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Study on operation control of microgrid based on improved droop control

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Abstract. In micro grid, the droop controlled micro power supply, the line impedance difference, the output voltage amplitude is not equal, and the microgrid complex structure and other factors will cause the reactive power of micro power output cannot achieve the same effect, so that reactive power circulation will appear between micro power supply. In order to solve this problem, an improved droop control strategy is proposed. That is to say, in traditional reactive droop control, line voltage drop and micro power access point voltage amplitude feedback are used as compensation amount for reactive droop control, which effectively tracks voltage change of microgrid and improves output voltage amplitude. The simulation model of microgrid is built in Matlab/Simulink. The simulation results show that the improved droop control can greatly improve the distribution precision of the reactive power sharing and improve the system stability of the microgrid.

1. Introduction

Nowadays, droop control has been widely used in micro grid in [1-2], especially in the micro grid peer-to-peer control, but the traditional droop control, because of the difference of line impedance voltage range and factors of micro grid complex structure of the DG output reactive power sharing is difficult to achieve the effect of [3], in serious cases, may generate reactive power circulation large micro power. Domestic and foreign scholars have conducted a series of research literature, designed the frequency dividing droop controller inverter harmonic, suppress voltage harmonics, but also in accordance with the power capacity of rational allocation of fundamental domains, so as to improve the accuracy of power distribution of parallel inverter; literature [4] joined the load end voltage amplitude feedback in the traditional droop control, to improve the accuracy of load distribution, but this method needs reactive power droop coefficient is relatively large, unfavorable to the stability of the system; the [5] will return control voltage and reactive power compensation is introduced into the traditional droop control, to improve the voltage deviation of reactive power distribution and accuracy of modified Q/V curve; ptosis the will control the virtual impedance technology is introduced in the traditional virtual reactance added to the output side of the inverter The output impedance is inductive, and then modified Q/V curve, and finally improve the accuracy of reactive power sharing effect, but the introduction of the virtual impedance will make the system voltage drop, adversely affect the quality of output voltage; the literature adopting improved dynamic virtual impedance control based on the virtual impedance value to adjust value, reduce line voltage drop inhibition of reactive circulation; literature adding reactive power deviation as the disturbance in P/f droop control, Q/V droop control and then using the perturbation to adjust the micro power, to reduce the error of reactive power distribution, but this method will cause the fluctuation of system frequency, to adversely affect power quality; the [6] is put forward the virtual impedance to reduce the micro power transmission line impedance is different, so as to improve the micro power allocation of reactive load fine Degree, but still can't fundamentally solve this problem. Therefore, it is urgent to find an effective way to improve the accuracy of reactive power distribution without affecting the power quality and negatively affecting the stability of the microgrid system.

Aiming at this problem, adding transmission line drop in traditional reactive power droop control and micro power access point voltage feedback as compensation power droop control, effective tracking of micro grid voltage changes, improve the output voltage amplitude varying condition, which can improve the stability of the system, but also can improve the quality of electric energy to improve the accuracy of reactive power sharing effect.

2. inverter droop control strategy

2.1. Inverter overall control strategy

The overall control of the inverter droop control method as shown in Figure 1: the inverter output voltage and current through power calculation, power droop control, voltage and current double loop control SPWM wave control inverter output, and ultimately achieve the purpose of controlling the inverter output.

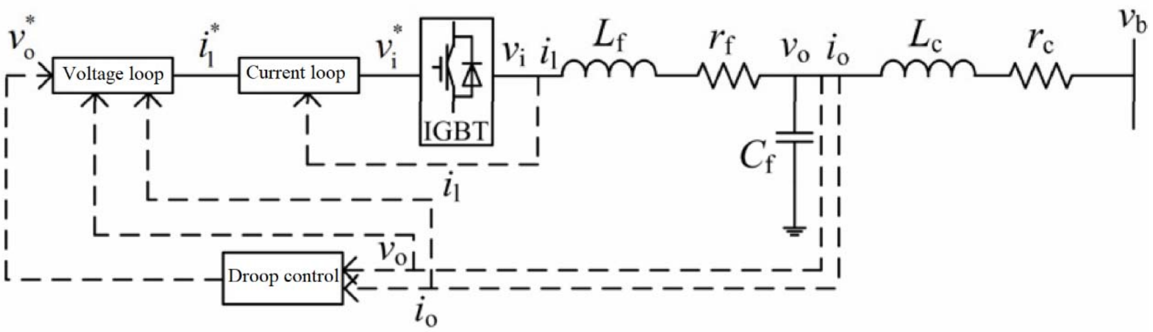

Figure 1. overall control scheme of inverters with droop control

In this paper, the inverter uses voltage and current double loop control to make the inverter have better voltage source characteristics. The voltage loop can quickly track the reference voltage V * generated by power droop control, and the current loop is used to further improve the dynamic response of the system. The inverter based on droop control can maintain the basic strategy of inverter voltage control in the process of microgrid system mode switching, and is easy to switch to grid connected island in microgrid. In practice, the static switch of microgrid can be directly disconnected, and the operation of grid connected islanding can be realized. Each inverter will adjust the voltage and frequency and voltage amplitude of microgrid according to droop curve and local load.

