Research on Peer-to-Peer Control Strategy for Microgrid Distributed Generation

Haojie Ruan*, Cheng Qian*, Changjiang Wang¹, Yichi Lin¹, Xiaobo Zhang¹
Ningbo Power Supply Company, State Grid Zhejiang Electric Power Company, Ningbo, China

*Corresponding author e-mail: elec_zhou@163.com, qiancheng0911@126.com, cjwang0501@126.com, Lincy0702@126.com, zhangxiaobo81@163.com

Abstract. In between a plurality of microgrid in complex coordination control problems, this paper proposed a droop control strategy for microgrid distributed generation, which can realize micro grid by cutting load, micro grid operation mode switch to smooth the distributed power supply voltage and frequency control. This method bases on droop control principle, research on the effects of P-f and Q-U droop characteristics, design of the droop controller output filter, power controller, voltage current double loop controller based on the established simulation model of the droop controller and the equivalent control strategy of micro grid simulation model. The results of simulation by Matlab/Simulink, analysis of the variation of the micro grid distributed power switch in islanded and grid connected operation mode and the frequency voltage and power, to verify the correctness and feasibility of droop control strategy.

1. Introduction
Today, as people's demand for electric energy increases, more and more attention is paid to distributed power generation. Common wind power generation, solar power generation, fuel cell power generation, etc. are all distributed power generation. Compared with traditional thermal power generation methods, they have the characteristics of low pollution, high energy efficiency and good social benefits [1, 2]. However, the current stage of distributed power generation also has problems such as complex single-machine control and difficult operation and maintenance, which restricts its difficult development on a large scale [3].

The microgrid integrates a variety of distributed power generation (DG), energy storage devices, loads, etc., and is equipped with complete control, protection, management and monitoring devices to form a small independent and controllable power distribution system. To some extent, to alleviate the conflict between large power grids and distributed power sources [4]. The microgrid has two operating modes: grid-connected and islanded. The DG in the micro-grid delivers electrical energy to the large grid through the inverter equipment. The control of the DG mainly includes master-slave control, peer-to-peer control and hierarchical control. The control strategy mainly includes U/f control, PQ control and droop control [5].

The problem of coordinated control of distributed power in microgrid seriously affects its rapid development and is a key issue that needs to be solved in the actual operation of microgrid. Domestic and foreign scholars have carried out extensive research on the control strategy of microgrid. The
literature [6] uses PQ-U/f combined control strategy to study the microgrid with different operating modes, and analyzes the characteristics of DG and the operating characteristics of microgrid. In [7], the microgrid switching mode control method is proposed to study the microgrid in grid-connected and island mode. When the island is isolated, some DGs use droop control to adjust the frequency and voltage of the microgrid. PQ control, microgrid frequency and voltage are regulated by the large power grid. Literature [8] studied microgrids with different operating modes, and pointed out that regardless of the operating mode, effective control of each DG in the microgrid should be guaranteed to maintain the U and f of the entire microgrid fluctuating within a reasonable range. In [9], the switching process of different operating modes of microgrid is analyzed, and the control method combining sagging and inverted droop is proposed. The advantage is that it can avoid the switching problem of control strategy. The disadvantage is that when switching from island mode to grid mode the adjustment time is too long. Literature [10] mainly studies the methods of PQ control and V/f control. The master-slave control strategy is used to simulate the microgrid, and the variation law of voltage and frequency is studied and analyzed.

Aiming at the complex coordination problem between multiple distributed power sources in microgrid, this paper proposes a droop control strategy method. The method can realize automatic adjustment of frequency and voltage when the load is increased in the micro-grid island mode; and when the micro-grid operation mode is switched, the distributed power supply can realize seamless switching of the micro-grid operation mode without changing the control method. Through the simulation results of Simulink, the variation law of frequency, voltage and power of distributed power supply in microgrid during islanding, grid-connected and operation mode switching is analyzed, and the correctness and feasibility of the droop control strategy are verified.

2. Microgrid basic structure

This paper constructs the peer-to-peer control microgrid structure as shown in Figure 1.

