Research on Grid Connected Optimization Scheduling of Micro-grid Utilizing on Improved Bee Colony Method

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Abstract

In order to achieve grid connected optimal dispatch of micro-grid, a improved bee colony method is put forward to carry out optimization of grid connected dispatch. Firstly, the optimal scheduling model of micro-grid grid connection, and the overall cost of generating electricity and environmental cost of micro-grid grid connection is used as objective function, and system power balance constraint, power constraint of micro power supply, contact line constraint that interacted with main grid and charge and discharge cycle of battery are used as constraint conditions. Secondly, the improved bee colony algorithm is established through introducing particle swarm algorithm. Finally, a residential area is used as an example, and the optimal dispatch of micro-grid grid connection is carried out based on proposed model, and simulation results showed that the proposed model has higher correctness and efficiency.

Keywords: Optimal dispatch, improved bee colony algorithm, micro-grid grid connection.

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1 Introduction

The grid connected micro-grid is connected with the large power grid, which can provide certain power support. The grid connected micro-grid depends on the load proportion it can supply, which reflects its power supply capacity and dependence on the large power grid to a certain extent. The self balance rate is defined as the load proportion that the grid connected micro-grid can supply in a certain period to represent its self balance ability. Different expected levels of self balance rate will affect the final capacity allocation scheme of the grid connected micro-grid. From the perspective of user benefit, considering the initial investment cost, replacement cost, operation and maintenance cost, residual value, power purchase cost and other economic factors, and considering the operation power constraints of grid connected micro-grid, the optimal scheduling of grid connected micro-grid is carried out under the economic objective.

With the help of complex system theory, it can be seen that there are many kinds of distributed generation, various operation states, different output characteristics and control methods in micro-grid, which make micro-grid have the main characteristics of complex system, such as complexity, nonlinear characteristic, openness, spatial hierarchy, organization and self-organization, and become a factor with many variables, complex operation mechanism and significant uncertainty. It is a multiple dimensional complex system. Therefore, the research, development and application of micro-grid technology should comprehensively understand and master the main features and critical technologies of micro-grid from the perspective of system, so as to lay a solid foundation for effectively solving various problems caused by distributed generation and improving the reliability, security, stability and economy of system power supply [1, 2].

The optimal scheduling of micro-grid has always been a hot research topic in the industry, and relevant scholars have made some theoretical and practical achievements in this aspect. Niche genetic algorithm is used to solve the optimal operation of each micro power source in micro-grid. Mixed integer linear programming is used to solve the economic dispatch model of wind power generation. The economic dispatch model of micro-grid considering operation cost and pollutant emission cost is solved by Chaos Quantum Genetic algorithm. Taking the minimum operation cost of micro-grid as the objective function, particle swarm optimization algorithm is applied in dealing with the micro-grid model, so as to reduce the operation cost of micro-grid connection [3].

To sum up, most of the existing studies are single analysis on the operation cost of micro-grid, and few literature comprehensively consider the operation cost, pollution control costs, grid connected benefits and power generation subsidies and other factors. At stage of finding out scheduling plan, the existing intelligent algorithms have some disadvantages, such as they are easy to obtain the local optimal solution, and the convergence of these traditional methods needs to be improved. Bee colony algorithm is a novel optimization method established lately, which can effectively improve the optimization problem with the help of division of labor and transformation of each role. Through analyzing disadvantages of traditional artificial bee colony algorithm and the characteristics of micro-grid grid connected dispatching, this paper proposes an improved artificial bee colony algorithm by improving initial population generation, coding mode, population optimization process and individual elimination.

Based on the above two points, this paper will comprehensively consider the micro grid power generation costs, environmental pollution control costs, grid benefits and new energy generation subsidies and other factors, and establish the micro grid optimal scheduling model under grid connected operation mode. In view of disadvantages of the normal particle swarm optimization method, the conventional bee colony algorithm is revised, which is used to implement the micro-grid grid connected optimal scheduling. Combined with the actual micro-grid case, the rationality of the mathematical theory and effectiveness of the optimization method proposed in this paper are verified.