2.2. Traditional droop control principle

Droop control is mainly used in the control of parallel operation of multiple inverters in the micro grid of the peer-to-peer control structure. Droop control can realize the decoupling of P/f and Q/V when the output impedance of the micro power supply is sensitive.

When the equivalent output impedance of the inverter is sensitive, and compared with the load impedance, the equivalent inverter output impedance and line impedance are small, deviation angle δ_i

are small and in the actual situation, you can think of $\sin\delta_i = \delta i$, $\cos\delta_i = 1$, DG output active power and reactive power respectively:

$$\begin{cases} P_i = \dfrac{E_i U}{x_i}\delta_i \\ Q_i = \dfrac{E_i U - U^2}{x_i} = \dfrac{U\left(E_i - U\right)}{x_i} \end{cases} \tag{1}$$

His traditional formula for the sag characteristic of the inverter is:

$$\begin{cases} f = f_0 - k_p P \\ E = E_0 - k_q Q \end{cases} \tag{2}$$

The traditional formula for the sag characteristic of the inverter is:

Type (2), k_p, k_q were *P/f* and Q*V* droop control coefficient, F0 and E0 respectively in the no-load micro power frequency and voltage amplitude, which is the initial value of *P/f, Q/V f, E* droop curve, respectively control the amount of micro power frequency and voltage amplitude, P, Q for the actual the measurement of micro power active power and reactive power value.

The formula (2) substituting (1) can be obtained:

$$Q_i = \frac{U(E_0 - U)}{x_i + k_{qi} U} \tag{3}$$

The filter and transformer reactance and line reactance are unified as the output side reactance of the distributed micro power supply. From the formula (3), we know that reactive power output is related to output side reactance x_i, no load voltage amplitude E_0, bus voltage U and Q/V droop control coefficient k_q.

3. improved droop control

Because the inductance of the output LC filter of the micro power inverter is larger, and the transmission line in the microgrid is shorter, the output impedance of the micro power supply is still perceptual. Therefore, the P/f and Q/V droop control still applies to in the microgrid.

Furthermore, the formula (3) can be obtained:

$$U = E_0 - \frac{Q_i}{U} x_i - k_{qi} Q_i \tag{4}$$

$\frac{Q_i}{U} x_i$ Can be considered as a voltage drop of a transmission line. Therefore, from the formula (4), we can know that the voltage compensation $\frac{Q_i}{U} x_i$ is added to the traditional droop control to compensate the voltage drop of transmission lines, and the distribution accuracy of reactive power load is increased.

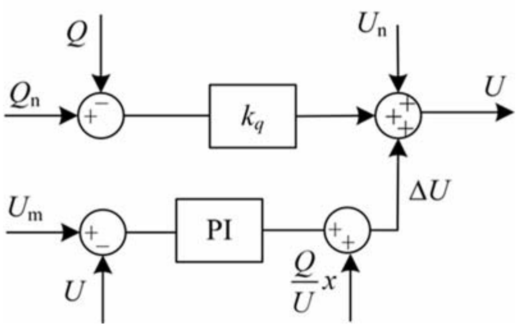

Figure 2. improved reactive power droop control structure

In Figure 2, Q_n, U_n rated micro power output power and voltage amplitude values of Q for the reactive power output of micro power k_q, reactive power droop coefficient of micro power, as shown in Figure 3, adjust the stable operation of the system, finally to the micro power output voltage amplitude of the same.

