront of the world, with the largest scale of wind power and the fastest growth in photovoltaic power generation. However, the randomness and intermittency of distributed power sources (DGs) such as wind power and photovoltaics increase the difficulty of system peak shaving and scheduling. The traditional peak shaving method of generator sets can no longer meet the large-scale demand for new energy grid connection. This article explores the feasibility of user side active participation in peak shaving, analyzes the current peak shaving mode and its advantages and disadvantages, and explains the impact of large-scale new energy grid connection on the power system. To solve the problem of peak shaving, this article studies the demand side management method and proposes a linkage between new energy generation and load characteristics to achieve power complementarity and reduce peak shaving pressure. A multi-objective peak shaving scheduling model is proposed to address the management challenges of decentralized distributed energy (DER) by utilizing virtual power plants (VPP) for coordinated optimization, with the goal of minimizing load variance and operating costs. [2]

In order to achieve the goals of peaking carbon emissions and achieving carbon neutrality, it is necessary to promote low-carbon energy transformation. Although the integrated energy system improves efficiency and renewable energy consumption through multi energy complementarity, it also increases the difficulty of scheduling. The limitations of information protection and autonomous decision-making make traditional scheduling methods no longer applicable, while non convex equations further increase the complexity of the problem. To address these issues, this study analyzed the distributed optimization and energy flow of multi regional power systems and integrated energy systems based on distributed computing and convex relaxation techniques, and proposed a two-layer solution algorithm suitable for distributed scheduling of various power grids.[3]

To ensure the economic efficiency of distributed power generation in power systems, we have established an optimization model with the goal of minimizing economic and environmental costs in systems including cogeneration units, photovoltaic cells, lead-acid batteries, and heat storage water tanks. Under the premise of meeting the constraints of power supply, heating demand, and unit operating parameters, an improved mixed integer nonlinear programming algorithm is adopted for evaluation. The results show that the optimal solution of the improved algorithm is more economical and environmentally friendly than traditional algorithms, with lower total system costs and reduced carbon emission costs. [4]

With the increase of distributed energy resources in active distribution networks, traditional centralized control structures are no longer applicable. We propose a new scheduling strategy based on multi-agent systems, aimed at achieving intra group autonomy and inter group coordination. Through improved distributed optimization methods, coordinated optimization is carried out at both global and local levels to optimize the "source load" requirements. The verification results show that this strategy has demonstrated effectiveness and rationality in the IEEE 33 node system. [5]

Given that the uncertainty of distributed energy output power poses challenges to the economic scheduling of microgrid systems, we combined the principle of robust optimization to handle the random factors in the traditional economic scheduling model of microgrid systems, and established a robust optimization model suitable for microgrid economic scheduling containing distributed energy systems. This model enables the micro grid system to dynamically optimize the scheduling of various power sources, thus reducing the economic cost of the safe and stable operation of the micro grid system. [6]

The invention relates to a distributed job task scheduling method and system based on genetic algorithms, aimed at addressing the problem of low system efficiency caused by uneven distribution of job volume. This method includes determining unique identifiers for nodes and jobs, constructing a task scheduling population, executing tasks in the job queue pool, evaluating the task with the longest execution time as a fitness value, rebuilding the population, and outputting the optimal solution when the maximum number of iterations is reached. The system includes corresponding modules, such as task scheduling and population building modules. [7]

A research and invention have disclosed a distributed job task scheduling method and system based on genetic algorithms, mainly to solve the problem of low system efficiency caused by workload imbalance. The operation of this distributed job scheduling method mainly consists of several steps: the first step is to read the job data and assign a unique identifier to each node and job based on the number of nodes; the second step is to construct the task scheduling group and evaluate the fitness value; the third step is to output the individual with the lowest fitness value and its value at the maximum number of iterations, while performing overall reconstruction.[7]

