A review on optimization dispatching and control for microgrid

Jianmin Hou, Chengye Ji, Junjie Wang and Meng Ke
1 School of Information and Control, Nanjing University of Information Science & Technology, Nanjing, China

*Corresponding author e-mail: jmhou@nuist.edu.cn

Abstract. As a new energy system, microgrid has gradually become an important means to solve the problems of traditional power grid. This paper summarizes the current operation strategy, optimization objective and solution objective model of microgrid. The control method of microgrid operation is also described.

1. Introduction
With the development of world's economy, the demand for energy in the world is also increasing. At this stage, the energy system still relies on traditional energy as the main source of energy. However, the traditional energy supply is becoming increasingly tense, and environmental problems such as the greenhouse effect are becoming more and more serious. Developing clean energy and building a new energy system have become the consensus of today's society.

Microgrid has the advantages of energy saving and emission reduction. It can realize energy cascade utilization, peak load and valley cutting, and ensure power security and stability. The Consortium for Electric Reliability Technology Solutions was the first to propose the concept of microgrid. It believes that the microgrid is a small power distribution system that integrates distributed power, load, energy storage and control [1]. Now, there is no unified standard for the microgrid structure in the world, but the understanding of the basic structure of the microgrid is basically the same in all countries and regions. At present, it can be considered that the new energy microgrid (Figure.1) is composed of wind, light, natural gas and other distributed energy systems, energy storage devices and controllable loads. It can achieve energy balance through energy storage and optimal configuration, and it can also be a local power system interconnected with the public power grid according to needs [2].

Compared with the traditional power grid, the microgrid has a combined cooling heating and power system (CCHP), and the renewable energy accounts for a large proportion. The microgrid is a complex system. The uncertainty of renewable energy resources, the structure of each system, the strong coupling between the three kinds of energy, and the different energy demands are all factors to be considered. Worldwide, the use of microgrid is also increasing dramatically. Therefore, it is necessary to carry out targeted research on system optimal dispatching methods and control in the construction of microgrid system.
2. Research on optimal dispatching for microgrid

2.1. Operation Strategy

Electrical fixed heating and thermal fixed electricity are two typical operating strategies for microgrid system [3]. Different scholars have different research scenes and objects. Table 1 summarizes the research of scholars.

| Scholars            | Research objects                        | Points                                                                 |
|---------------------|-----------------------------------------|------------------------------------------------------------------------|
| Ren Hongbo [4]      | Combined heat and power system          | By comparing different load ratios, the optimal equilibrium point is found, and the economic and energy saving benefits are optimal. |
| Zhao Feng [5]       | Hospital cooling and heating power supply system | Designed a three-level collaborative optimal dispatching method         |
| Wu Hongbin [6]      | Combined cooling heating and power system | Designed a cold-heat-power supply-light-heat integrated operation system. |
| Wang Yi [7]         | Combined heat and power system          | In Liao Ning province, the mode of thermostatic electricity can realize the largest degree of local consumption of electricity |

The above-mentioned experts and scholars have divided into two categories of research strategies for microgrid operation strategies. One is to compare the two operation strategies according to the operation scenario and the system structure operation, and find the optimal operation mode. The second is to propose a strategy for a certain place, and verify the comparison between the two strategies. However, current research only considers the situation during normal operation. The impact of the surrounding environment, different energy allocations, policies, etc. has not been considered.

2.2. Optimization Objective

The optimal dispatching of microgrid is based on the different characteristics of each equipment in the system. Considering the balance of cold, hot and electric load and the uncertain output of renewable energy, the optimal dispatching strategy with the minimum operating cost of microgrid is formulated.
2.2.1 Optimization objectives based on cost and environmental considerations. Economic dispatching is the first objective to be considered in the optimal dispatching of microgrid. EL-SHARKH [8] proposed a short-term dispatching scheme based on cost to solve the optimization problem and minimize the operating cost of microgrid. The energy storage state also greatly reduces the operation cost. LI Baoen [9] established the economic optimization model with energy storage equipment as the target. Faced with the economic dispatch of microgrid, various distributed systems and energy storage devices can also be dealt with through the method of mixed integer programming [10].