The distributed power sources DG1 and DG2 are inverter-type micro power supplies, all of which adopt droop control and are equivalent to DC power. Load1 and Load2 are constant power loads connected to DG1 and DG2 respectively. Load3 is a common load connected to the 380V common bus. Switch K controls whether the microgrid is connected to the grid. When the switch K is closed, the microgrid is boosted by the transformer and then integrated into the 10KV distribution network.
The distributed power sources DG1 and DG2 adopt droop control, and the entire microgrid adopts a peer-to-peer control strategy.

3. Microgrid structure of Peer-to-Peer control modelling
The control of distributed power supply in microgrid mainly includes master-slave control, hierarchical control and peer-to-peer control [11].

The master-slave control strategy requires the DG in the microgrid to have a master unit and a slave unit. This control strategy is simple and easy, but the disadvantage is that it relies too much on the master unit, and its capacity and performance requirements are relatively high. During the operation mode switching, there is a switching process of the control strategy.

The hierarchical control strategy, through the upper control communication unit, provides information in real time to realize information communication between different DGs and loads, so that the microgrid runs smoothly. The advantage is that it can realize the optimal operation of multiple microgrids, and the disadvantage is that it relies too much on communication means.

Peer-to-peer control strategy, all DGs in the micro-grid are peer-to-peer, mainly based on the local information of the DG access system point to realize the “plug and play” function of the micro-grid [12]. The DG in the peer-to-peer control strategy uses droop control to automatically adjust the voltage and power when the microgrid load changes, so that the microgrid is stable at the new operating point. The advantage is that the control strategy can be not changed during the switching mode of the micro-grid operation mode, and the disadvantage is that the power quality cannot be effectively maintained.

This paper mainly studies the droop control strategy. By designing the droop controller and using the droop control strategy of the distributed power supply of the microgrid, it can realize the smooth control of the distributed power supply voltage and frequency when the microgrid is switched and the microgrid operating mode is switched.

3.1. Droop control principle
The droop control is to detect the output power of multiple DGs in the microgrid, solve the active and reactive power of the DG, and obtain the reference values of the frequency and voltage according to the P-f and Q-U droop characteristics, thereby adjusting the sinusoidal control signal and controlling Inverter to regulate the active and reactive power of the microgrid system [13-14]. A microgrid containing multiple DGs is essentially a parallel system containing multiple inverter power supplies. The principle of droop control is shown in Figure 2.
In Figure 2, the output voltage of DG is $V$, the output current is $i_L$, the filter inductance of the LC filter is $L_f$, the filter capacitance is $C_f$, the load impedance is $Z$, the current filtered by the LC filter is $i_0$, and the voltage is $u_0$. The current flowing to the LC filter is $i_c$; $m$ is a controllable sinusoidal signal; $P_n$, $U_0$, and $f_n$ are the actual given power, voltage, and frequency.

In the droop control process, first, the measurement module collects $i_0$ and $u_0$ after passing through the LC filter; after the power calculation module, the $P$ and $Q$ of the inverter are obtained, and compared with the actually given $P_n$, $U_0$, and $f_n$, and the reference values $U$ and $f$ are obtained according to the $P$-$f$ and $Q$-$U$ droop characteristics; then, the $dq$ axis component $u_{dref}$ and $u_{qref}$ of the voltage are calculated by the voltage synthesis module, and the current $i_c$ of the filter is controlled by the voltage and current double loop control module PI to obtain the required PWM adjustment signal $m$; finally, the inverter is controlled to achieve dynamic balance of the microgrid.

The $P$-$f$ and $Q$-$U$ droop characteristic curves are shown in Figure 3 below.
As shown in Figure 3, the adjustment of the DG voltage and frequency of the microgrid is adjusted by the Pf and QU droop relationship curves in Figure 3. For example, when the output P and Q of the DG are respectively reduced, the operating balance point of the DG is from the B point move to point A [15].

The droop control strategy method of the distributed power supply of the micro-grid can automatically adjust the voltage and frequency in the micro-grid spontaneously, and the seamless switching of the micro-grid operation mode can be realized without artificially changing the control method of the DG.

### 3.2. Droop controller design

#### 3.2.1. LC filter design

When designing the filter, since the inverter with sinusoidal modulation will generate harmonics, harmonics should be filtered out to reduce the impact on the system.

