MODELING AND OPTIMIZATION OF MICRO GRID SUPPLY AND DEMAND SYSTEM FOR RENEWABLE THERMAL ENERGY

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The economic benefit of microgrid is the key factor to realize environment-friendly power supply. With the wide application of new energy power generation, scholars have carried out a lot of research on microgrid models, but the existing models cannot reflect the important role of renewable energy in microgrid operation. Therefore, the author proposes a power generation and storage model based on renewable heat energy and microgrid. In order to minimize the cost and meet the requirements of CO_2 emission limitation, the cost of power generation, storage and production in the microgrid is analyzed in detail. At the same time, the optimization method of renewable energy microgrid system operation is also studied. First of all, by analyzing the characteristics of the microgrid system, a mathematical model and simulation calculation system are established to help understand the microgrid system. Secondly, the author has carried out a separate study on the energy storage in the microgrid system, and listed the benefits and costs of the energy storage process. In the grid-connected state, the performance of each unit in the microgrid system is better, the system is more stable and safe, and the operating cost is reduced again..

Key words: *renewable thermal energy, microgrid, supply and demand system, modeling and optimization*

Introduction

Microgrid is an important way to promote the transformation from traditional energy structure to renewable energy structure. Microgrid refers to a small power generation and distribution system composed of distributed power supply, energy storage device, energy conversion device, load, monitoring and protection device, *etc*. Generally, it has the following main features:

- The micro-grid generator is responsible for converting power from the power source and providing necessary control.
- Compared with external large-scale projects, microgrid mainly meets customers' needs from the perspective of energy conservation and energy security.
- There are two types of microgrid operation: when the microgrid and the main grid work simultaneously, the whole microgrid is regarded as a load, and the main grid provides frequency and voltage support for the microgrid. When the main grid fails or is ready to be isolated, the microgrid must quickly and independently disconnect from the main grid and switch to the independent mode, so as to continue power supply, as shown in fig. 1.

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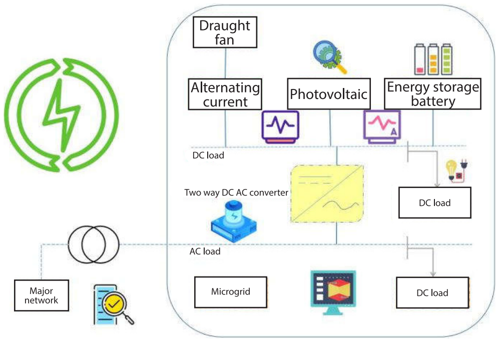

Figure 1. Microgrid of renewable thermal energy

Based on the theoretical modeling and topology analysis of complex networks, we can observe from the supply side and the demand side, and accurately describe the evolution characteristics and internal mechanism of the microgrid and its related subsystems. The author attempts to establish a threshold network model for the interaction between listed photovoltaic enterprises, a real-time electricity demand response model and a credit system for smart grid based on supply-demand price, and a microgrid configuration optimization model including power generation and energy storage. Secondly, the author also made a separate study on the energy storage in the microgrid system.

Literature review

China is a big country of energy consumption and CO_2 emissions, and resource waste and environmental pollution have become major obstacles to sustainable economic development. There are many problems in China's energy supply and demand structure. For example, the proportion of fossil energy with high pollution and high emissions represented by coal and oil is too high, the proportion of new energy is low, and the energy efficiency is low. Making full use of renewable energy can reduce the excessive dependence on traditional fossil energy and improve the security of energy supply. The Paris climate conference urged all countries in the world to establish a global emission reduction target of controlling the temperature rise at 2 °C at the end of this century and strive to achieve the goal of controlling the temperature rise at 1.5 °C, which provided external institutional constraints for China to accelerate sustainable development, and also brought new opportunities for the transformation of renewable energy development mode. The transition from traditional energy to renewable energy is an inevitable trend. The adjustment of energy supply and demand structure still has a long way to go, which requires corresponding changes in climate governance policies, technologies and markets. The traditional power grid is based on the thermal power system, and the grid-connected generation of renewable energy has been a prominent problem that hinders the large-scale utilization of renewable energy. In the context of increasing pressure on energy and environment, many countries, especially developed countries, have formulated various incentive policies to promote the development of renewable energy industry. At present, the global output of solar cells is growing at a rate of 30-40% per year, and the installed capacity of wind power generation maintains a growth rate of more than 30% per year. China's resources and load centers have the characteristics of reverse distribution. Energy and traditional power grids are unevenly distributed, and resources and loads are poorly matched. It is difficult for some regions to consume renewable energy locally [1].

