A Microgrid Operation Control Strategy Based on Wide Area Information

Mingjin Wang
Kunming University of Science and Technology Oxbridge College, Kunming, Yunnan, China
Email: 674142973@qq.com

Abstract: Distributed Generator (DG) has many environmental benefits and potential values, but it is not controllable power for the large power grid, and brings many bad influences to the power grid, so that the power grid takes the way of isolation and restrictions that greatly limits the development of DG. In order to effectively solve the contradictions between DG and the power grid, the microgrid concept is put forward. Microgrid is a small power system containing micro powers and local loads, which can operate with connecting to the power grid, or run in isolated island way with breaking away from the power grid. On the basis of analyzing the principle of DG, two control methods are established: PQ Control and V/f Control. And then, a microgrid operation control strategy based on wide area information is proposed. Using wide area information to get the following data: the switching power and the breaker state of the Point of Common Coupling (PCC); the output of DG; the local loads and so on. In the operation of isolated island, the control strategy controls and adjusts the DGs and loads quickly, makes the power balance, ensures that the voltage and frequency in the microgrid conforms to the standard, and ensures the important loads working steadily and reliably. Finally, the feasibility and effectiveness of the proposed control strategy are verified by matlab/simulink simulation.

1. Introduction
In order to solve the imminent "energy crisis", protect the earth's environment and save energy, as well as effectively solve the problems of the interconnected power grid, Distributed Generator (DG) has attracted the attention of countries all over the world and developed rapidly [1-3]. But DG’s output power is instability, which has the characteristics of intermittent and random. With the capacity per unit of DG increasing, the scale expansion, the permeability increasing, it will directly affect the power quality and the relay protection of power grid and so on, in order to improve the security and stability of the power system, the large power system often adopts the method of limit and isolation to the DG, which minimizes the impact on power grid [4]. In order to coordinate the contradiction between the power grid and DG, CERTS puts forward the concept of microgrid [5-7]. The microgrid generally runs in two modes: parallel operation and isolated island [8]. The microgrid is different from the power grid, because there are multiple micro powers; it needs coordination control, and adjusts the required voltage and frequency. Literature [9] proposed a method based on the switching control strategy for the grid-connected operation or isolated island operation, the micro powers use the PQ control in grid-connected operation, and one of micro powers change to V/f control in isolated island operation, however isolated island detection is a difficult problem, so the method may be unsuccessful when switching control mode. Literature [10] introduced the PQ control and V/f control, and
researched the operation mode of the microgrid. Literature [11] proposed an undifferentiated V/f control strategy based on droop control in unplanned isolated island way, but in this kind of control, the micro powers are treated as infinite power, the capacity of the main-controlled distributed power is not considered, which is not in line with the actual situation.

2. Distributed power control method
At present, DG in the microgrid mostly adopts power electronic device interface, and there are two most common control strategies for DG: PQ Control and V/f Control.

2.1 PQ Control
PQ control is often used in the grid-connected operation, the DG is controlled to outputs constant active power and reactive power according to the reference power value. The DG with this control mode has the characteristics of variable output, randomness and intermittency. In this control mode, the DG controlled by PQ control depends on power grid providing voltage and frequency as reference. When the DG controlled by PQ control is given active power reference \( P_{ref} \) and reactive power reference \( Q_{ref} \), it will output power according to the reference value. The characteristic curve of PQ control is shown in Fig.1.

![PQ control characteristic curve](image)