To improve the efficiency and safety level of virtual power plants (VPP), we have improved blockchain technology and applied it to the optimization scheduling of VPP. Firstly, a blockchain based optimization algorithm adapted to the VPP environment was proposed, and then the traditional blockchain system was improved to establish an optimized blockchain system suitable for VPP. Finally, we proposed a scheduling strategy for VPP. The simulation results show that the optimized blockchain system significantly improves the scheduling efficiency of VPP and shows significant advantages in reducing costs, improving energy utilization efficiency, and reducing carbon dioxide emissions. [8]

We have designed a multi-agent architecture for the distributed scheduling problem of multi park integrated energy systems, proposed a distributed economic scheduling framework, and established a centralized optimization scheduling model with multiple decision-making entities. By introducing the alternating direction multiplier method, the decentralized autonomous problem of centralized optimization scheduling has been successfully solved, and the challenges of low information security and high communication costs have been overcome. Finally, taking the multi park integrated energy system as an example, the superiority of the new method was verified. [8]

3. Research on Optimization Scheduling Technology Based on Distributed Power Cluster Model and Advanced Algorithms

3.1 Introduction to Distributed Power Cluster Model

The distributed power cluster model is a system that organizes multiple distributed energy resources (DER) into clusters and coordinates and manages them through network connections (as shown in Figure 1). These distributed energy resources include wind turbines, battery energy storage, solar cells (Figure 2 shows the circuit diagram of the solar panel) and so on, which are distributed in different geographical locations or logical regions. According to organization and characteristics, distributed power supply clusters can be divided into several categories, including geographic location, technological type, hybrid type, and functional characteristics. A geographical location cluster is composed of resources from adjacent regions, while a technology type cluster contains resources of the same type. Hybrid clusters mix different types of resources, while functional feature clusters are classified based on their functions, such as energy production, storage, and management. These classifications help to better manage and utilize distributed energy.