The above research is to establish the cost target model of microgrid system and seek the optimal solution. The use of energy storage equipment also takes the uncertainty of renewable energy output as the starting point, and the influence of time-sharing electricity price on the cost target is not considered. Considering the time-sharing electricity prices [11], under the condition of energy demand, set up and additional opportunities earnings dynamic dispatching model, the particle swarm optimization based on simulated annealing algorithm for solving, to improve the energy storage device in the role of economic operation.

At present, more and more attentions are paid to environmental protection in China. Environmental costs are also an important part of optimization goals. Many scholars mainly consider the minimum emission of greenhouse gases such as CO$_2$, SO$_2$ and NO$_x$ when studying environmental costs [12]. Now there are two mainstream emission reduction methods: first, considering operation and environmental costs, constructing multi-objective functions to find the minimum operating cost; The second is to set emissions as a binding condition for dispatching [13].

2.2.2 Optimization objectives based on randomness. The study on the optimal operation of microgrid is mostly based on the deterministic load and renewable energy. The uncertainty of renewable energy and load is not considered. However, predictions of renewable energy and loads are often inaccurate and not the same as actual values. The microgrid is a complex system with uncertainty, multiple structures and strong coupling. The inaccuracy of climate fluctuations and prediction models can lead to the randomness of renewable energy output power, so the optimal dispatching of microgrids is difficult [14].

In recent years, relevant scholars have proposed some effective methods to reduce the impact of randomness on microgrid. For example, the prediction accuracy based on load and renewable energy increases significantly with time scale reduction. In order to reduce the impact of prediction error on microgrid dispatch, the daily model predictive control method is considered as an effective method [15]. Characteristics of the house and the power grid above it will affect the system. Reference [16] proposed a two-stage energy management method, which was used to modify the day-ahead plan in the day-ahead stage. Pei Wei [17] proposed an energy coordination optimization method for the multi-time scale of renewable energy and cogeneration hybrid microgrid. The power fluctuations were suppressed by the micro-turbine and energy storage at the time scale and the second time scale respectively.

To sum up, the fluctuation of load and the uncertainty of renewable energy have great influence on microgrid. Uncertainties in the output of renewable energy will occur that the power generation cannot meet the load [18]. The current research only focuses on the uncertainty of renewable energy output, but the impact of this uncertainty on the system is rarely studied. Finding a reasonable dispatching model is the next stage to consider.

2.3. Solutions for optimal dispatching model

In the process of microgrid optimization and dispatch, the modeling and model solving of optimization problems are closely connected. Mathematical programming methods and intelligent algorithms are usually used to solve the microgrid optimal dispatching model (figure.2).
The microgrid optimization and dispatching model is very complex, which is affected by loads, uncertainties of renewable energy output, operation mode, optimization objective and other variables. Relevant scholars put forward different methods to solve the model in the face of different constraints. Linear programming models are used to deal with microgrid economic dispatching issues. The model divides the system into a power subsystem and a steam subsystem, proposes a solution for each subsystem, and then coordinates the two solutions to achieve the optimization of the joint system [19]. SASHIREKHA [20] combined evolutionary programming with hill-climbing algorithm, in which evolutionary programming was used to search for the optimal solution, hill-climbing technology was used to monitor the feasibility of the optimal solution, and two methods were mixed to deal with short-term dispatching problems. The problem of dependence between the multiple demands of cogeneration and the capacity of thermal power is solved by the improved direct search algorithm [21].

Due to the parallel and efficient optimization performance of intelligent algorithm, its generality and robustness are strong. The implementation process is simple and does not need to adjust the algorithm according to specific problems. Therefore, it is widely used in the energy management nonlinear programming of microgrid. SACHS [22] proposed the multi-objective particle swarm optimization algorithm for small habitat to solve the optimization model of microgrid which is restricted by economy and environment. Genetic algorithm has good global searching ability, and the heuristic algorithm improved based on genetic algorithm is used to solve the optimal solution of seed price of micro-grid optimization model [23]. Considering the uncertainty of load fluctuation and wind energy output in the microgrid, the tabu search algorithm can obtain the global optimal solution in the super time [24].

From the above research, it can be found that the microgrid optimization dispatching model can find a more appropriate solution method, but there are many constraints in each model, and the optimal algorithm is difficult to find. This is also the focus of the next phase.
3. Operation control of microgrid

Microgrid system is a complex multi-objective control system. It needs to deal with loads, energy distribution, long and short-term dispatching, voltage regulation and other aspects. The table 2 summarizes the current control system.