The traditional L-type filter has a simple structure and can only be applied to a small switching frequency. To achieve the requirements of the grid-connected harmonics of the micro-grid, the inductance of the corresponding L-type filter should be large enough, but it will lead to filter controller increased difficulty [16]. Since the LCL type filter is too difficult to calculate the three-phase voltage d and p-axis components in the dq rotating coordinate system, the LC type filter is used in this paper, and a small resistance is inserted in series to suppress the shortcoming of oscillation. LC filter transfer function is below.

\[
G_f(s) = \frac{u_0(s)}{V(s)} = \frac{R_f + 1/(j\omega C_f)}{j\omega L_f + R_f + 1/(j\omega C_f)}
\]

\[
= \frac{j\omega \cdot 2\xi \omega_0 + \omega_0^2}{(j\omega)^2 + j\omega \cdot 2\xi \omega_0 + \omega_0^2}
\]

In the above formula (1), \(\omega_0 = \sqrt{L_fC_f} \), \(\xi = R_f / 2\sqrt{L_f/C_f} \).

The resonant frequency is below.

\[
f_c = 1/(2\pi\sqrt{L_fC_f}) \quad 10f_n \leq f_c \leq 10f_s / 10
\]

In the above formula (2), \(f_n \) is fundamental frequency, \(f_s \) is carrier frequency.

The parameters of the filter are designed according to formula (1) and formula (2). After many experiments, when the parameter is set to \(L_f=0.6mH, C_f=1500uF, R_f=0.01 \Omega \), the filtering performance is better.

#### 3.2.2. Power controller design

The power controller takes the filtered \(i_0 \) and \(u_0 \) as input quantities, calculates the instantaneous active and reactive power, and obtains the corresponding average power through the low-pass filter LPF. Compared with the actual given \(P_n, U_0, \) and \(f_n \), the reference value voltage \(U\) and the frequency \(f\) are calculated according to the droop characteristic of Figure 3. After voltage synthesis and dq conversion, \(u_{dref}\) and \(u_{qref}\) are obtained, and finally output to the voltage-current double-loop controller.

The power controller designed in this paper is shown in Figure 4.
From the droop control link in Figure 4, the formula is as follows.

\[
\begin{align*}
\begin{cases}
  f = f_n + m(P_n - P) \\
  U = U_0 - nQ
\end{cases}
\end{align*}
\]

(3)

In the above formula (3), \(m, n\) are respectively P-f, Q-U droop characteristic coefficient, \(f_n\) is the rated frequency, \(P_n\) is the rated active power of DG, \(U_0\) is the initial voltage amplitude of DG, and P and Q are the actual output active and reactive power of the inverter.

The droop characteristic coefficient can be obtained from the relationship of the sagging characteristic curve in Figure 3.

\[
\begin{align*}
\begin{cases}
  m = \frac{f_n - f_{\text{min}}}{P_{\text{max}} - P_n} \\
  n = \frac{U_0 - U_{\text{min}}}{Q_{\text{max}}}
\end{cases}
\end{align*}
\]

(4)

In the above formula (4), \(P_{\text{max}}\) and \(Q_{\text{max}}\) are the maximum active power and the maximum reactive power; \(f_{\text{min}}\) and \(U_{\text{min}}\) are the minimum frequency and the minimum voltage amplitude corresponding to \(P_{\text{max}}\) and \(Q_{\text{max}}\).

The three-phase AC quantity after DG inversion is transformed into the DC quantity in the two-phase dq coordinate system by the Park formula to realize the zero-state error control of the PI controller.

Park transformation formula is below:

\[
\begin{bmatrix}
X_d \\
X_q
\end{bmatrix} = \frac{2}{3} \begin{bmatrix}
\sin \omega t & \sin(\omega t - \frac{2}{3} \pi) & \sin(\omega t + \frac{2}{3} \pi) \\
-\cos \omega t & -\cos(\omega t - \frac{2}{3} \pi) & -\cos(\omega t + \frac{2}{3} \pi)
\end{bmatrix} \begin{bmatrix}
X_a \\
X_b \\
X_c
\end{bmatrix}
\]

(5)
Using the formula (5), the voltage dq axis components $u_{dref}$, $u_{qref}$ are calculated and output to the voltage-current double-loop controller.

