Research on operation strategy of new energy microgrid theory model containing biomass energy

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Abstract. In order to alleviate the energy crisis and improve environmental quality, rational use of renewable energy has become a development trend. This paper proposes a research on the new energy micro-grid operation strategy, and selects the appropriate power generation method according to the development status of each distributed energy in the microgrid. Specially establish the biomass power generation, photovoltaic power generation, wind power generation and storage battery models of the micro-grid, and infer the power generation output characteristics according to the power generation characteristics of each module. A brief analysis of the micro-grid model containing biomass power generation established in the article is carried out, and the basic operation strategy of the micro-grid is proposed, which provides a theoretical basis for the development of the micro-grid in the future.

1. Introduction

With the continuous progress of technology and society, micro-grid appear in daily life as a new type of power system structure. Compared with the traditional power grid, the micro-grid represents a power local area network that integrates various distributed power sources and new energy sources in a specific area. It has two operating modes: one is island operation, which can achieve self-sufficiency; the other is grid-connected operation maintains the stability of the network through power exchange with the large grid. At the same time, micro-grid is also a development stage of traditional large-scale power grids gradually moving towards intelligence, and it is a method to complete automatic distribution network.

At present, the micro-grid is still in the development stage, and many experts and scholars are working hard to explore their own research directions. Yingxiang Wang established an active distribution network economic optimization scheduling model with distributed energy storage, and used the proposed differential evolution improved wolf pack algorithm (DWPA) to solve the problem. The minimum operating cost obtained was 37952.5 yuan. DG and distributed Energy storage scheduling strategy [1]. According to the characteristics of distributed generating units in each microgrid, Yuhao Bai established an economic benefit evaluation model for distributed generating units to optimize the configuration of power generation equipment in the micro-grid. Its annual
electricity cost is 1.99% higher, but pollution control costs are reduced. Up to 48.74%[2]. Qiu Mo took the campus microgrid with 230WP installed photovoltaic capacity, 20kw rated power of wind power, 292-section carbon-lead storage battery, and the annual maximum daily load of 213KWh as examples, using dynamic simulation combined with multiple genetic algorithms. The typical power grid system adjusts the 24h operation strategy, and the results verify the effectiveness of the model and the dynamic dispatch method [3]. Using a park in Shenzhen as an example, Zejian Liu realized a comprehensive energy system scientific capacity allocation system, which reduces CO2 emissions by 2.1×107kg per year compared with the traditional distribution system, and obtains an annual emission reduction income of 441,000 yuan [4].

However, the above literature does not take into account that with the continuous development and utilization of new energy, there are more and more components of the micro-grid, and the optimization of micro-grid operation becomes more and more complicated. Therefore, this article will establish a new energy micro-grid model containing biomass energy. Make the theoretical research of microgrid more comprehensive, objective and applicable.

2. New energy micro-grid system model

2.1. Biomass power generation cogeneration system model

The biomass power generation cogeneration model can be realized by a gas generator. In the gas generator, when the continuous flow of gas is used as the working fluid to drive the generator impeller to rotate at high speed, biomass energy is converted into heat energy, and then the heat energy is converted into mechanical energy.

When the gas turbine is working, the power output of the gas turbine, the amount of heat that can be recycled, and the consumption of fuel calorific value can be approximated by a linear function, and its output characteristic model is as shown in equation (1):

\[
\begin{align*}
P_{GE} &= a_{GE}F_{GE} + b_{GE} \\
Q_{GE,SMOKE} &= c_{GE}F_{GE} + d_{GE}
\end{align*}
\]

In the above formula, \(P_{GE}\) is the output power of the gas turbine; \(Q_{GE,SMOKE}\) is the thermal power of the high-temperature gas output by the gas turbine; \(a_{GE}, b_{GE}, c_{GE}, d_{GE}\) are the performance fitting coefficients of the gas generator. Gas turbines with different power generation capacities have different fitting parameters. Table 1 shows the fitting parameters of several typical capacity gas generators.
Table 1. Fitting parameters of typical capacity gas generator.

