Integrated Energy Optimal Dispatch of Industrial Park Based on Improved Grey Wolf Algorithm

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Abstract. As a physical unit providing integrated energy services directly to the load terminal, the micro-energy system in the industrial park is also an independent stakeholder in the future energy market. To ensure the sustainability of its business model, it is necessary to maximize its own benefits on the premise of meeting the basic energy guarantee of the park enterprises. In order to solve the nonlinear problem of multi-energy scheduling, it is necessary to preprocess it into a linear problem, which will lead to computational errors and affect the accuracy of the results. In this paper, the islanding optimal dispatching model of the micro-energy network in the park considering demand response not only realizes the "peak load shifting" of load and the reliable operation of the system in the islanding state, but also realizes the optimal autonomy of the energy supply and demand process and the economic operation of the system. Compared with the traditional particle swarm algorithm, the improved gray wolf algorithm in this paper has faster convergence speed and better solution results. The simulation results of typical days under grid-connected mode tell that the grid-connected operation scheduling model of the micro-energy grid in the park considering demand response can achieve high energy utilization and low pollutant emissions.

Keywords: Industrial park · Multi-energy dispatch · Grey Wolf algorithm · Load model

1 Introduction

Micro-energy system for the industrial park is the expansion and extension of the concept of microgrid under the background of the new round of power system reform and energy Internet in China, which has enriched the energy input and output types of microgrid and increased the flexibility of the system's operation and energy utilization efficiency [1]. Micro-energy system covers natural gas, renewable energy, and electric energy at the same time. It also involves a variety of energy transmission and distribution networks and energy load demand, including energy storage, control, protection and information and communication equipment. Through multi-energy interconnection,

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information exchange and market price guidance, it realizes internal multi-energy coordinated operation and friendly interaction with external multi-types of energy networks. As an extension of the microgrid, the core characteristics of the micro-energy system are basically the same as those of the microgrid, showing the characteristics of low voltage and small capacity [2].

Reference [3] considers the influence of power network loss and thermal network loss of electric and thermal integrated energy system on dispatching results, and constructs a multi-energy dispatching model considering electric and thermal energy, which makes the system solution closer to reality. In reference [4], the two-stage optimization model of the virtual power plant is constructed on the basis of the virtual power plant interconnected by electricity and heat, which ensures the relevant social and economic benefits and significantly improves the system economy on the basis of ensuring that the virtual plant meets the system operation. Reference [5] proposed a system model based on unified energy flow to describe the static relationship of the system network. It further proposed a coupling characteristic to represent the energy transfer process. In reference [6], for the electric microgrid system, the heat energy allocation trading mechanism of heat energy classification and time-sharing optimization demand is considered in the market trading mechanism. The game theory is introduced to balance the interests of both sides of the transaction, and the economic advantages of the proposed model are proved.

In this paper, an integrated energy system scheduling method for industrial parks is proposed. Through the multi-energy unified screening model, the typical and extreme periods that are more in line with the system requirements are obtained. By integrating the optimization results and putting them into the intelligent algorithm as part of the initial population, the purpose of high-speed optimization operation is achieved. The simulation results present that the proposed optimal scheduling method of an integrated energy system is more suitable for the system requirements compared with the same type of acceleration algorithm. The optimal operation method can indeed accelerate the solution speed of the intelligent algorithm with the initial population.

2 The Improved Algorithm

In this paper, the initial population improvement is introduced into the traditional gray wolf algorithm, so that the improved algorithm can improve the search efficiency and search accuracy based on retaining the parallelism of the gray wolf algorithm, while avoiding the defect that the gray wolf algorithm is easy to fall into local optimal solution [7].

In the actual search scene, the gray wolf will choose the scheme of approaching and surrounding the target, which can be expressed by mathematical formulas (1) and (2).

$$\vec{\omega} = \left|\vec{Z}.\vec{W}_O(n) - \vec{W}(n)\right| \tag{1}$$

$$\vec{W}(n+1) = \vec{W}_O(n) - \vec{X}.\vec{\omega} \tag{2}$$

where, n is the current number of iterations, $\vec{X}$, $\vec{Z}$ is the synergy coefficient vector, $\vec{W}_O$ is the position vector of the target, and $\vec{W}$ is the position vector of the individual gray wolf.

The synergy coefficient vector sum is used to control the process of the gray wolf individual approaching the target, and their specific mathematical expressions are shown in Eqs. (3) and (4).

$$X = 2\vec{\delta}.\vec{t}_1 - \vec{\delta} \tag{3}$$

$$\vec{Z} = 2\vec{t}_2 \tag{4}$$

where: $\vec{\delta}$ is the linear decrease from 2 to 1 in the iterative scenario. $\vec{t}_1$ and $\vec{t}_2$ are random vectors in the range of (0, 1). When constructing the model, according to Formula 1 to Formula 4, the decrease of the value will directly cause the decrease of the value, that is, the actual parameter of a random vector set in an interval has a linear decrease in the iteration scenario. When it is in the [1,1] interval, the position of the agent at the subsequent time will be searched, and any position between the gray wolf and the prey can be obtained [8].