2 Optimal Scheduling Theory of Micro-grid Grid Connection

In the process of micro grid integration, there are many kinds of power generation UNITS, like wind power, photo voltaic, fuel cell, battery, micro gas turbine, main grid and so on. For wind power, photo voltaic renewable energy should be fully utilized, more use of maximum power point tracking (MPPT) operation mode. For controllable micro sources such as micro gas turbine and fuel cell, their output can be changed according to the demand of micro-grid load. By improving the bee colony algorithm, and output of each micro source can be optimized, especially battery charge-discharge power and the output power of the main power grid are controlled, so as to obtain part of the revenue and reduce the cost [4].

2.1 Goal Function of Optimal Scheduling

Taking the overall generation cost and environmental cost of micro-grid as the minimum, and the benefits of grid connection and new energy subsidies as the maximum, the following multiple objective optimization function is established [5].

$$\min F(P) = \sum_{t=1}^{T} [F_1(P(t)) + F_2(P(t)) - F_3(P(t)) - F_4(P(t))] \tag{1}$$

where F denotes the total operation cost of micro-grid connection, $F_1(P(t))$ represents power generation cost, $F_2(P(t))$ denotes environmental cost, $F_3(P(t))$ denotes the revenue cost of micro-grid connection, $F_4(P(t))$ denotes the revenue of energy subsidies.

(1) Power generation cost
The power generation cost concludes fuel cost and operating expenses of each micro power source

$$F_1(P(t)) = \sum_{i=1}^{N} C_{f,i}(P(t)) + \sum_{i=1}^{N} C_{o,i}(P(t)) \tag{2}$$

where $C_{f,i}(P(t))$ denotes fuel expenses of ith micro power at t moment, $C_{o,i}(P(t))$ denotes the operation cost of ith micro power at t moment, N denotes types of micro power supply.

(2) Environmental penalty cost
Gas pollutants such as $\mathrm{NO_x}$, O_2 and CO_2 will be produced in the process of putting each micro power source into use. The penalty coefficients of different gas pollutants are different. The emission amount of corresponding pollutant gas can be obtained from the output of each micro power source. The treatment cost of such gas pollutants is counted as the environmental penalty cost, which is shown as follows [6]:

$$F_2(P(t)) = \sum_{i=1}^{N} \sum_{j=1}^{M} \kappa_{ij} \cdot P_i(t)) \cdot \xi_j \tag{3}$$

where κ_{ij} denotes the penalty coefficient of the jth gas emission of ith micro-grid, ξ_j denotes environmental penalty cost rate of jth gas, M denotes the number of pollutant gases.

(3) Benefits from grid connection
The benefits of micro-grid integration are generated by the energy transaction between micro-grid and large grid [7]

$$F_3(P(t)) = p_g(t) \cdot |P_g(t)| \tag{4}$$

$$p_g(t) = \begin{cases} p_b(t), & P_g(t) \geq 0 \\ p_s(t), & P_g(t) < 0 \end{cases} \tag{5}$$

where $P_g(t)$ denotes the interactive power between micro-grid and large power grid in t period, $p_g(t)$ denotes the electricity transaction price of micro grid and large grid in t period, $P_g(t) \geq 0$, the time sharing power price is taken, $P_g(t) < 0$, the time sale power price is taken.

(4) New energy subsidy income
To encourage construction and operation of renewable new energy, government implements a power generation subsidy policy for wind power and photovoltaic power generation, and new energy subsidy income is calculated by [8]

$$F_4(P(t)) = s_{b,w} P_w(t) + s_{b,p} P_p(t) \tag{6}$$

where $s_{b,w}$ denotes the unit allowance price of wind power generation, yuan/(kW.h); $P_w(t)$ denotes the generation power of wind power, kW; s_b denotes the unit subsidy price of photo voltaic power generation, yuan/(kW.h); $P_p(t)$ denotes the generation power of photo voltaic power, kW.

2.2 Constraint Condition

During the operation of micro-grid, the constraints of objective function mainly include system power balance, output power limitation of each micro power source, interactive power limitation between micro-grid and main grid, battery charging and discharging period, etc.

(1) System power balance constraints
Power balance constraint is a critical constraint for micro-grid operation, that is, the sum of micro-grid output and micro-grid load demand are equal in a scheduling cycle [9]

$$P_{lt}(t) = P_w(t) + P_p(t) + P_f(t) + P_m(t) + P_{mg}(t) + P_i(t) \tag{7}$$

where $P_{lt}(t)$ denotes the total power of load in micro-grid in t period, $P_f(t)$ denotes the generating power of fuel cell at t moment, $P_m(t)$ denotes generating power of micro gas turbine at t moment, $P_{mg}(t)$ denotes the charge discharge power of battery to micro-grid at t moment, $P_i(t)$ denotes the interaction power between micro electric net and large electric net at t moment.