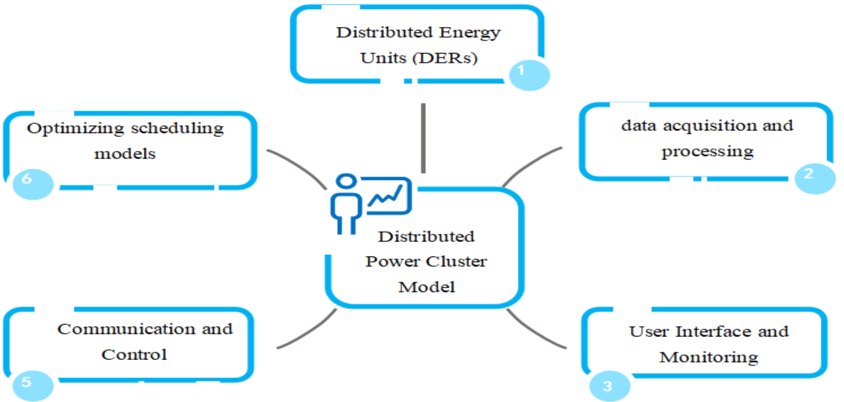

Figure 1: Composition of the Distributed Power Cluster Model

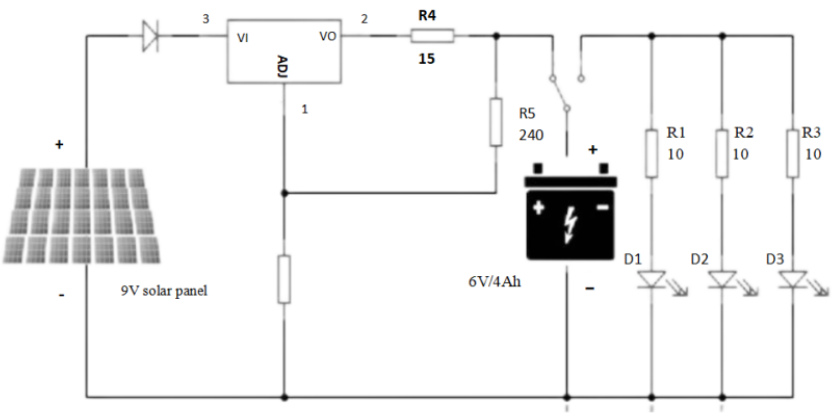

Figure 2: Solar panel circuit diagram

The design of the distributed power generation cluster model aims to improve energy utilization efficiency by coordinating and scheduling multiple DER, achieving full utilization of energy within the cluster, maximizing energy utilization, and enhancing system flexibility, enabling it to flexibly respond to different energy inputs and demand changes, providing strong support for system adaptability and flexibility. Through centralized management and optimized scheduling, energy costs and production and distribution costs are reduced, and energy efficiency is improved. Most importantly, the model helps to improve system stability, reduce energy fluctuations and fault risks through unified scheduling and management, and ensure stable operation of the system. In summary, the distributed power cluster model provides important support for the sustainable development and optimized operation of the energy system, Promoted the large-scale application and intelligent management of clean energy.

The construction of distributed power cluster model usually includes three main stages: the first stage is the collection of various necessary data, including energy resource output, user demand data and grid state data; The second stage is data processing and cleaning, which can ensure the accuracy and completeness of the collected data, and then analyze the data to understand the relationship and impact of energy resources; The third stage is the construction of the model, the selection of appropriate modeling methods and technologies, and then the determination of various parameters of the model, including energy characteristics parameters, user demand parameters and power grid parameters. In the process of building the model, we need to consider the dynamics and complexity of the system, and the model we need also needs to apply various mathematical modeling methods to build, including optimization model and simulation model. The last step is to verify and optimize the model. The accuracy and reliability of the established model should be verified, and the parameters and algorithms of the model should be continuously adjusted to improve the applicability and performance of the model, further improve the operating efficiency and economy of the distributed power generation cluster, and realize the sustainable development and optimal operation of the system.

3.2 Overview and Selection of Advanced Algorithms

Genetic algorithm is an optimization algorithm based on the principle of biological evolution, which seeks the optimal solution or approaches the optimal solution of a problem by simulating natural selection, crossover, and mutation processes. The core steps include initializing the population, evaluating fitness, selection operation, crossover operation, mutation operation, and repeated iteration. In practical applications, genetic algorithms are widely used to solve various optimization problems, including function optimization, machine learning parameter optimization, intelligent control system design, and other fields. Its flexibility and efficiency make it an effective tool for solving complex problems, with broad application prospects. In contrast, Artificial Neural Network (ANN) is a computational model that mimics biological neural networks, consisting of input layers, hidden layers, and output layers (as shown in Figure 3). Neurons are connected by weights and trained using backpropagation algorithms. During the training process, the output is calculated through forward propagation, and then the weights and bias values are adjusted through backpropagation based on the error with the real label to optimize the network parameters. Through continuous iterative training, the neural network can gradually learn the features and patterns of the data, and realize the prediction and classification of complex problems. When it comes to selecting advanced algorithms, both genetic algorithms and artificial neural networks are important candidates and can be selected according to the characteristics and requirements of a particular problem.