By 2020, China's installed solar capacity will exceed 110 million kW, and wind power will exceed 210 million kW. The fifth annual energy plan announced the goals of developing new energy, understanding the evolution of energy production and consumption, and pursuing clean, low-carbon, safe and energy-saving innovation. The *13th Five-Year Plan* energy target has been issued, and many specific plans have been formulated to formulate policies and paths for the development of renewable energy in the next stage. Renewable energy has been highly valued by the country and the government, and development policies have been introduced continuously. However, there is still a lack of relevant research on how to transform the existing energy system into a new energy system dominated by renewable energy. Insufficient basic research and systematic thinking on the *transformation* of renewable energy [2].

Methods

Unlike traditional power models, micro-electric networks usually have two normal operation modes, namely, independent operation mode and grid-connected operation mode. The dynamic characteristics of multiple energy inputs (air, light, hydrogen, gas, *etc*.), multiple energy outputs (electricity, heat, cooling), and multiple energy conversion (light/electricity, wind/electricity, wind/electricity, AC/DC) in the microgrid are more complex than that of a single distribution system. Microgrid has the advantages of good management efficiency and good performance in different use environments

– Master-slave control

The master-slave control mode means that when the microgrid is in the island operation mode, one of the distributed power sources adopts constant voltage and constant frequency control (V/F control for short) to provide voltage and frequency reference to other distributed power sources in the microgrid, while the other distributed power sources can adopt constant power control (P/Q control for short). The distributed power controller using V/F control is called the master controller, while other distributed power controllers are called the slave controller.

– Peer control

The so-called *peer-to-peer* control mode means that all distribution points of the microgrid have the same control, and there is no master-slave relationship between devices. All power and distribution centers implement local control according to regulations. The selection of distribution control strategy is very important, and the current droop control methods mainly include low-frequency power droop, increasing generator operating power, reducing terminal voltage and reactive power output, *etc*. At present, most microgrids use peer-to-peer control in laboratory-scale networks.

– Hierarchical management

Microgrid systems with hierarchical control mode are usually equipped with a central controller to send control signals to distributed power sources in the microgrid. The central controller can predict the energy production and load demand of the distributed power generation, and then formulate the work plan. It can control the output power and adjust the operation plan in real time based on the voltage, current, energy and other status data to ensure the stop, start and stability of all distribution points, loads and power equipment. The voltage and frequency of the microgrid and the system can be protected.

Peer-to-peer control Since there are multiple peer-to-peer power supplies, the system has sufficient redundancy. Each distributed power supply can automatically participate in power distribution through droop control, thus realizing the *plug and play* of distributed power supply. However, this type of power supply needs a stable primary energy supply, and when the system topology changes, the control mode will change, which can not effectively maintain the power quality. The hierarchical control strategy is highly dependent on the upper communication unit, which requires the control unit to maintain real-time communication with all micro power supplies and loads. When communication problems occur, the microgrid system will be paralyzed [3, 4].

Microgrid control strategy analysis

There are two operation modes of microgrid: grid connection and island, and the transition state of switching between the two modes. Distributed generation in microgrid requires a large number of power electronic equipment interfaces to connect to the grid, which is not conducive to the stable operation of the grid. Therefore, a fast and effective control strategy is crucial for the safe and stable operation of the microgrid. The control strategy includes two levels: micro-source control and micro-grid integrated control. Micro source control is a control strategy that can be used for a single component in the microgrid, while integrated control strategy is a control scheme for the overall operation of the microgrid [5].

Micro power supply control method

In order to reduce the cost of electricity generated by renewable energy such as solar energy and wind energy in the microgrid, the energy supply has been continuously monitored to control the output of micro-energy supply. For uninterruptible power supplies such as gas turbines or energy storage devices, continuous voltage measurement and frequency control are used to ensure the stability of the voltage and frequency of the microgrid. Ensure that the system works normally during island operation.