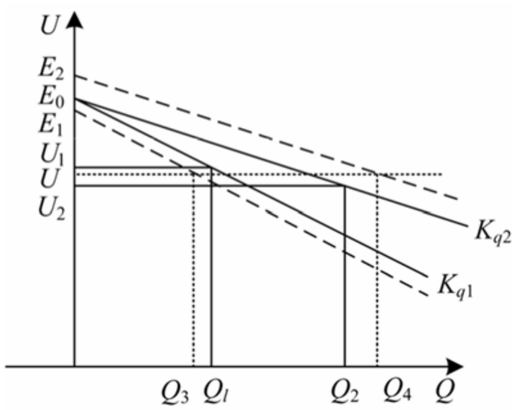

Figure 3. Sketch map of drooping curve

In Figure 3, the solid line is improved reactive power droop curve, U_1, U_2 as the actual voltage distributed power 1, 2, U for micro grid voltage, E_0 micro power voltage, the output power of Q_1, Q_2 respectively before the improvement of distributed power droop curve 1, 2; the dotted line is the droop curve. The improved E_1, E_2 to join the micro grid voltage sag curve initial feedback, Q_1, Q_2 respectively. The output power droop curve improved distributed power 1, 2. It can be seen that the improved reactive power droop control can change the reactive power output of the distributed power, and make the output voltage of the distributed power in the microgrid equal.

4. Simulation Analysis

In order to verify the validity of the improved droop control, the establishment of a micro grid simulation model in Matlab/Simulink, to simplify the structure as shown in Figure 4 of the simulation model, the micro grid is composed of 3 micro power supply, power grid by three-phase voltage source equivalent ideal, PCC distributed micro grid switch.

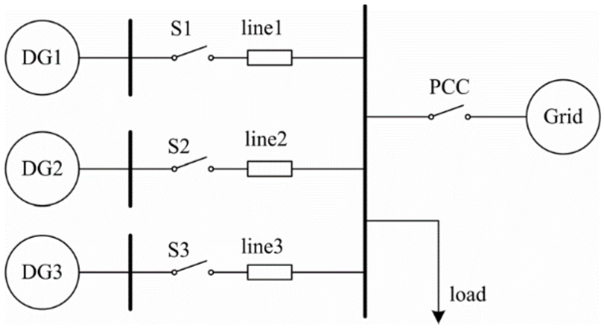

Figure 4 simplified structure of microgrid

Table 1. Control parameters of microgrid system

Distributed power supply	DG1	DG2	DG3
Rated powe *P*/kW	10	12	20
Rated power *Q*/kW	0	0	0
P/*f* droop coefficient/(Hz/kW)	0.02	0.016 7	0.01
Q/*V* droop coefficient/(V/kW)	0.8	0.668	0.4
Rated frequency /Hz	50	50	50
Rated voltage amplitude /V	311	311	311

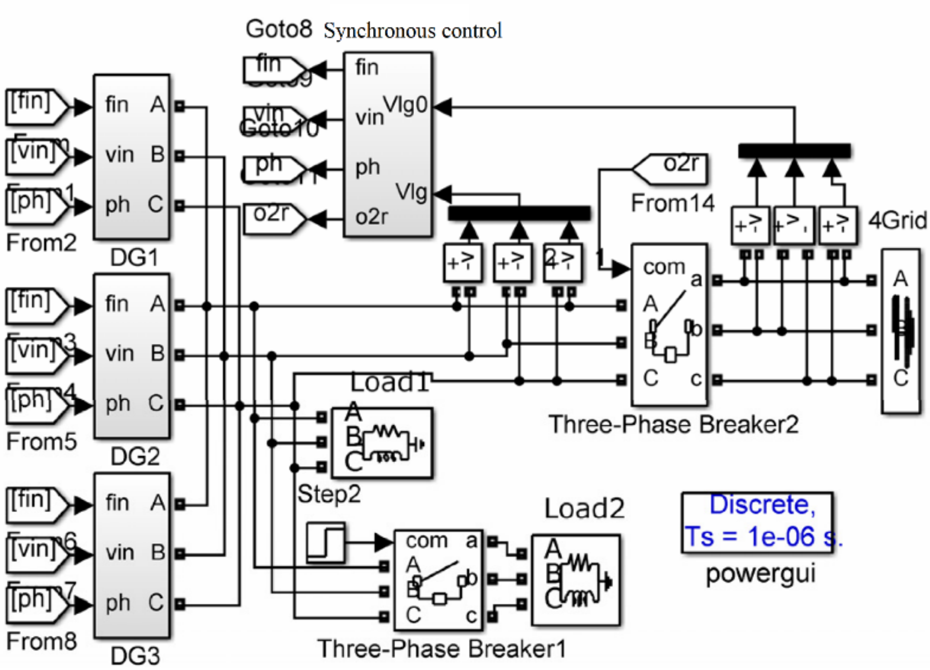

Figure 5. The overall Simulink simulation model of the microgrid

The simulation process of microgrid is: (1) before 1 s, the operation of microgrid islanding; (2) when the load is 1 s, the load of microgrid suddenly changes, the total active load increases from 50 kW to 60 kW, and reactive power load is 10 kvar.