3.2.3. Voltage and current double loop controller design. In the design of voltage and current double-loop controller, the capacitor current is used as the inner loop control, and the voltage is used as the outer loop control method. Compared with the inductor current as the inner loop control, this design method can directly and accurately reflect the changes of the system voltage and load, and quickly adjust the system to achieve equilibrium [17].

It can be seen from the schematic diagram of the droop control of Figure 2 that the LC filter capacitor voltage and the inductor current satisfy the following equation.

$$\begin{align*}
C_f \frac{du_0}{dt} &= i_L - i_0 \\
L_f \frac{di_L}{dt} &= \frac{1}{2} \tilde{m} V_{dc} - u_0
\end{align*}$$

(6)

In the above formula (6), $\tilde{m}$ is SPWM signal, and $\tilde{m} = m^* \sin(\omega t - \phi - \frac{2}{3} \pi)$.

According to formula (6), the structure of the voltage and current double loop controller is designed as shown in Figure 5.

![Figure 5. Voltage and current double loop controller](image)

As can be seen from Figure 5, it mainly includes a voltage control loop, a current control loop, and an open loop portion of the system. The voltage is controlled by the outer loop, which is mainly to stabilize the load voltage and improve the steady-state accuracy. $K_{up}$ and $K_{ui}$ are proportional and integral coefficients respectively, and PI control is adopted. The capacitor current is controlled as an inner loop with a scaling factor of $K$. $i^*_c$, $u^*_c$ are reference values for the capacitor current $i_c$ and the load voltage $u_c$.

The transfer function of the inner loop of the current is below.
Current proportional gain transfer function is below.

\[ G_i(s) = \frac{KV_{dc} C_f s}{L_f C_f s^2 + \frac{KV_{dc}}{2} C_f s + 1} \]  

(7)

When designing the capacitor current inner loop, the value of \( i_c/i_0 \) should be as small as possible within the frequency band to reduce the influence of the filter capacitor.

The proportional control coefficient \( K \) of the inner loop of the current has a direct influence on the dynamic response of the system. The larger the \( K \) value, the faster the dynamic response, but an excessive \( K \) value can also cause system instability. After many experiments, when \( K=5 \), the system has faster dynamic response and stability.

When the proportional control coefficient \( K=5 \), at \( f_n=50Hz \), the voltage outer loop transfer function is below.

\[ u_0 = G_u(s)u^*_0 - Z(s)i_0 \]  

(9)

In the above formula (9), Voltage proportional gain \( G_u(s) \), inverter equivalent output impedance \( Z(s) \) are

\[ G_u(s) = \frac{KV_{dc} C_f s^2 + \frac{KV_{dc}}{2} K_{up}s + \frac{KV_{dc}}{2} K_{ui}}{L_f C_f s^3 + \frac{KV_{dc}}{2} C_f s^2 + (1 + \frac{KV_{dc}}{2} K_{up})s + \frac{KV_{dc}}{2} K_{ui}} \]  

(10)

\[ Z(s) = \frac{L_f s^2}{L_f C_f s^3 + \frac{KV_{dc}}{2} C_f s^2 + (1 + \frac{KV_{dc}}{2} K_{up})s + \frac{KV_{dc}}{2} K_{ui}} \]  

(11)

It can be seen from the above formulas (10) and (11) that the inverter power supply using the droop control method, \( Z(s) \) is related not only to the line impedance and the filter parameters, but also to the control parameters \( K_{up} \) and \( K_{ui} \).

In the high-voltage power system, since the line impedance is much larger than the resistance, the Pf and QU droop characteristics are always established, and the droop control is used in the low-voltage micro-grid. It is necessary to ensure that the impedance of the line is greater than the resistance, so that the droop characteristic is established, so the control parameter \( K_{up}, K_{ui} \) is designed the equivalent output impedance of the inverter power supply is inductive.