| Rated power (kw) | Running characteristic fitting parameters | $a_{GE}$ | $b_{GE}$ | $c_{GE}$ | $d_{GE}$ |
|------------------|------------------------------------------|----------|----------|----------|----------|
| 800              |                                          | 0.2932   | -193.42  | 0.5963   | -1.43    |
| 1210             |                                          | 0.3494   | -488.31  | 0.5782   | -441.26  |
| 2040             |                                          | 0.3554   | -797.38  | 0.5615   | -917.56  |
| 3515             |                                          | 0.3758   | -1153.64 | 0.5500   | -1245.32 |
| 4600             |                                          | 0.3809   | -1312.12 | 0.5650   | -1740.54 |
| 5200             |                                          | 0.4249   | -1944.49 | 0.5631   | -2036.53 |

In the actual operation of the gas generator, its output is also subject to technical constraints, including the maximum technical output, the minimum technical output and the ramp constraints of the unit. At the same time, considering the safe operation and service life of gas generators, it is usually necessary to set the minimum continuous operating time and minimum continuous downtime.

The output constraint of the gas generator is as follows:

$$P_{GE,\text{min}} \leq P_{GE} \leq P_{GE,\text{max}} \quad (2)$$

Among them, $P_{GE,\text{min}}$ represents the minimum output of the gas generator, and $P_{GE,\text{max}}$ represents the maximum output of the gas generator.

The climbing constraints of the gas generator set are as follows:

$$\begin{cases}
    P_{GE}^t - P_{GE}^{t-1} \leq P_{GE,\text{up}} & (P_{GE}^t \geq P_{GE}^{t-1}) \\
    P_{GE}^{t-1} - P_{GE}^t \leq P_{GE,\text{down}} & (P_{GE}^t \leq P_{GE}^{t-1})
\end{cases} \quad (3)$$

Among them, $P_{GE}^t$ represents the power generation of the gas turbine in the current period; $P_{GE}^{t-1}$ represents the power generation of the gas turbine in the previous period; $P_{GE,\text{up}}$ represents the maximum power increase of the gas turbine in the period $t$; $P_{GE,\text{down}}$ represents the maximum power down range of the gas turbine in the period $t$.

2.2. Photovoltaic power generation model

The sun shines on the semiconductor p-n junction, forming new hole-electron pairs. Under the action of the electric field in the p-n junction, the light-generated holes flow to the p-area, and the photo-generated electrons flow to the n-area, and a current is generated after the circuit is turned on. Figure 2.

![Figure 2. Working state of P-N junction.](image-url)
In practical applications, photovoltaic cell manufacturers only provide parameters under standard illumination and temperature, including: maximum power voltage $U_{mmp}$ and current $I_{mmp}$. And power $P_{mmp}$, short-circuit current $I_{sc}$. The open circuit voltage $U_{oc}$ simplifies the power generation model, and the photovoltaic model is obtained as equation (4).

$$I = I_{sc} \left( 1 - C_1 \left[ \exp \left( \frac{U}{C_2 U_{oc}} \right) - 1 \right] \right)$$

$$C_1 = \left( 1 - \frac{I_{mmp}}{I_{sc}} \right) \exp \left( \frac{U_{mmp}}{C_2 U_{oc}} \right)$$

$$C_2 = \left( \frac{U_{mmp}}{U_{oc}} - 1 \right) \ln \left( 1 - \frac{I_{mmp}}{I_{sc}} \right)$$

(4)

2.3. Wind power generation model

The transformation of wind into electrical energy is wind power technology. Wind energy is a clean and pollution-free, and also a renewable energy source. It has been used by people a long time ago. Originally, people used it mainly for grinding noodles and pumping water, but now people use it to generate electricity. At present, there are windmills generating electricity, which has reached a breeze speed of three meters per second. Reaching this speed means that electricity can be started. This has become popular around the world. Wind power generation is clean and efficient, and does not cause radiation to the environment. And pollution, so it is very popular with people.

According to the principles of aerodynamics and Bates theory, with air density $\rho \left( \text{kg/m}^3 \right)$, wind energy utilization coefficient $C_p$, wind wheel radius $R$, and wind speed $v$ at the height of the wind wheel as independent variables, the output equation of wind power generation is obtained as equation (5).

$$P_m = C_p \rho \pi R^3 n \left( \frac{\pi R}{30 \lambda} \right)^3$$

(5)

The output power of wind power generation is affected by some parameters in the formula(5), and the wind energy utilization coefficient $C_p$ is the most influential factor. When other influencing factors remain unchanged, directly changing $C_p$ can have an effective impact on the output power of the wind turbines. Because wind energy is uncontrollable, in practical applications, the magnitude of wind is random, so we can control $C_p$ to ensure the stability of the output. When the real-time wind speed is less than the rated wind speed, $C_p$ can be increased, and when the real-time wind speed is greater than the rated wind speed, $C_p$ can be decreased.