(2) Power constraint of the micro power supply
Due to the restrictions of their own structure and various power electronic devices, the output power for every distributed micro source was limited in a certain range [10].

$$P_{a,\min}(t) \leq P_a(t) \leq P_{a,\max}(t) \tag{8}$$

where $P_a(t)$ denotes the real power o in t period, $P_{a,\min}(t)$ denotes the bottom limitation of output power in t period, $P_{a,\max}(t)$ denotes the upper limitation of output power in t period.

(3) Contact line constraint that interacted with main grid
Since the capacity of the connection line between the micro network and the main network was limited, the interaction power between the two should meet the restrictions.

$$P_{p,\min} \leq P_p(t) \leq P_{p,\max} \tag{9}$$

where $P_p(t)$ denotes the power exchange value between the micro net and the main net at t time; $P_{p,\min}$ denotes the bottom limitation of power exchange value between the micro net and main net at t time, $P_{p,\max}$ denotes the upper limitation of power exchange value between the micro net and main net at t time.

(4) Charge-discharge cycle of battery was limited
In a dispatch cycle, the initial process of charge of equipment of storing energy should be the same as the state of charge after the dispatch was completed, which meant that the total amount of charge-discharge of the equipment of storing energy device should be 0.

$$\sum_{t=1}^{T} P_{\mathrm{mg}}(t) = 0 \tag{10}$$

3 Improved Bee Colony Algorithm

Many interesting group behaviors could be observed on some animals, such as bees, ants, fish and so on. Their highly coordinated behavior of looking for food and gathering reflected this phenomenon compared to the entire system, these individuals could only deal with a limited amount of problems. However, when these local behaviors were combined, it would have a global impact [11].

In the process of looking for food, the bees remembered the food features such as shape, color and smell, and gradually formed their own searching experience. They searched for bees near the hive and took the information of the food source back to the hive through a swing dance, recruiting more bees to gather honey based on this shared information, they abandoned the food source of poor quality and adjusted the search strategy to make the bees move to the elite food source of good quality, and finally gathered in the elite food source. Inspired by this natural phenomenon, he imitated the bees' foraging behavior to find the best solution.

3.1 The Basic Concept of the Swarm of Bees

There were three types of bees in the hive: leading the bees, following the bees, and detecting the bees; the bees of each role shared different work and cooperated with each other, and the roles would change according to the rate of return. Each food source represented a solution, corresponding to a path in the optimal problem of the micro electric net connection; the profit of the food source honey represented the solution, and the quality corresponded to the quality of the path in the TSP problem, which was the last length of the path. For each food source, there were several factors related to it: the honey of the food source (solution), the profit of the honey (quality of the solution), and the quantity of the honey [12].

Detecting bees: To explore the food source around the hive, and to obtain information about the profit of the honey from the food source, and then return to hive, and convey information about honey source through unique swing dance of bees in dance area. The Scout bees could effectively jump out to scout the new food source when the calculation was local optimal. The condition of jumping out was that the bees did not find a better food source for some time, and the number of times they could travel through the food source was limited [13].

Following bees: the following bees in the hive observe the information about the honey source in the dance area and decide whether to follow the dancing bees to gather honey according to the return rate. According to the rate of return of the leading bee, the follower bee could strengthen the circulation of the elite food source of the leading bee, strengthen the elite function of the leading bee, and accelerate the restrain of the calculation.

Leading bees: decide the leading role according to the profit ratio of bees. Bees with higher income could recruit more bees to follow them, so that the calculation could quickly restrain to the best. When the honey from the food source was collected, the bees were led to follow the bees.

When bees visited the food source, if the quality of the honey from this food source was better than that of this bee before, they would choose this place as the new honey source and return to hive to share information of food source with other bees. Otherwise, previous position would be maintained. If the food source didn't improve further within the limited time, the food source would be abandoned [14].