Set \( K=5, f_n=50Hz, K_{ui}=100, K_{up} \) gradient from 0.1 to 1000, \( Z(s) \) frequency domain response curve is shown in Figure 6.
Figure 6. $Z(s)$ frequency response curve on $K_{up}$ change

It can be seen from Figure 6 that $K_{up}$ is a boundary, and when it is less than 1, the equivalent output impedance $Z(s)$ is resistive; when it is greater than 1, $Z(s)$ is inductive. $Z(s)$ with high resistance in the high frequency band can suppress harmonics better, but it cannot select the value of the inductive frequency band too wide. Considering this, $K_{up}=10$ is chosen in this paper.

Set $K=5$, $f_n=50\text{Hz}$, $K_{up}=10$, when $K_{ui}$ changes from 1 to 5000, the $Z(s)$ frequency domain response curve is shown in Figure 7.

Figure 7. $Z(s)$ frequency response curve on $K_{ui}$ change
It can be seen from Figure 7 that with the increase of \( Kui \), \( Z(s) \) is more resistive, and when \( Kui=1 \), it is inductive; when \( Kui=5000 \), it is resistive. Similarly, in order to effectively suppress high-band harmonics, the value of the inductive frequency band cannot be selected. For comprehensive consideration, this paper chooses \( Kui=100 \).

In summary, when designing the voltage-current double-loop controller, \( K=5 \), \( Kui=100 \), and \( Kup=10 \) are selected, which can better suppress the high-band harmonics and make the equivalent output impedance inductive at 50Hz. At the same time, it also meets the relationship between Pf and QU.

3.3. Droop controller simulation model construction

According to the droop controller designed above, the simulation model of the droop controller is constructed by using Simulink software, which mainly includes three parts.

The droop controller simulation model is shown in Figure 8.

![Figure 8. Droop controller simulation model](image)

In the figure 8, \( fn, Pn, U_0 \) are the given rated frequency, rated power and voltage amplitude, \( IC \) is the feedback current of the filter, \( Vabc \) is the load voltage, and \( Iabc \) is the load current.

The drooping controller collects the voltage and current of the inverter power supply, and calculates the required PWM adjustment signal through the DQ conversion and power calculation module, the droop control and the reference voltage module, and the voltage and current double loop control module. Control is made to achieve dynamic balance of the microgrid.

1) DQ transform and power calculation module

The design DQ transformation and power calculation module is shown in Figure 9.
Figure 9. DQ transform and power calculation model

The LC current filter current IC, load voltage \( V_{abc} \), and load current \( I_{abc} \) are calculated by dq conversion power to obtain instantaneous active and reactive power, and the average active and reactive power are obtained through a low-pass filter.

(2) Droop control and reference voltage module
The design droop control and reference voltage module is shown in Figure 10.

Figure 10. Droop control and reference voltage model

The active power input by the previous module, according to the Pf droop characteristic, the frequency of the reference voltage is obtained; from the reactive power, according to the QU droop characteristic, the amplitude of the reference voltage is obtained; the frequency and the amplitude are
synthesized to obtain a three-phase reference. The voltage vector is transformed by dq to obtain the d and q axis components of the voltage.

(3) Voltage and current double loop control module
The design voltage and current double loop control module is shown in Figure 11.

![Figure 11. Voltage and current double loop controller model](image)

The d and q axis components of the voltage are input to the voltage outer loop proportional integral (PI) controller, and the current is combined and input into the current inner loop ratio (P) controller. After the dq change, the sinusoidal signal M is obtained and input to the PWM Generator. The module calculates the PWM control signal to control the inverter to stabilize the microgrid.

3.4. Construction of Peer-to-Peer Control Microgrid Simulation Model
According to the peer-to-peer control microgrid structure diagram of Figure 1, the Simulink software is used to construct the peer-to-peer control microgrid simulation model, as shown in Figure 12.

In the figure, two DG1 and DG2 are controlled by the droop controller designed in this paper. Both lines have constant power loads Load1 and Load2, and the common load Load3 is connected to the micro-network common AC bus. The micro-grid passes the circuit breaker switch K and a transformer with a ratio of 0.4/10 is connected to a 10KV large power grid.
4. Simulation analysis

4.1. Droop controller simulation model verification
In order to ensure the correctness of the designed peer-to-peer control microgrid simulation model, the correctness of the droop controller simulation model should be verified. The simulation calculation of the design of the drooping controller model is shown in Figure 13 below.
Figure 13. Droop controller simulation model numerical example