3 Industrial Park Energy Dispatching Optimization Method

The traditional user response model only considers the coupling effect between different energy sources in the current period, but does not consider the interaction on the time scale. The response strategy and actual response quantity in the previous period will have a greater impact on the actual response quantity in the following period [9]. In this paper, the demand change quantity is divided into two kinds, one is the active response quantity describing the user's comfort loss, and the other is the actual response quantity describing the change quantity relative to the baseline load. The baseline load refers to the electricity demand of the user before participating in the demand response, which is obtained according to the historical energy consumption of the user. The user benefit model describing the demand-side response characteristics on the time scale is shown in Eq. 5.

$$\kappa_{\max}^{t}(fn) = \vec{\omega} \sum_{i=1}^{n} \theta(\vec{x}, \vec{y})_u^t \tag{5}$$

where, $\kappa_{\max}^{t}$ is the actual response quantity of the user's energy; f_n is the active response quantity of the energy; $\theta(\vec{x}, \vec{y})$ is the effect of the response trend in time period t on the response trend in time period u [10].

The dynamic characteristics of users on the time scale are mainly manifested in the following two aspects:

According to the description of the first constraint condition, the response variation in the previous period will affect the response potential of the user in the later period;

According to the description of the third constraint condition, because the actual response quantity of the user in the current period is affected by the response condition

Table 1. Experimental parameter settings

Comparison method	Comprehensive cost/¥	Cost saving/¥
Actual value	31480	0
Particle swarm optimization	29572.1	1907.9
The algorithm in this paper	26723.7	4756.3

in the previous period, the active response quantity in the current period is not equal to the actual response quantity, which is shown in Formula 6.

$$\theta_{(x,y)} = \sum_{i=1}^{n} (\alpha\beta)_i^2 f_n \tag{6}$$

where, $\theta_{(x,y)}$ is the degree of influence of the time period's response strategy on the response strategy of time period k.

4 Simulation and Analysis

4.1 An Overview of the Example

Based on the MATLAB software computing environment, the optimal scheduling of the park micro-energy grid under island operation and grid-connected operation is simulated and analyzed to verify the rationality and effectiveness of the model and solution algorithm in this paper [11].

To verify the performance of the improved algorithm in this paper, the traditional particle swarm optimization algorithm is used for comparison. The optimal comprehensive cost of the park micro-energy network on a typical day in the case of an isolated island is obtained respectively. The parameters are presented in Table 1.

4.2 Results and Analysis

Energy dispatch analysis.

The objective function is solved according to the relevant data of the typical day. The output and operation cost of each equipment of the micro-energy network in the park under the condition of islanding in the typical day are obtained. The results of energy dispatch are displayed in Fig. 1.

In Fig. 1, the energy load demand in the park is met by wind power generation, photovoltaic power generation, micro-gas turbine power generation, and battery charging and discharging. At night, the electric load is low. The wind power can meet the load demand, even leave a surplus, because the micro-gas turbine runs in the mode of "determining power by heat". In order to meet the heat energy required by the cold and warm water machine to supply the cold load, the micro-gas turbine generates part of the electric energy. At this time, the battery as a regulator begins to charge to absorb

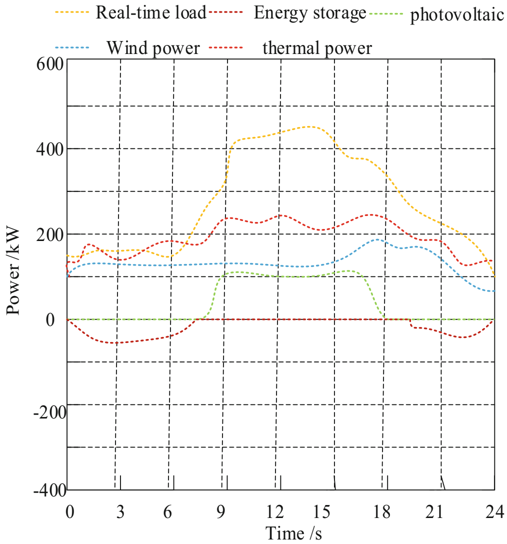

Fig. 1. Integrated energy dispatch analysis

the surplus electric energy, but the battery is limited by its own capacity and charging power. Power cannot be fully consumed, resulting in power abandonment at night [12].

Algorithm accuracy analysis.

Each algorithm is tested and compared, and the results are presented in Fig. 2.

The particle swarm optimization algorithm falls into the local optimal solution after 34 iterations, while the proposed algorithm gets the optimal cost after 25 iterations.