**Table 2. Control system classification.**

| Name             | Divide                          | Characteristics                                                                 | Advantages                                      | Shortcomings                                      |
|------------------|---------------------------------|-------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------------------|
| Centralized      | Hierarchical control            | The central controller issues commands to the inverter and adjusts            | Controllable and easy to install.               | Poor flexibility and scalability. Once the central processor fails, the system will crash. |
| Decentralized    | Master-slave control            | Use any distributed power supply as the primary controller and other distributed power supplies as the secondary controller. Master controller controls slave controller | Information processing is fast and weak on the communication system. | Poor reliability, if the main controller fails, the entire system will not run. |
|                  | Peer-to-peer control            | All distributed power supplies are in equal position and are controlled by system voltage and frequency information. | No communication connection, simple control and easy to implement. | Voltage and frequency fluctuate with load changes, resulting in unstable system operation. |

3.1 Centralized control

The centralized control of microgrid is similar to the centralized control of the traditional power system. A central control unit is set up and all information flows into the unit. After real-time processing, control instructions are given and control signals are transmitted to each unit in the microgrid through high-speed communication network. Hierarchical control (Figure.3) generally gives control commands to the inverter through the central control unit and participates in dynamic regulation, which can be regarded as centralized control.

![Hierarchical control diagram](image)

**Figure 3:** Hierarchical control

Each layer in the hierarchical control has its own control target, and the top layer will issue control commands to the next layer, but will not affect the stable operation of the system. Li Jingying [25] proposed a two-level hierarchical control strategy. The underlying primary control controls the voltage and frequency of the underlying power supply and the inverter, and the upper secondary control mainly adjusts the microgrid system. Through the synchronization between the microgrid and the main...
grid, the stability of the microgrid is maintained and the quality of the electrical energy is improved. Zhang Ye [26] proposed a three-layer FM structure control strategy: the bottom layer control inverter reasonable allocation of inverter output active and reactive power; the second layer control for long-term load change switching operation mode; third layer control Economic dispatching based on power generation planning and load forecasting. Yi Yonghui [27] proposed a three-layer control strategy based on multiple time scales. The control framework consists of the master station dispatching layer, centralized control layer and local control layer.

Centralized control has the advantages of strong controllability and easy installation. But the shortcomings are also very obvious: On the one hand, all the information flows into the central control unit. Once the central control unit fails, the whole system will collapse. On the other hand, a large amount of information flows in, requires a large amount of computation, and the system is not flexible and extensible. Therefore, this method is more suitable for small and local microgrid systems, and is more suitable in cases where information is easy to collect and communication and computational requirements are not high.

3.2 Decentralized control
The decentralized control strategy of microgrid is contrary to the centralized control. Generally, there is no central control unit. Different information flows to different control centers, and different control commands are issued by different control centers. All control functions are dispersed in each sub-module, and the output, input and system signals of each module are interrelated, but the dependence on the communication system is weak.

3.2.1 master-slave control. The master-slave control is to select one controller as the master controller in the microgrid, the other as the slave controller, and the master controller controls the slave controller through communication. In the master-slave control strategy, the main power supply is controlled by V/F control, while other power sources are controlled by PQ control. Jointly maintain the stability of system voltage and frequency [28]. Li Xingqiao [29] established the master-slave structure in the isolated island micro grid. The main controller is controlled by V/F of the inner loop of the external voltage loop current, and the slave controller is controlled by PQ of the single current loop.

In the microgrid system controlled by master and slave, if the main power supply fails, the whole system will be unable to continue to operate. Adaptive master-slave control is proposed. When the master controller fails, the power supply is immediately assigned as the master controller. However, communication stability becomes the key to its operation [30]. Therefore, master-slave control is mostly applied in small micro grid.

3.2.2 peer-to-peer control. In peer-to-peer control, each micro power source is in the same position, and the system can be comprehensively controlled by the local information of voltage and frequency. In the peer-to-peer control microgrid system, each distributed system has no communication connection and can realize plug and play. Each distributed power inverter adopts the droop control, which automatically adjusts the output voltage and frequency through the change of load distribution to find the balance point of the system [31].