In the figure, Load1 and Load2 are constant power loads. Before the system is running, the breaker is disconnected. When the system is running for 0.3~0.6s, the Load2 load is connected to the microgrid. After 0.6s, the circuit breaker is disconnected and the Load2 load is cut off. The simulation runs for 1 second. The simulation parameters are set as follows:

DG: \( V_{\text{DC}}=800 \text{V}, \quad f_0=50 \text{Hz}, \quad P_n=20 \text{kW}, \quad U_0=311 \text{V}; \) LC filter: \( R_f=0.01 \Omega, \quad L_f=0.6 \text{mH}, \quad C_f=1500 \mu \text{F}; \) droop controller: \( m=10^{-5}, \quad n=3 \times 10^{-4}, \quad K=5, \quad K_{up}=10, \quad K_{ui}=100; \) load: \( P_1=20 \text{kW}, \quad Q_1=10 \text{kVar}; \quad P_2=5 \text{kW}, \quad Q_2=5 \text{kVar}. \)

The simulation results are shown in Figure 14, Figure 15, and Figure 16.

Figure 14. DG output active and reactive power
It can be seen from Figure 14 to Figure 16 that 0~0.3s, DG only supplies power to Load1. The active and reactive power of DG output meets the active and reactive power consumed by Load1, and the output voltage, current and system frequency are stable. 0.3~0.6s, the circuit breaker is closed, the load Load2 is connected to the system, and the active and reactive power of the DG output increases. In the simulation diagram, the voltage and frequency of the DG output decrease within a certain range. 0.6~1.0s, cut off the load Load2, the active and reactive power of the DG output is reduced. In the simulation diagram, the voltage and frequency of the DG output rise to the original value.

The whole process is in full compliance with the P-f and Q-U droop characteristics, and the voltage and frequency fluctuations are small, which has better anti-interference ability. The correctness of the droop controller and its simulation model designed in this paper is verified.

4.2. Simulation of microgrid load increase and change

In order to realize the smooth control of distributed power supply voltage and power when microgrid load-increasing load and micro-grid operation mode are switched, the droop control strategy method of micro-grid distributed power supply is adopted, and the constructed peer-to-peer control microgrid is
constructed by Simulink software. The simulation model is simulated and verified, and the correctness and feasibility of the method are verified.

Figure 12 shows the parameters of the peer-to-peer control microgrid simulation model as follows:

DG1: $V_{DC}=800\text{V}$, $f_n=50\text{Hz}$, $P_n=20\text{kW}$, $U_0=311\text{V}$; LC filter 1: $R_f=0.01\ \Omega$, $L_f=0.6\text{mH}$, $C_f=1500\mu\text{F}$; droop controller 1: $m=10^{-5}$, $n=3\times10^{-4}$, $K_s=5$, $K_u=10$, $K_{iu}=100$, Carrier frequency $f_s=6\text{kHz}$.

DG2: $V_{DC}=800\text{V}$, $f_n=50\text{Hz}$, $P_n=20\text{kW}$, $U_0=311\text{V}$; LC filter 2: $R_f=0.01\ \Omega$, $L_f=0.6\text{mH}$, $C_f=1500\mu\text{F}$; droop controller 2: $m=10^{-5}$, $n=3\times10^{-4}$, $K_s=5$, $K_u=10$, $K_{iu}=100$, Carrier frequency $f_s=6\text{kHz}$.

Load: $P_1=20\text{kW}$, $Q_1=5\text{kVar}$; $P_2=20\text{kW}$, $Q_2=5\text{kVar}$; $P_3=10\text{kW}$, $Q_3=10\text{kVar}$.

Line: 380V Line $R_1=R_2=0.641\ \Omega/\text{km}$, $X_1=X_2=0.101\ \Omega/\text{km}$; 10kV Line $R_3=0.347\ \Omega/\text{km}$, $X_3=0.236\ \Omega/\text{km}$.

In Figure 12, when the load balancing simulation of the microgrid is performed, the circuit breaker switch K is always in the off state. When the system starts running, switches K1 and K2 are closed at the same time. DG1 and DG2 supply power to their respective loads. When running to 0.3s, load Load3 is connected to the system. When running to 0.6s, load Load3 is removed from the system and the system simulation runs for 1 second. The simulation results are as follows.