3.2 Algorithm Step of Bee Colony Method

The conventional bee group calculation was according to the location of the honey source, and the honey amount of the honey source was used to show the adaptability. The steps of the calculation were as follows:

Step 1: Initial stage. The number of honey source is defined by s_N, and the solution space dimension is defined by D, the number of mercenary bees was the same as that of the honey source. The honey source $X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})$ denotes a candidate solution. $i = 1, 2, \ldots, S_N$, D denotes dimension of search space. The range of honey source is $[X_{\min}, X_{\max}]$, the initial honey source is generated by [15]

$$X_{ij} = X_{j,\min} + 0.5\gamma_{ij}(X_{j,\max} - X_{j,\min}) \tag{11}$$

where γ_{ij} is the random number, which is larger than -1 and less than 1, $j = 1, 2, \ldots, D$, every time the solution was solved, the adaptability function was:

$$\mathit{Fitness} = \begin{cases} \dfrac{1}{1 + f(x_{ij})}, & f(x_{ij}) \geq 0 \\ 1 + |f(x_{ij})|, & f(x_{ij}) < 0 \end{cases} \tag{12}$$

Step 2: The mercenary bee stage. The mercenary bees were responsible for exploring the honey source and creating a random candidate solution near it [16]:

$$x_c = X_{ij} + 0.5\mu_{ij}(X_{ij} - X_{kj}), \quad i \neq k \tag{13}$$

where X_{ij} denotes the jth dimensional component of ith honey source μ_{ij} denotes the moving scale coefficient, $\mu_{ij} \in (-1, 1)$, $k = 1, 2, \ldots, S_N$, k is the food source selected randomly different from i, all variables of the newly generated food source will be inherited from the original food source except the j-dimensional variable.

When fitness function value of new food source is better than that of old food source, V_i can replace X_i.

Step 3: Following bee stage: after the leading bee searches, the following bee determines the next food source to search by roulette selection according to the existing information, and calculates the probability of each food source according to the following formulas:

$$p_i = \frac{fit(X_i)}{\sum_{i=1}^{S_N} fit(X_i)} \tag{14}$$

p_i is the probability of choosing the ith food source from the angle of following bees. In [0,1], a number r with uniform distribution is randomly selected. If $p_i > r$, the following bee will search around its corresponding food source. Obviously, the more abundant the food source, the more likely it is to be chosen. After the food source is selected, the following bees generate a new food source in space according to Equation (13), and greedy selection mechanism is used to determine whether to keep the new food source.

Step 4: In the stage of detecting bees, after all the leading bees and detecting bees complete the search, the algorithm checks the counter. If a food source has not been improved after limit iterations, the corresponding leading bee will be converted to detecting bees, and a new food source will be randomly generated to replace the old food source in the search space according to expression (12).

In the bee colony algorithm, every time the bees in the circle search the neighborhood according to Equation (13), replace the honey source according to the greedy criterion, and then observe the bees to follow according to the following probability calculated by Equation (12). However, the algorithm does not have the memory of the global optimal value and participate in the algorithm process, resulting in the algorithm may fall into the local optimal solution due to the lack of global exploration ability, which is embodied in two aspects On the other hand, the greedy selection mechanism based on fitting value: the fitting value of iterative function is used as the only standard greedy selection in the process of observation bee allocation, neighborhood exploration and population updating; the single global detection strategy: the eliminated bees in the updated population will be transformed into reconnaissance bees, and will be initialized randomly to perform global detection task, but in the next cycle, they will be compared with each other Both of them will lead to the rapid loss of individual diversity, and the algorithm will quickly converge to the local extreme. Artificial bee colony algorithm only uses the strategy of random individuals in the whole Bureau detection, which is simple and ineffective, Therefore, a more effective global search strategy is needed to make the algorithm obtain the global solution and retain from precocity.

According to the characteristics of conventional bee colony algorithm, which does well in exploration but does not well in development, the optimization is carried out with reference to particle swarm algorithm [17, 18]

$$x_c = X_{ij} + \mu_{ij}(X_{ij} - X_{kj}) + \chi(X_{gj} - X_{ij}) \tag{15}$$

where X_{gj} represents the tth component of the global optimal solution vector obtained by the algorithm. Due to the introduction of the optimal solution mechanism, if the current solution is far away from the optimal solution, the global guidance can speed up convergence process of h6algorithm and make new generated solution approach optimal solution more quickly, It can also increase global optimization capability of the method for the region near the global optimal solution.