The relationship between $C_p$ and $\lambda$ is shown in Figure 3. When the fan is running, there is a special point $\lambda_m$, which is the best tip speed ratio (the ratio of the blade tip speed to the wind speed). At this speed, the coefficient $C_p$ will get the maximum value. That is, the fan produces the maximum output power.
Figure 3. The relationship curve between wind turbine blade tip speed ratio $\lambda$ and wind energy utilization coefficient $C_p$.

After the above analysis, in the actual wind power generation project, the dispatch monitoring department can change the speed control device of the wind turbine to perform power adjustment. The speed of the wind turbines is controlled to obtain the required power to obtain different power outputs. When the wind speed is different, the real-time output power of the wind turbines is as in formula (6).

$$P_m = \begin{cases} 
0 & v < v_m \\
\left(v - v_m\right)\left(v_e - v_m\right)P_e & v_m \leq v < v_e \\
P_e & v_e \leq v < v_{out} \\
0 & v > v_{out}
\end{cases}$$

(6)

Among them: $v$ is the actual wind speed; $v_m$ is the cut-in wind speed of the wind turbines; $v_{out}$ is the cut-out wind speed of the wind turbines; $v_e$ is the rated wind speed of the wind turbines; $P_e$ is the rated power of the wind turbines.

It can be found from the above formula that when the actual wind speed is less than the cut-in wind speed, the torque of the fan cannot start the fan. When the wind speed is between the cut-in wind speed and the cut-out wind speed, the fan starts to generate electricity, and the power whose wind speed is greater than the rated wind speed remains at the rated output power. The characteristic curve of power and speed of wind energy captured by the wind turbine is shown in Figure 4.
2.4. Energy storage system model

Batteries were once considered to be one of the most widely used chemical sources in the world because of their safety, reliability, voltage stability, wide application range, and low price. In the popularization and development of microgrid technology, storage batteries can provide reliable functional support. This article uses the battery as a prototype to establish a corresponding energy storage model.

2.4.1. Equivalent battery model. The equivalent model of the battery is shown in Figure 5. The electromotive force is affected by and its load state \(SOC\). The polarization resistance of the transition process is \(R_0\); the internal resistance \(R_s\) is affected by the ambient temperature, current and \(SOC\); \(C\) indicates the differential capacitance of the battery, which is affected by \(SOC\).

\[
\begin{align*}
U &= E - IR \\
SOC &= SOC_0 + \int \frac{Idt}{Q_b}
\end{align*}
\]

Where \(SOC_0\) is the initial state of charge of the battery; \(Q_b\) is the battery capacity.

The life cycle of a battery is affected by a variety of reasons, but it is largely determined by the depth of discharge, so a certain limit should be imposed on the depth of discharge during its use. Figure 6 uses a battery manufactured by a well-known company in the United States as an example to describe its depth of discharge and life cycle. According to the figure, we can know that when the battery is discharged at full capacity, the number of times of charging and discharging the battery is about 1000 cycles; when the depth of discharge is half of its capacity, the number of times is about 2000 cycles. Therefore, in order to maximize the benefit of the battery, the depth of discharge must be controlled within a certain range, usually 60% to 70%. 

Figure 4. The characteristic curve of power and speed of the wind turbine capturing wind energy.
2.4.2. Battery pack power model. The rated voltage of the battery $U_{bat} (V)$; single capacity $C_{bat} (Ah)$; the power stored in a series of battery packs is:

$$E_{bat} = 0.001N_{bat} C_{bat} U_{bat}$$  \hspace{1cm} (9)$$

Let $\lambda$ is the depth of discharge, the discharge energy of a single cycle group is:

$$E_{bat \_ f} = 0.001N_{bat} C_{bat} U_{bat} \lambda$$  \hspace{1cm} (10)$$

Power required for charging process:

$$E_{bat \_ ch} = 0.001N_{bat} C_{bat} U_{bat} \lambda / \eta$$  \hspace{1cm} (11)$$

Under normal circumstances, the battery works under constant voltage conditions and the working current is less than 0.1, so the output power of the battery pack is:

$$P_{bat} = 0.0001N_{bat} C_{bat} U_{bat}$$  \hspace{1cm} (12)$$

In the above formula, $\eta$ represents the charging efficiency, the power unit is KW, and the electric energy unit is KWh.