**Figure 17.** DG1 output active and reactive power

**Figure 18.** DG2 output active and reactive power
It can be seen from the simulation diagram 17 to Figure 20 that DG1 and DG2 automatically bear the corresponding power according to the change of the load. Since the parameters set by the load Load1 and Load2 are the same, the DG1 and DG2 output have the same active and reactive power in the simulation result. When running to 0.3s, Load3 is connected to the system, and the power output of DG1 and DG2 increases, and the system frequency and voltage are reduced. When running to 0.6s, the system cuts Load3, the power output of DG1 and DG2 decreases, and the system frequency and voltage return to the original value.

The simulation results show that the microgrid can adjust the power of the load when the load is increased by using the droop control strategy of the distributed power supply of the microgrid, which can realize the smooth control of the distributed power supply voltage and frequency.

4.3. Microgrid operation mode switching simulation

In Figure 12, the operation mode switching of the microgrid is simulated, the switches K1 and K2 are always closed, and the load Load3 is connected to the system. When the system starts running, the circuit breaker K is closed and the micro-grid is connected to the grid. When it runs to 0.5s, K disconnects and the micro-grid changes to the island mode. When it runs to 1.0s, K closes and the micro-grid re-connects to the grid. The simulation runs for 1.5 seconds. The simulation results are shown in the figure below.
Figure 22. Microgrid bus voltage

Figure 23. System frequency diagram

(1) Grid mode switching to island mode
It can be seen from Figure 21 to Figure 23 that when the microgrid is connected to the grid, DG1 and DG2 absorb some of the active power from the large grid; when 0.5s is switched to the island, the active power of the DG output increases. In order to compensate for the shortage of active power, the system frequency is reduced at this time. The designed droop controller fully complies with the Pf drooping characteristics, and the system frequency fluctuation is small, and the system frequency is relatively stable. When 0~0.5s is connected to the grid, DG1 and DG2 transmit some reactive power to the large power grid. When switching to island operation, the reactive power of the DG output decreases. At this time, the system voltage increases and the designed drooping. The controller is fully compliant with the QU drooping characteristics and the microgrid voltage fluctuations are small. When the microgrid is switched from the grid-connected mode to the island mode, the voltage and frequency are relatively stable.

(2) Island mode switch to grid-connected mode
It can be seen from Figure 21 to Figure 23 that the 0.5~1.0s microgrid is operating in an island. When the microgrid is reconnected at 1.0s, the active power of the DG output is reduced, the reactive power of the output is increased, and the corresponding system frequency is increased. Large, the voltage is reduced. When the microgrid is reconnected to the grid, there is a gap between the rated value and the rated mode. In the process of switching from the island mode to the grid-connected mode, the active and reactive powers have certain impacts, and the performance needs to be further improved. During the switching process, the system frequency and voltage are kept within the allowable range of fluctuation, and finally transition to the steady state of grid-connected operation. Compared with the control method of sagging and inverted drooping [9], the adjustment time of the droop control strategy method is improved.

5. Conclusion
Aiming at the complex coordinated control problem between multiple distributed power sources in microgrid, this paper proposes a droop control strategy method for distributed power supply of microgrid. According to the droop control principle, the Pf and QU droop characteristics are studied. The droop controller based on filter, power controller and voltage-current dual-loop controller is designed. The
simulation model of the droop controller and the peer-to-peer control strategy are established. Microgrid simulation model. Finally, through the simulation, the variation law of the voltage and frequency of each distributed power supply in the micro-grid during the islanding, grid-connected and operation mode switching is analyzed.

The simulation results show that the droop control strategy of the distributed power supply of the microgrid can automatically allocate the power of multiple distributed power supplies in the microgrid during island operation, and realize the automatic adjustment of the system voltage and frequency to ensure the smoothness of the microgrid. At the same time, smooth control of voltage and frequency can be realized when the micro-grid operation mode is switched, and smooth switching between the two operation modes is realized.

The next research direction is to analyze the active and reactive power with a certain impact when switching to the grid-connected mode according to the island mode. The droop controller model is further improved to better achieve smooth control of distributed power supply voltage and frequency.

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