By adjusting χ, we can coordinate exploration and development ability of algorithm, but concurrently, the global optimization capability of method can be decreased to a certain extent. To deal with the problem effectively, we apply the crossover operation of genetic algorithm for further optimization. Genetic algorithm is a self-adaptive and self-organizing search algorithm developed from the natural selection and evolution mechanism of the biological world The improved bee colony algorithm combines crossover operation of conventional genetic algorithm. It improves development capability of conventional bee colony algorithm by picking bees for neighborhood search and then crossover operation with the global optimal value. Meanwhile the global search capability is considered, following expression can be introduced [19, 20]:

$$x_c = \begin{cases} X_{ij} & \mu_{ij} < cr \\ X_{gj} + \chi(X_{gj} - X_{ij}) & \text{other} \end{cases} \tag{16}$$

In the formula, cr is the threshold value set by the algorithm. When the random number is less than the threshold value, the original component is kept. Or else, the appropriate part obtained after the crossover operation is retained. The exploration ability and development performance of the algorithm can be controlled by adjusting threshold value. When cr is larger, it is conducive to the development of the algorithm, but it will reduce the exploration ability correspondingly. Otherwise, it is conducive to exploration, but it will decrease development performance of method.

4 Case Study

To verify the effectiveness of proposed optimization model, a micro-grid connection is used as research objective to carry out optimal simulation of its regulation. The basic frame of the micro-grid connection is illustrated in Figure 1.

Take a residential area in a certain place as an example. The typical daily 24 h photo voltaic power generation output, wind turbine output and AC and DC loads of the community are listed in Table 1.

Fuel cost of each micro source power generation is listed in Table 2.

Price of electricity purchase and sale on micro network is listed in Table 3.

The parameters of improved bee colony algorithm are listed as follows: $\mu_{ij} = 0.3$, $\gamma_{ij} = 0.2$, $\chi = 2$, and the population size is 50, and the maximum iteration times is 300.

The traditional bee colony algorithm and improved bee colony algorithm are applied to carry out regulation optimization of micro-grid connection.

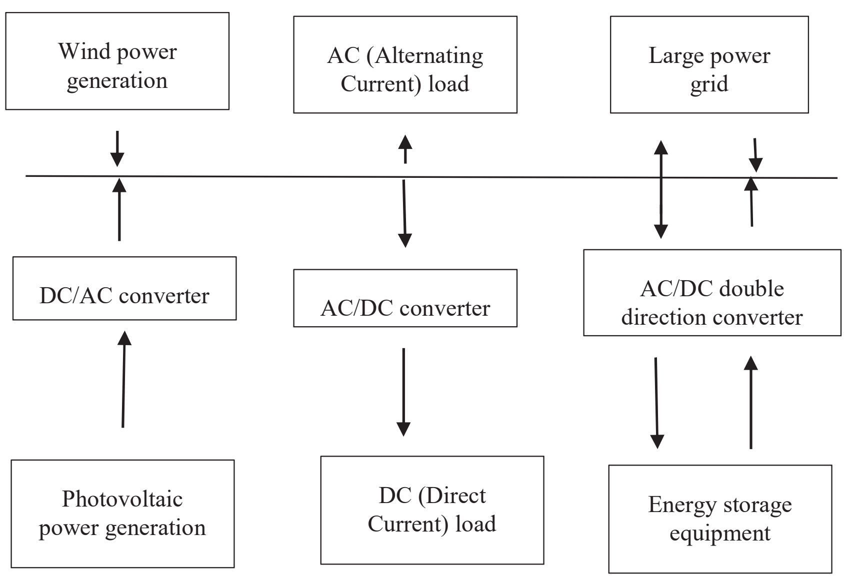

Figure 1 Basic structure of micro-grid connection.

Table 1 Typical PV, fan output and AC/DC load parameters

	Power/kW			
Time/h	AC Load Power Generation	DC Load Power Generation	Photo Voltaic Power Generation Output	Wind Power Generation Output
1	60.2	56.9	0	155.3
4	40.4	31.6	0	121.7
8	58.6	39.2	40.6	43.1
12	81.5	82.7	115.4	29.6
16	83.2	83.8	84.8	55.7
20	78.4	42.6	20	200.1
24	59.7	39.9	0	135.5

Table 2 Fuel cost of each micro source power generation

Micro Source	Rate Power/kW	Fuel Cost/Yuan(kW.h)$^{-1}$	Operation Cost/Yuan(kW.h)$^{-1}$
Wind power	80	0	0.05
Photo voltaic	80	0	0.01
Fuel cell	120	0.25	0.13
Micro gas turbine	120	0.34	0.20
Charge discharge of battery to micro-grid	40	0.26	0.06
Interaction power between micro and large electric net	40	0.25	0.08