Peer-to-peer control is often used to solve problems such as load power distribution and system voltage frequency fluctuation. Yao Sun [32] pointed out that in the distributed generating set of micro grid, the load is distributed through the control of virtual impedance, angular droop and frequency droop to maintain the stable operation of the system. Zhang Xiaobo [33] combined the characteristics of master-slave control and peer-to-peer control, solved the problems existing in local information and droop control of peer-to-peer control, and realized the connection and smooth switch of isolated islands.

In general, peer-to-peer control has the advantages of simple control, high reliability and easy implementation, but the disadvantages are also obvious. The change of load power is easy to cause the instability of voltage and frequency, so it compares the adoption of micro grid with low requirements on voltage and frequency quality [34].
4. Conclusion
Renewable energy has the advantages of abundant resources and friendly environment. With the rapid development of modern economy, the development of renewable energy is becoming more and more important.

(1) the use of microgrid technology can solve the problem of uncertainty of renewable energy output. However, at present, energy storage equipment is used to solve the problem of uncertain output. Energy storage form is single, which is not conducive to the switching of operation mode. The next step is to study the multi-energy storage form.

(2) the construction of micro grid also provides an effective strategy for the flexible dispatching of distributed energy resources on the user side. However, at present, the study of micro grid is still in the initial stage, and the dispatching strategy only proposes solutions for specific constraint variables. In the future, the forms of energy utilization will be more diversified, and the constraint variables in the system will be more. The establishment of a more perfect optimal dispatching model is the focus of future research.

(3) the controller in microgrid can only control simple and small scenes. When large amounts of information flow into the controller, the system may crash or be difficult to control at high speed. The controller with high efficiency and stable operation is also the key research object.

Acknowledgments
This work was financially supported by “National Natural Science Foundation of China Project” (Grant No. 71503136).

References
[1] Yang Xin, Su Jian, Lu Zhipeng, Liu Haitao, Li Rui. Overview of microgrid technology [J]. Proceedings of the CSEE 2014, 34 (01); 57-70.
[2] National energy administration. Guidance from the national energy administration on promoting the construction of new energy microgrid demonstration projects [DB/OL]. http://zfxxgk.nea.gov.cn/auto87/201507/t20150722_1949.htm.
[3] Zi dan, Gabbar, Eldessoukry. Optimal planning of combined heat and power systems within micro-grids[J]. Energy, 2015, 93: 235-244.
[4] Ren Hongbo, Wu Qiong, Ren Jianxin. Study on energy efficiency of natural gas distributed thermoelectric co-generation system based on the perspective of demand side [J]. Proceedings of the CESS, 2015 (17): 4430-4438.
[5] Zhao Feng, Zhang Chenghui, Sun Bo, etc. The three-level co-integrated optimization design method for the cold, thermal and electric power supply system [J]. Proceedings of the CESS, 2015, (15): 3785-3793.
[6] Wu Hongbin, Wang Dongxu, Liu Xingyue. Strategy evaluation and optimization of solar cold and thermal power supply system [J]. Automation of electric power systems, 2015 (21) :46-51.
[7] Wang Yi, Xue Yongfeng, Zhang Min, etc. Mathematical model of power analysis of heating unit based on energy balance method [J]. Automation of electric power systems, 2014, (8): 108-112.
[8] EL-SHARKHIM, RAHMAN, ALAM. Short term dispatching of multiple grid parallel PEM fuel cells for microgrid applications [J]. International Journal Hydrogen Energy, 2014, 35(20).
[9] Li Baoen, Li X W, Wu Bx. Study on energy optimal dispatching strategy of microgrid based on SOC state of energy storage [J]. Power System Protection and Control, 2017, 45(11): 108-1114.
[10] Wu X, Wang X L, Wang J X. Mixed integer programming method for microgrid economic dispatching problem [J]. China journal of electrical engineering, 2013, 33(28):2-8.
[11] Zhang F, Liang J. Dynamic dispatching of the cold - heat combined power supply microgrid with additional opportunity income [J]. Power system automation, 2015, 39(14):8-15.
[12] PIPERAGKAS, ANASTASIADIS, HATZIARGYRIOU. Stochastic PSO based heat and power dispatching under environmental constraints incorporating CHP and wind power units [J]. Electric Power System Research, 2015, 81(1): 209-218.
[13] Gu Wei, Wu Zhi, Wang Rui, et al. Multi-objective optimization of combined heat and power micro-grid considering pollutant mission [J]. Automation of Electric Power Systems, 2012, 36(14):177-185.