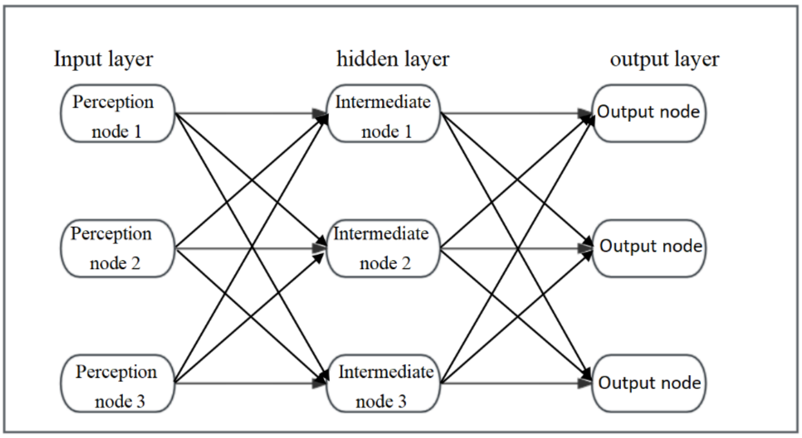

Figure 3: Working principle diagram of artificial neural network

Optimization algorithms play a crucial role in solving complex problems, such as particle swarm optimization (PSO) and simulated annealing (SA) algorithms, which use different search strategies to find the best solution or approximate optimal solution in the solution space to solve the current problem. Particle swarm optimization algorithms model the behavior of birds or schools of fish, taking inspiration from the behavior of these populations of organisms as they search for food or resources. Each "particle" in a particle swarm optimization algorithm represents a potential solution, and it searches for the best solution by simulating its motion in the solution space. During the search process, the "particle" adjusts its position according to the historical optimal position of the individual and the optimal position of the group, constantly optimizing the quality of the solution (As shown in Figure 4). The simulated annealing algorithm simulates the metal annealing process by accepting the probabilistic "difference decomposition" and searching for the global optimal solution in the solution space, which gradually reduces the acceptance probability and thus balances the relationship between global and local search. When selecting optimization algorithms, researchers should consider the specific characteristics of the problem and the requirements of the solution. For example, because the parameter selection and convergence of particle swarm optimization algorithms are relatively stable, all particle swarm optimization algorithms are suitable for solving optimization problems in continuous space; The simulated annealing algorithm is suitable for solving problems with large solution Spaces and complex constraints because it can find a balance between global search and local search. These improved optimization algorithms have their own advantages in different scenarios. Choosing the right algorithm when encountering problems can improve the efficiency and accuracy of problem solving.

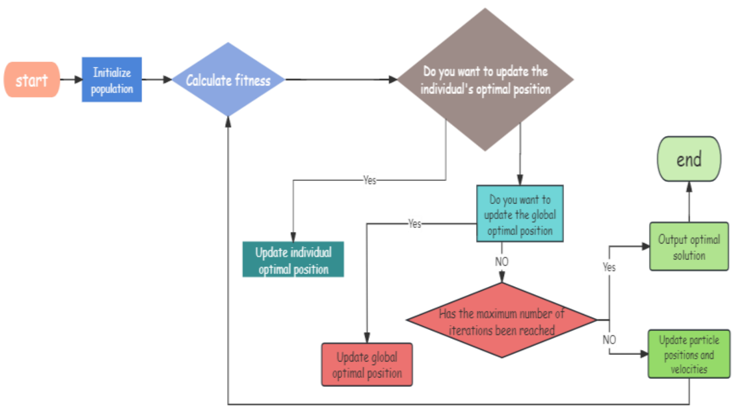

Figure 4: Flowchart of Particle Swarm Optimization Algorithm

3.3 Research on Optimization and Scheduling Technology for Distributed Power Cluster

The research on optimal dispatching technology of distributed power generation cluster is mainly aimed at improving the efficiency and economy of power system, and effectively managing and regulating distributed energy. The definition and optimization of objectives are very important in the research, and the objectives of this time include reducing the operating cost of the system, improving the reliability of the power supply and improving the efficiency of energy utilization. The realization of these goals requires the establishment of a mathematical model describing the scheduling problem, which needs to comprehensively consider various constraints such as supply and demand balance, power flow balance, equipment operation restrictions, etc. The volatility and uncertainty of distributed energy should also be fully taken into account, and how to coordinate the scheduling with traditional power generation methods should also be considered. These complex analysis and modeling efforts provide an important basis for the development of optimized scheduling techniques, which help to improve the efficiency and economy of the system, promote the widespread application of clean energy and the further development of smart grids.