Table 3 Price of electricity purchase and sale on micro-grid

Peak and Valley Time	Peak Period	Normal Period	Valley Period
Price of purchase on micro-grid/yuan (kW.h)$^{-1}$	1.22	0.70	0.42
Price of sale on micro-grid/yuan (kW.h)$^{-1}$	0.66	0.39	0.12

The iteration curves of traditional bee colony algorithm and improved bee colony algorithm are show in Figure 2. As seen from Figure 2, the improved bee colony algorithm has quicker optimal speed than traditional bee colony algorithm. Results showed that the improved bee colony

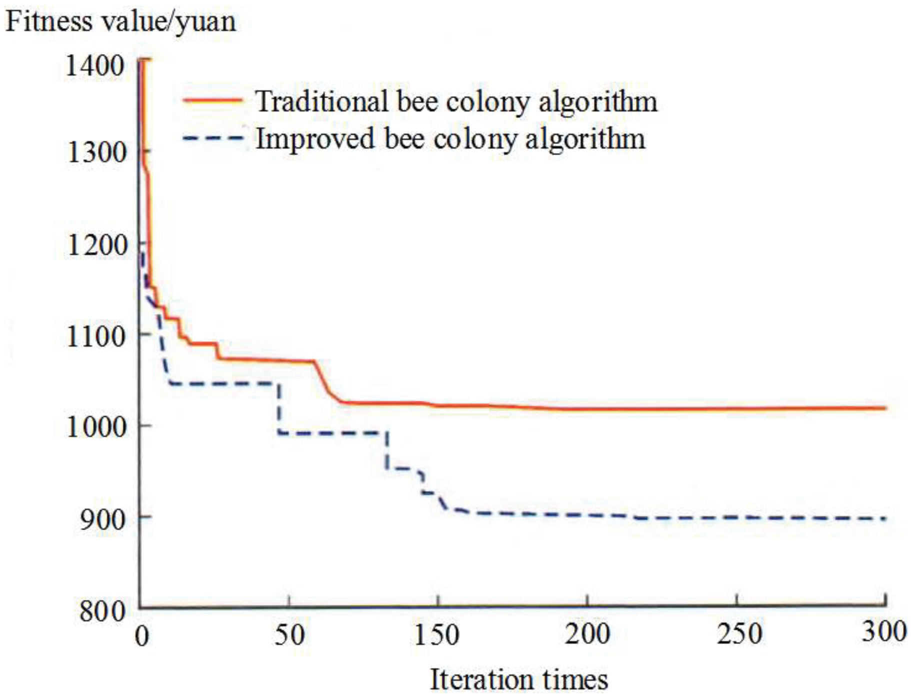

Figure 2 Iteration curves of two methods.

algorithm can optimize the regulation of micro-grid connection with high efficiency.

The output power per moment of every micro source is shown in Figure 3, and the output power of the whole micro-grid has lowest operation cost. Based on analysis for Figure 3, The optimal scheme of micro-grid can be determined by comprehensively considering the generation cost, environmental treatment cost and grid connected income of each micro source in micro-grid.

The whole cost of micro-grid is listed in Table 4 before and after optimization is shown in Figure 4. As seen from Figure 4, the total operation cost of micro-grid obtained from traditional bee colony algorithm is more than that from improved bee colony algorithm, therefore the improved bee colony can obtain the better solution. The reason for this phenomenon is that the improved bee colony algorithm can jump out of local optimal solution and obtain the global optimal solution.