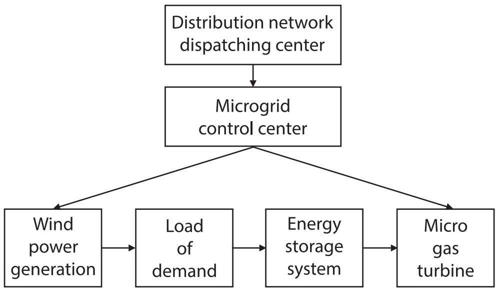

Figure 2. Schematic diagram of control system of microgrid system

Micro grid master-slave control system structure

The schematic diagram of the master-slave controller is shown in fig. 2. The power supply distributed in the microgrid (including the master power supply and the slave power supply) is connected to the AC bus of the microgrid through the three-phase inverter. The microgrid is connected to the grid through the static transmission system (STS). When the system is closed, the microgrid is connected to the grid, and the load of the microgrid can be powered by the distribution system. If the power supply of the switchboard is greater than the load, it can still supply power to the large power grid; After removing the static switch, the microgrid will switch to the autonomous operation mode, and the load in the microgrid will be independent of the power supply allocated to the microgrid. The main power controller has power failure detection, static switch switching control and main power converter monitoring functions. When the microgrid is connected to the main power supply, the main power supply uses constant power control. When the microgrid is in island operation, the main power supply is switched to constant voltage/constant frequency control.

When the microgrid is connected to the network, the upstream system of the transmitter receives the power supply and distribution transmission instructions issued by the upstream of the microgrid system, and mainly makes business decisions to maintain the security of the distribution network; The intermediate transmission layer will not only receive the best power transmission information, but also send all the generation and transmission information in the microgrid system, and participate in the switching control to ensure the security and stability of the microgrid business. The local control layer at the bottom usually adjusts the voltage, current and frequency of each power supply to meet the input requirements of each generator and ensure the stability, safety and economy of the system. When the microgrid is running off the network, the intermediate transmission layer directly sends the microgrid data to the local management layer for direct control and management. In order to realize the intelligent, efficient and effective management and control of microgrid system, it is necessary to study the optimal use of microgrid to obtain the best performance microgrid system. When studying the optimal performance of the microgrid, it is necessary to first define the specific structure of the microgrid system, identify and simplify each part of the system, and develop structural procedures [6, 7].

Experiment

Microgrid simulation case parameters

Taking micro-grid system as the research object, micro-grid system mainly includes photovoltaic power generation unit, wind power generation unit, micro gas turbine unit and supporting energy storage battery system. The specific parameters, output and climb power limit parameters of controllable units are shown in tab. 1.

Table 1. Parameters of controllable unit

Type	Capacity [F]	Upper limit of output [kW]	Lower limit of output [kW]
Energy storage battery	500	160	–160
Micro gas turbine	100	180	0
Liaison plane	0	200	–180

Micro grid simulation calculation results

According to the obtained data and equipment parameters, a pre-optimal operation model for grid connection and off-grid optimization of microgrid system based on MATLAB platform is established. Based on the powerful mathematical calculation ability of MATLAB platform, simulation calculation and model solution are carried out. Under the grid-connected and off-grid state of the microgrid system, the calculation results of the operation cost and energy storage loss cost of each micro-power supply are shown in tab. 2:

Table 2. Cost Details of simulation calculation of micro grid system connection and off grid

Type	Off network [Wh]	Grid connection [KV]
Total operating cost	2500	2200
Cost of micro gas turbine	87	76
Tie line cost	14	11
Energy storage cost	4	5

As shown in tab. 2, the annual operating cost of the micro-grid system in the network is 760000 yuan, which is lower than the annual operating cost of the micro-grid system in the national grid (870000 yuan), and performs better. At the same time, in terms of power lines and networks, by comparing the operating costs of various power sources, it can be seen that in the grid-connected state, the operating economy of each generator unit is also better, because the micro-grid system can fully absorb the output of photovoltaic. During grid-connected operation, the energy storage battery system and micro gas turbine can be ensured to operate within the economic and efficient load range through energy exchange with the superior distribution network. Therefore, in the case of external power line failure or special dispatching instructions, the operation cost of microgrid system can be reduced and the economy of microgrid system and equipment can be improved [8]. The optimal operation curves of each part of the system optimized by the particle by particle optimization algorithm based on the recommended value of the microgrid system are shown in figs. 3 and 4.