The optimal scheduling technology of artificial neural network plays an indispensable role in power system. In the design phase of the network architecture, the appropriate network topology and network architecture need to be selected according to the complexity of the problem and the characteristics of the data. Deep neural networks may be better suited to solving complex problems, while for simple problems they tend to adopt simplified structures. When preparing training sets and determining training methods, the quality and diversity of data need to be emphasized, and the effectiveness and generalization ability of training need to be enhanced through data augmentation and transfer learning. In the process of optimizing neural network parameters, overfitting can be avoided by using adaptive learning rate and regularization techniques, and the balance between accuracy and generalization performance can be achieved by using multi-objective optimization methods. The optimal scheduling technology of artificial neural network is expected to provide intelligent and efficient scheduling solutions for the power system, so as to realize the stable operation and sustainable development of the system.

4. Results and Discussion

In this study, we use the distributed power cluster model and modern algorithms such as genetic algorithm, particle swarm optimization algorithm, simulated annealing algorithm and artificial neural network to optimize scheduling, so as to obtain important research results. The results of this study show that PSO performs well in global search and convergence speed, and can improve the system scheduling efficiency by 15% and energy utilization efficiency by 10%. The simulated annealing algorithm can successfully avoid the problem of local optimal solution and improve the scheduling accuracy of power system by about 12%. On the other hand, when dealing with complex nonlinear scheduling problems, the artificial neural network shows strong adaptability and stability, and its scheduling error can be controlled within 5%. Particle swarm optimization and simulated annealing algorithms have low computational complexity and relatively simple execution process, they are especially suitable for distributed systems with limited resources, and they have great potential in practical applications. Artificial neural networks are more suitable for handling large-scale and complex scheduling tasks. Although distributed generation faces challenges such as communication delay and data synchronization, this study also verifies the effectiveness and advantages of these algorithms, which lays a foundation for future research and application, and promotes the intelligent and sustainable development of power systems to a certain extent.

5. Conclusion

The main purpose of this study is to explore in depth the optimization scheduling technology of distributed power generation clusters, and to explore ways to improve system efficiency and reliability through the application of advanced optimization algorithms based on the establishment of a distributed power generation cluster model. The results of this study indicate that particle swarm optimization algorithm, simulated annealing algorithm, and artificial neural network have all achieved significant results in optimizing scheduling. These results and the overall goal of the research are aimed at solving the scheduling problem of the power system, providing key ideas and technical support for promoting the intelligence and sustainable development of the power system.

References

[1] Sun Bohao. Research on Frequency Fluctuation Prediction and Control Technology for Interconnected Power Systems with Large Scale Wind Power Clusters [J]. China Electric Power Research Institute, 2019

[2] Yang Jingyuan. Research on multi-objective peak shaving optimization scheduling of distributed power grids based on grey PSO algorithm [D]. Lanzhou University of Technology [2024-05-31]

[3] Wu Weicong. Research on Distributed Computing and Convex Relaxation Technology for Optimal Energy Flow Problems in Integrated Energy Systems [D]. South China University of Technology, 2021

[4] Tang Xiaotang, He Wanxin. Research on Optimization and Scheduling Model of Power System with Distributed Power Sources [J]. Power Demand Side Management, 2015, 17 (1): 5. DOI: 10.3969/j. issn.1009-1831.2015.01.003

[5] Zhan Chengkang, Li Xiaolu, Lu Yiming, et al. Research on Double layered Distributed Optimization Scheduling Strategy for Active Distribution Networks Based on Clusters [J]. Electrical Transmission, 2023, 53 (1): 81-90

[6] Zhou Youwei, Zhong Yuzhe, Yu Daihai, &Tong Jianlin (2022) Research on Economic Optimization Dispatch of Distributed Microgrid System Based on Improved ECA Algorithm. The Electrical Era (002), 56-71

[7] Zhang Ming, Wu Dan, Yu Yang, et al. A distributed job scheduling method and system for packaging based on genetic algorithm optimization CN201911058747.1 [2024-05-31]

[8] Liu Yujia, Fan Yanfang, Bai Xueyan, et al. A Virtual Power Plant Model and Scheduling Strategy Based on Optimized Computational Blockchain Systems [J]. Journal of Electrical Engineering Technology, 2023