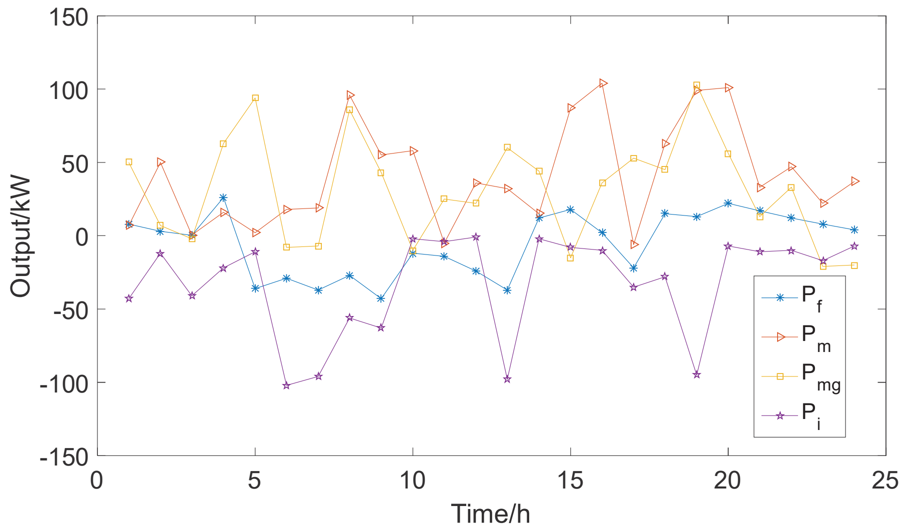

Figure 3 Output power curve of every micro source.

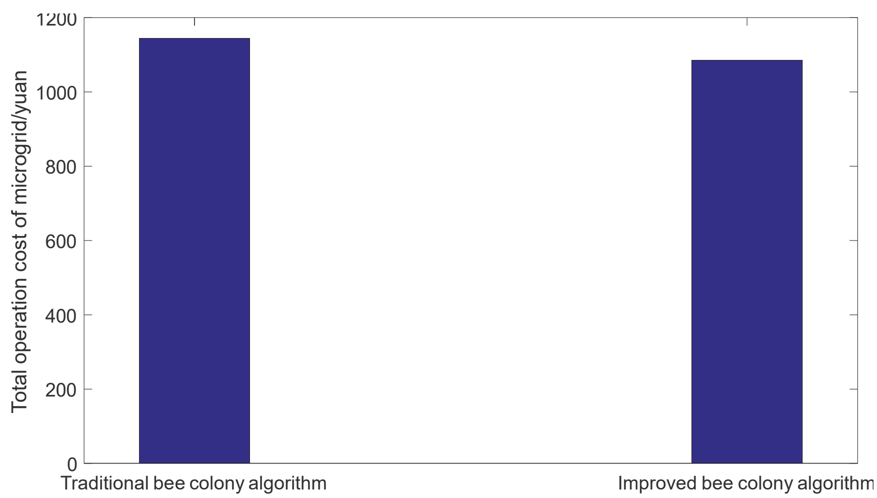

Figure 4 Total operation cost of micro-grid based on two methods.

5 Conclusions

In this paper, we consider many factors to build a micro-grid grid scheduling model. Aiming at the shortcomings of traditional artificial bee colony algorithm, an improved artificial bee colony algorithm is proposed. Improved bee colony algorithm is applied to optimal scheduling of micro-grid, and final analysis results illustrate that improved optimization model has better convergence. Improved bee colony algorithm can more accurately and efficiently optimize the scheduling of micro-grid.

References

[1] Saeed Abrisham ForoushanAsl, Majid Gandomkar, Javad Nikoukar, Optimal protection coordination in the micro-grid including inverter-based distributed generations and energy storage system with considering grid-connected and islanded modes, Electric Power Systems Research, 2020, 184(7):106317.

[2] Wei Jin, Yongli Li, Guangyu Sun, Yan Gao, Admittance Model for Three-phase AC Micro-grid with Unbalanced Load Compensated by the Multi-functional Grid-connected Inverter, Energy Procedia, 2019, 158(2):2475–2480.

[3] Seyed Masoud Moghaddas-Tafreshi, Soheil Mohseni, Mohammad Ehsan Karami, Scott Kelly, Optimal energy management of a grid-connected multiple energy carrier micro-grid, Applied Thermal Engineering, 2019, 152(4):796–806.

[4] Martin Vincent Mancuso, Pietro Elia Campana, Jinyue Yan, Evaluation of Grid-Connected Micro-Grid Operational Strategies, Energy Procedia, 2019, 158(2):1273–1278.

[5] Brida V. Mbuwir, Fred Spiessens, Geert Deconinck, Distributed optimization for scheduling energy flows in community micro-grids, Electric Power Systems Research, 2020, (187):106479.

[6] M.F. Roslan, M.A. Hannan, Pin Jern Ker, R.A. Begum TMIndra Mahlia, Z.Y. Dong, Scheduling controller for micro-grids energy management system using optimization algorithm in achieving cost saving and emission reduction, Applied Energy, 2021, 292(6):116883.