[14] Liu X. Optimization of a combined heat and power system with wind turbines [J]. International Journal of Electrical Power Energy Systems, 2012, 43(1):1421-1426.

[15] GU W, Wang Z, Wu Z, et al. An online optimal dispatching dispatche for CCHP microgrids based on model predictive control [J]. IEEE Transactions on Smart Grid, 2016:1-11.

[16] Luo Z, Wang z, Gu W, et al. A Two-Stage energy management strategy for CCHP microgrid considering house characteristics[C]. IEEE Power energy society general meeting, 2015 :1-5.

[17] Pei Wei, Deng Wei, Shen Ziqi, etc. Renewable energy mix with cogeneration piconets energy coordination optimization [J]. Automation of electric power systems, 2014, 38 (16):9-15.

[18] Li Cunbin, Zhang Jianye, Li Peng. Multi-objective optimization model of microgrid operation considering cost, pollution discharge and risk [J]. Proceedings of the CSEE, 2015, 35(5):1051-1058.

[19] Wu D W, Wang R Z. Combined cooling, heating and power: a review [J]. Progress in Energy & Combustion Science, 2016, 32(5):459-495.

[20] SASHIREKHA, PASUPULETI, MOIN, et al. Combined Heat and Power (CHP)economic dispatching solved using Lagrangian relaxation with surrogate subgradient multiplier updates [J]. International Journal of Electrical Power Energy System, 2013, 44(1):421-430.

[21] Chen C L, Lee T Y, Jan R, et al. A novel direct search approach for combined heat and power dispatching [J]. International Journal of Electrical Power Energy System, 2012, 43(1):766-773.

[22] SACHS, SONNTAG, SAWODNY. Two-layer model predictive control for a cost-efficient operation of island energy system[C]. American Control Conference (AACC), Chicago, IL, USA, July, 2015: 4941-4946.

[23] Li C, BOSIO F, CHEN F, et al. Economic dispatching for operating cost minimization under real-time pricing in droop-controlled DC micro-grid[J]. IEEE Journal of Emerging & Selected Topics in Power Electronics, 2016, 1(5):587-595.

[24] Zhu Y S, Wang J, Zhai B Y. Dynamic environmental economic dispatching of power system including electric vehicle [J]. Power automation equipment, 2016, 36(10):16-23.

[25] Li Jinying. Study on micro-grid layered control and power quality improvement [D]. Doctoral dissertation of north China electric power university, 2015.

[26] Zhang Ye, Guo Li. Study on the strategy of seamless interchanging control of microgrid based on vertical control system [J]. Guangdong electric power, 2016, 29(4):22-28.

[27] Yi Yonghui, Ren Zhihang, Ma Hongwei, et al. Research on rapid stability control technology of microgrid with high permeability of distributed power supply [J]. Power system protection and control, 2016, 44(20):31-36.

[28] Wang Chengshan. Microgrid analysis and simulation theory [M]. Beijing: science press, 2013.

[29] Li Xingqiao, Zhao Xiangyang. Research on island microgrid master-slave mode [J]. Applied Mechanics & Materials, 2015:1026-1029.

[30] Zhang Tianyu, Luo Fengzhang, Wang Chengshan, et al. Impact analysis of information system on microgrid operation reliability [J]. Power system automation, 2016, 40(23):28-35.

[31] Zhang Qinghai, Peng Chuwu, Chen Yandong, et al. Control strategy for parallel operation of multiple inverters in microgrid [J]. Journal of China electrical engineering, 2012, 32(25):126-132.

[32] Yao Sun, Xiaochao Hou, Jian Yang, et al. New perspectives on droop control in AC microgrid [J]. IEEE Transactions on Industrial Electronics, 2017, 64(7):5741-5745.

[33] Zhang Xiaobo, Guan Jun, Zhang Baohui. A master slave peer to peer integration microgrid control strategy based on communication[C]. Power and Energy Engineering Conference. IEEE, 2016:1106-1110.

[34] Zhang Nan. Research on the control and optimization operation of the wind-solar microgrid system [D]. Master dissertation of north China electric power university, 2013.