3. Case analysis

3.1. Typical daily micro-grid operation example

Figure 7 shows the typical 24h daily load, photovoltaic output and wind energy output curve of a micro-grid in a certain area.
According to the daily load curve, the daily load can be divided into three stages: flat, peak and valley. 0-7 o'clock and 22-24 o'clock are in the low period of electricity use; 7-16 o'clock is in the flat period of electricity use; 16-22 is in the peak period of electricity use. The electricity prices of large power grids are also divided into peak electricity prices, peak electricity prices, and low peak electricity prices depending on the time of electricity consumption.

According to the wind energy output curve, it can be clearly found that the utilization of wind resources has strong uncontrollability, and it can be known that wind output will also produce strong uncontrollability. However, we can also see in the figure3.1 that the power of wind power generation at night is significantly higher than during the day.

According to the photovoltaic output curve, it can be seen that photovoltaic power generation has a stronger regularity compared with wind resources. The output of photovoltaic power generation at night is 0. Starting from the appearance of light at 5 o'clock, as the ambient temperature increases, the output of photovoltaic power generation begins to increase. And it can appear a day's peak power generation at noon, and then slowly decline until it decreases to 0 at 21 o'clock.

This article will add biomass energy and energy storage modules based on this microgrid operation example, in which biomass energy output can be achieved by gas turbines to meet the microgrid power balance constraints. At the same time, the energy storage system is used as a regulating unit to maintain the stability and reliability of the system.

3.2. Typical daily operation strategy of the microgrid

The operation model of the micro-grid is divided into two types: island operation and grid-connected operation. In the grid-connected state, it can purchase electricity from the large grid during the low period of the electricity load, which significantly reduces the extra load of steam turbine equipment at night. The service life and depreciation cost can make the improvement of economic efficiency. At the same time, the over-load generation of the microgrid is sold to the large power grid, which has made a certain contribution to the cost reduction, and the grid operation strategy under the grid is significantly better. Therefore, this paper proposes a typical 24-hour optimal operation strategy for a microgrid in a grid-connected state:

1) The energy storage module is in the charging state at 0-6 o'clock. At this time, the photovoltaic power generation cannot enter the working state. The wind turbine and gas turbine can supply power to the system, and the excess electricity can be stored in the energy storage module. In this low
electricity consumption period, the micro-grid can use the large grid to buy a small amount of electricity to supply or store energy to the microgrid when the electricity price is low, and then output it during the peak electricity consumption period to reduce the electricity burden of the microgrid.

2) The battery can start to discharge at 7 o'clock and stop until 15 o'clock. During this period of time, photovoltaic power generation can reach the maximum power output of the day, and wind turbines can also enter a stable output stage. At this time, the power output of the micro-grid can be much higher than the load of the system. At this time, the microgrid can obtain a large amount of revenue during the peak electricity consumption period by selling electricity to the large grid.

3) At 16:00, the microgrid can start to charge the energy storage modules centrally, and the load required in the microgrid is mainly purchased from the large grid. At 17:00, the micro-grid supplies excess power to the large grid. At this time, the load side is supplied by the microgrid, and the power consumption on the load side starts to increase and enters the peak period of power consumption.

4) The peak period shift of power consumption starts at 18:00. At this time, wind power and photovoltaic power generation are all powered by the load side, and energy storage modules and gas turbine modules also provide power for the load side. If the load demand cannot be met, it can be purchased from the large grid.

4. Conclusions
This paper takes the micro-grid in a certain area as a reference, and adds biomass power generation and battery energy storage units. It can be found that the micro-grid can produce higher power generation benefits, and the cogeneration mode of biomass power generation can effectively achieve energy efficiency. Effective use, greatly reducing the cost of heat and cooling load. Although in the process of energy reuse, the instability of the micro-grid system limits its wide application, the regulation function of the battery energy storage unit can improve the reliability of the micro-grid. As the investment time increases, the depreciation cost of the micro-grid units will also decrease, which brings about the economic benefits of the micro-grid, and its power generation costs will become more competitive.

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