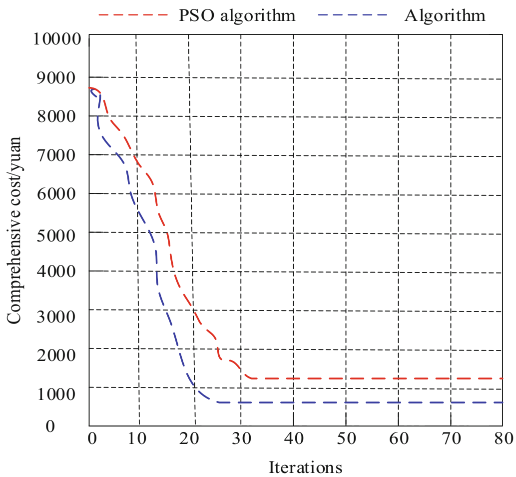

Fig. 2. Comparison of algorithm accuracy

Therefore, it can be concluded that the improved particle swarm optimization algorithm combined with longicorn search not only has faster convergence speed but also can avoid the defect that the traditional particle swarm algorithm is easy to fall into the local optimal solution.

The results verify that the comprehensive cost of the system calculated by the proposed algorithm is 11. 6% lower than that calculated by the traditional particle swarm algorithm, which reflects the superiority of the proposed algorithm.

5 Conclusion

In this paper, an integrated energy system scheduling method based on an improved gray wolf algorithm is proposed. After considering the source load factors of the industrial park, more accurate index parameters are automatically selected as part of the initial population of the intelligent algorithm to speed up the convergence speed of the algorithm, while a large number of random populations can prevent the results from having no solution. The experiment verifies the effectiveness of the proposed improved algorithm for the integrated energy system scheduling, which is more accurate than the traditional algorithm and improves the operational feasibility.

In this paper, the scheduling process of the micro-energy grid in the industrial park is studied, and the established micro-energy grid system model is relatively rough. The next step is to study the thermodynamic characteristics of each equipment that may exist in the actual operation, such as flue gas flow, air pressure, etc., and to establish a more accurate and perfect equipment energy model in the future.

References

1. Chen W, Qiu J, Chai Q. Customized Critical Peak Rebate Pricing Mechanism for Virtual Power Plants. IEEE Transactions on Sustainable Energy, 2021, 12(4): 2169–2183.
2. Abdolrasol M G M, Mohamed R, Hannan M A, et al. Artificial neural network based particle swarm optimization for microgrid optimal energy scheduling. IEEE Transactions on Power Electronics, 2021, 36(11): 12151–12157.
3. Ge L, Li Y, Yan J, et al. Short-term Load Prediction of Integrated Energy System with Wavelet Neural Network Model Based on Improved Particle Swarm Optimization and Chaos Optimization Algorithm. Journal of Modern Power Systems and Clean Energy, 2021, 9(6): 1490–1499.
4. Saberi-Aliabad H, Reisi-Nafchi M, Moslehi G. Energy-efficient scheduling in an unrelated parallel-machine environment under time-of-use electricity tariffs. Journal of Cleaner Production, 2020, 249: 119393.
5. Liangce, He, Zhigang, et al. Environmental economic dispatch of integrated regional energy system considering integrated demand response-Science Direct. International Journal of Electrical Power & Energy Systems, 2020, 8(03): 18–24.
6. Wang Y, Tang L, Yang Y, et al. A stochastic-robust coordinated optimization model for CCHP microgrid considering multi-energy operation and power trading with electricity markets under uncertainties. Energy, 2020, 198: 117–273.
7. Zhao P, Gu C, Huo D, et al. Two-Stage Distributionally Robust Optimization for Energy Hub Systems. IEEE Transactions on Industrial Informatics, 2020.

8. Hosseini S H R, Allahham A, Walker S L, et al. Uncertainty Analysis of the Impact of Increasing Levels of Gas and Electricity Network Integration and Storage on Techno-Economic-Environmental Performance. Energy, 2021, 222(3): 119968–119981.
9. Uchman W, J Kotowicz, Li K F. Evaluation of a Micro-cogeneration Unit with Integrated Electrical Energy Storage for Residential Application. Applied Energy, 2021, 282: 1–15.
10. Wu D, Han Z, Liu Z, et al. Comparative Study of Optimization Method and Optimal Operation Strategy for Multi-Scenario Integrated Energy System. Energy, 2021, 217: 1–15.
11. Silverman R E, Flores R J, Brouwer J. Energy and Economic Assessment of Distributed Renewable Gas and Electricity Generation in a Small Disadvantaged Urban community. Applied Energy, 2020, 280: 115974.
12. Xu Y, Xu K. Multi-objective Optimal Dispatching of the Integrated Energy System in the Industrial Park[C]//2021 IEEE/IAS Industrial and Commercial Power System Asia(I&CPS Asia). IEEE, 2021: 912–917.