[7] Simon Eberlein, Krzysztof Rudion, Small-signal stability modelling, sensitivity analysis and optimization of droop controlled inverters in LV micro-grids, International Journal of Electrical Power & Energy Systems, 2021, 125(2):106404.

[8] Sergio F. Contreras, Camilo A. Cortés, Johanna M.A. Myrzik, Probabilistic multi-objective micro-grid planning methodology for optimizing the ancillary services provision, Electric Power Systems Research, 2020, 189(12): 106633.

[9] Xiaoyi Ding, Wei Sun, Gareth P. Harrison, Xiaojing Lv, Yiwu Weng, Multi-objective optimization for an integrated renewable, power-to-gas and solid oxide fuel cell/gas turbine hybrid system in micro-grid, Energy, 2020, 213(12):118804.

[10] Koraljka Kovačević Markov, Nikola Rajaković, Multi-energy micro-grids with ecotourism purposes: The impact of the power market and the connection line, Energy Conversion and Management, 2019, 196(9):1105–1112.

[11] Yibing Li, Weixing Huang, Rui Wu, Kai Guo, An improved artificial bee colony algorithm for solving multi-objective low-carbon flexible job shop scheduling problem, Applied Soft Computing, 2020, 95(10):106544.

[12] Hu Yu, Sun Zhensheng, Cao Lijia, Zhang Yin, Pan Pengfei, Optimization configuration of gas path sensors using a hybrid method based on tabu search artificial bee colony and improved genetic algorithm in turbofan engine, Aerospace Science and Technology, 2021, 112(5):1006642.

[13] Laifu Wen, Jiulong Cheng, Fei Li, Jiahong Zhao, Zhihao Shi, Hongchuan Zhang, Global optimization of controlled source audio-frequency magnetotelluric data with an improved artificial bee colony algorithm, Journal of Applied Geophysics, 2019, 170(11):103845.

[14] Mei Zhang, Yingtong Tan, Jinhui Zhu, Yinong Chen, Haiming Liu, Modeling and simulation of improved artificial bee colony algorithm with data-driven optimization, Simulation Modelling Practice and Theory, 2019, 93(5):305–321.

[15] Depeng Kong, Tianqing Chang, Wenjun Dai, Quandong Wang, Haoze Sun, An improved artificial bee colony algorithm based on elite group guidance and combined breadth-depth search strategy, Information Sciences, 2018, 442–443(5):54–71.

[16] Hong Liu, Bin Xu, Dianjie Lu, Guijuan Zhang, A path planning approach for crowd evacuation in buildings based on improved artificial bee colony algorithm, Applied Soft Computing, 2018, 68(7):360–376.

[17] Kunkun Peng, Quanke Pan, Biao Zhang, An improved artificial bee colony algorithm for steelmaking–refining–continuous casting scheduling problem, Chinese Journal of Chemical Engineering, 2018, 26(8):1727–1735.

[18] Min-Rong Chen, Jun-Han Chen, Guo-Qiang Zeng, Kang-Di Lu, Xin-Fa Jian, An improved artificial bee colony algorithm combined with

extremal optimization and Boltzmann Selection probability, Swarm and Evolutionary Computation, 2019, 49(9):158–177.
[19] Włodzimierz Jefimowski, Adam Szeląg, Marcin Steczek, Anatolii Nikitenko, Vanadium redox flow battery parameters optimization in a transportation micro-grid: A case study, Energy, 2020, 195(5):116943.
[20] I. Zafeiratou, I. Prodan, F. Boem, L. Lefevre, Handling power losses in a DC micro-grid through constrained optimization, IFAC-PapersOnLine, 2020, 53(2):12956–12961.

Biography

Qiangshan Zhang, male, master, associate professor, school of mathematics and computer science, xinyang vocational and technical college, xinyang outstanding young science and technology expert, member of Chinese computer society.

He mainly teaches computer network technology, data structure, database technology, website design and management, introduction to e-commerce and other professional courses. His main research direction is computer network and database.

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He has presided over and participated in a number of scientific research projects, including science and technology research projects sponsored by the Department of Science and Technology of Henan Province and projects sponsored by the Department of Education of Henan Province for young backbone teachers. He has won a second prize of Xinyang City Science and Technology Progress Award, a third prize of Xinyang City Science and Technology Progress Award, a first prize of Henan Division of the National Multimedia Education Software Grand Prix, and a number of first and second prizes of Henan Provincial Department of Education.