Increased to 13 kvar; (3) the voltage and frequency control module starts at 1.5 s, 1.6 s startup phase control module, micro grid and grid synchronization control into the pre stage, when conditions meet the grid type, micro grid; (4) 3 s, disconnect the PCC switch, micro grid by grid operation switching mode to islanded operation mode.

The output reactive power of the microgrid is improved before and after improvement, such as Figure 6, Figure7It is shown.

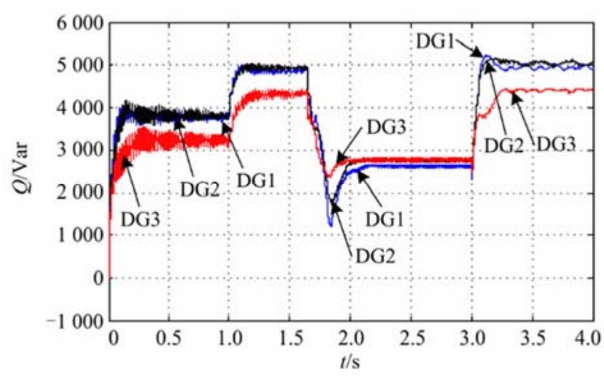

Figure 6. Output reactive power before improved

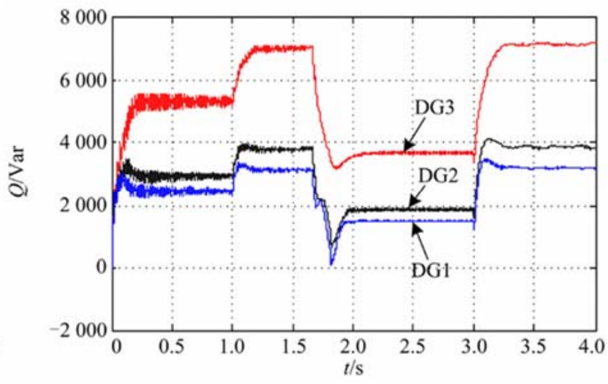

Figure 7. Output reactive power after improved

From Figure 6and Figure 7, it can be seen that the reactive power of the microgrid is greater than the reactive power due to the existence of the line impedance. Before reactive power droop control is improved, the reactive power output of the distributed power is obviously not allocated according to the reactive droop coefficient ratio. After improvement of reactive droop control, it can be seen from Figure 11.

(1) 0~1 s microgrid and distributed power output reactive power ratio: Q3/Q2 = 5400/3000=1.80, Q3/Q1 = 5400/2500=2.16, Q2/Q1 = 3000/2500=1.20;

(2) 1~1.5 s, the microgrid is running on the island and the load is abrupt.

Grid pre synchronization control: Q3/Q2 = 7100/3900=1.82, Q3/Q1 = 7100/3200=2.22, Q2/Q1 = 3900/3200=1.22;

(3) 2~3 s, enter the micro grid connected mode and stable, Q3/Q2 = 3600/1900=1.89, Q3/Q1 = 3600/1500=2.4, Q2/Q1 = 1900/1500=1.27;

(4) 3~4 s, the microgrid is again converted to the island after the operation,

Q3/Q2≈7100/3900=1. 82, Q3/Q1≈7100/3200 = 2. 22, Q2/Q1≈3900/3200=1.22;

The ratio of reactive droop coefficient is kq_2/kq_3=0.668/0.4= 1.67, kq_1/kq_3=0.8/0.4=2.00, kq_1/kq_2= 0.8/0.668=1.197, which shows that although reactive droop control has not been improved after improvement.

But from Figure 10, figure 11 can be seen in the micro grid by the islanding operation mode and grid connected mode switch, the system will appear serious reactive power shortage, through local reactive power compensation equipment and power controller for fast compensation.

5. Conclusion

The droop controlled micro power sources, such as the difference in line impedance, the output voltage amplitude and the complex structure of the microgrid, will lead to the unreasonable distribution of reactive load, which will lead to reactive power circulation among the micro power sources. According to the Droop load voltage amplitude, through the method of adding pressure drop in the transmission line reactive power droop control and micro power amplitude access point voltage feedback, the microgrid operation reaches a steady state the micro power output voltage is the same, so as to improve the accuracy of reactive load distribution of micro power, improve the stability of micro grid.

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