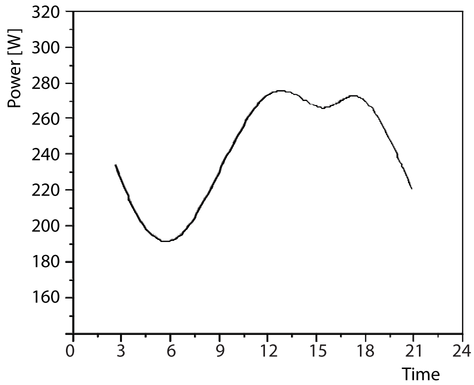

Figure 3. Day-ahead optimal operation curve of off-grid microgrid

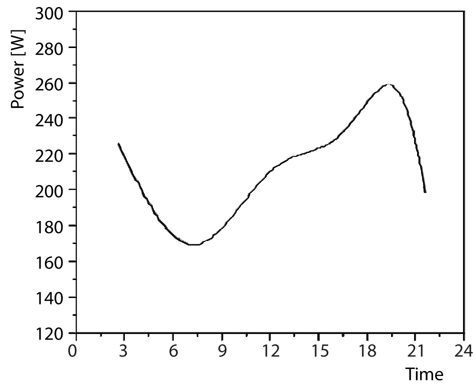

Figure 4. Day-ahead optimal operation curve of grid-connected microgrid

When the micro-grid system is running off the grid, there is no energy exchange with the external grid. Therefore, it can be seen from fig. 3 that the independent energy load is closed, and the increase of the energy output curve decreases. When calculated according to 24 hours a day, the load of the energy storage battery is low from 0-5 o'clock, and the output power is reduced from 230-130W. This is because the wind power generation capacity is sufficient at this time, the micro gas turbine has low power output, and the energy storage battery is in the state of charge. From 6:00-12:00, the load began to increase more rapidly, and the output power increased from 150-280W. At this time, the output of wind energy decreases, the output of photovoltaic units increases, and the output of micro gas turbines increases. The energy storage battery enters the shutdown state and releases the stored energy to reduce the load. From 13:00-18:00, the load gradually decreased, and the output power decreased from 270-260 W. The output of wind and photovoltaic power generation was stable, and the micro gas turbine could continuously work to generate electricity and charge the energy storage battery. From 19:00-24:00, the output of photovoltaic power generation decreased, the output power decreased from 260-210 W, the output of micro gas turbines and energy storage batteries increased, and the energy balance was maintained.

As shown in figs. 3 and 4, when the micro-grid system is connected to the grid, the efficiency of each part of the system varies from point to point in the grid by increasing the external power of the line, but the whole structure remains unchanged. From 00:00-07:00, the load is usually low, and the output of wind power generation and micro gas turbine is sufficient. At this time, the battery is in the charging stage. At this time, only the external power grid can be used for power supply to reduce costs; From 11:00-16:00, the output power of wind power generation decreased, the photovoltaic unit can output at maximum power, and the energy storage battery can control the power supply in multiple states; From 19:00-23:00, the load began to reach the second peak. At this time, the wind power generation increased, the power of micro gas turbines and hub lines increased, and the energy storage battery closed to balance the peak load. The comparison results can be obtained by comparing the performance of different devices in the network and outside the microgrid, as shown in tab. 3.

Table 3. Energy storage, micro gas turbine parallel and off grid operation status

Type	Total energy storage battery consumption [mAh]	Average power of micro gas turbine [kW]
Off network [Wh]	740	96
Grid connection [kV]	820	100

According to the analysis in tab. 3, in the grid-connected state, the controllable unit micro gas turbine in the system has higher average output power, higher efficiency and more economical and safe operation state due to the existence of energy exchange in the external grid. From the analysis in figs. 3 and 4, and tab. 3, it can be seen that the SOC curve of energy storage battery operation under grid connection is larger, the total throughput of charge and discharge is larger, and the battery capacity is more fully utilized; At the same time, when the power grid is connected, the SOC value is large (there are many areas with SOC $>$ 0.4), the energy storage battery operates at a higher state of charge, and the battery operation loss is small, which is conducive to extending the battery life. In short, the performance of each unit in the micro-grid system is better, the system is more stable and safe, and the operating cost can be reduced again [9, 10].

Conclusion

The author studied the best working mode of a renewable energy microgrid, and optimized the working methods of coordination, operation and distribution of microgrid and its energy products and energy storage units; In order to ensure the effectiveness of the use of microgrid system, the optimization method and model of microgrid operation are created. The calculation model of load and generation output of microgrid is analyzed, and the improved method is used to estimate the short-term and ultra-short-term load and renewable energy output; Taking the microgrid energy storage as the target, the income and battery loss during the operation of the microgrid are studied and analyzed, the optimal performance of the energy storage is given, and the numerical model is established.

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