2.2 V/f Control
V/f control is mainly used to regulate voltage and frequency in independent operation and isolated island state. Generally, it is used for the DG with large capacity, which can generate stable voltage and frequency as the main power when isolated island operation occurs. When the DG of V/f control sets the reference value of voltage and frequency, it will control that the inverter outputs voltage and frequency which is equal to the reference voltage and frequency under the action of PI controller, so it can be used as a constant voltage and frequency power [12-13]. Under the V/f control, the fluctuations of loads, the frequency and voltage disturbance within the microgrid is assumed by the main control DG. The characteristic curve of V/f control is shown in Fig.2.
V/f control requires a given reference voltage and frequency, the initial voltage is set as 1(pu) and the frequency is 50Hz. It can be seen from Fig.2 that: when the DG runs at point A, its active power and reactive power are $P_2$ and $Q_2$ respectively, and the voltage is 1(pu), the frequency is 50Hz; when the DG runs at point B, its active power and reactive power are $P_3$ and $Q_3$ respectively, and the voltage is 1(pu), the frequency is 50Hz. When the DG runs at point C, its active power and reactive power are $P_1$ and $Q_1$ respectively, and the voltage is 1(pu), the frequency is 50Hz. Obviously, the voltage and frequency are unaffected by the output power, it remains the same.

3. A microgrid operation control strategy based on wide area information

When the microgrid is running in isolated island way, due to the lack of support from the power grid’s voltage and frequency, so it must be controlled by the microgrid itself to maintain its own voltage and frequency, and all the loads must be supplied by the DGs. How to operate the microgrid safely and stably without relying on the power grid becomes a key problem. Therefore, the operation control strategy of microgrid is the key to its stable and reliable operation. The control of microgrid must solve several problems:

a) Power balance problem: In order to ensure the normal operation of the microgrid, it is necessary to ensure the balance between supply and demand of the microgrid.

b) Frequency stabilization problem: The fluctuation of power grid frequency in normal operation should not exceed ±0.2Hz.

c) Voltage stabilization problem: GB12325-2008”The Allowable Deviation of Power Supply Voltage” specifies clearly the voltage deviation of different voltage levels [14]: the voltage deviation of three-phase power supply of 10kV and below voltage levels is between -7% and 7%.

Based on the above analysis, this paper presents a microgrid operation control strategy based on wide area information. Using wide area information obtains the following information: the exchange power and the switch state at the Point of Common Coupling (PCC); the output of each DG in the microgrid; the state of grid-connected switches, the local loads and so on. The DG with large capacity and fast response is selected as the master DG. The master DG adopts two control modes: PQ control and V/f control. The switch state at PCC reflects the operation mode of the microgrid, if it is closed, the microgrid is in the grid-connected operation mode; and if it is disconnected, the microgrid is in the isolated island operation mode. The exchange power at PCC reflects the unbalanced power in the microgrid. The loads in the microgrid are classified into: important loads, sensitive loads and cutting loads. The loads are regulated and controlled by the load controller. The principle diagram of microgrid operation control is shown in Fig.3.
When the microgrid operates in the isolated island mode. At the same time, the master DG immediately changes to V/f control mode to provide voltage and frequency and other DGs adopt PQ control mode to operate. According to the exchanged power at PCC, using the power balance fast control technology to achieve power balance in the microgrid. The specific steps are as follows:

1. Before isolated island operation, using wide-area information obtains the exchange power $\Delta P$ at PCC, output $P_{DG}$ of each DG and load of each branch line.

2. Setting the discrimination threshold. The total rated active power $P_{DG}$ of DG is:

$$P_{DG} = \sum_{i=1}^{n} P_{DGi}$$

Where, $P_{DGi}$ is the rated active power of the $i$th DG, $P_{DG}$ is excluding energy storage;

Due to the master DG has large capacity and its output has a certain adjustment range, so the discrimination threshold is set as:

$$\Delta P_{c} = P_{DG} \times 10\%$$  \hspace{1cm} (2)

According to the comparison of the value $\Delta P$ and threshold $\Delta P_c$ in (1), the power balance in the microgrid can be judged:

a. When $|\Delta P| \leq \Delta P_c$, the power difference is within the set discrimination threshold, and the total output of DGs and the total loads in the microgrid are balanced, which have reached the conditions of isolated island operation, so there is no need to adjust;

b. When $0 > \Delta P$ and $\Delta P > \Delta P_c$, the active power deficit of the microgrid should be balanced by cutting off load. The scope of excision is $[-\Delta P_c, \Delta P + \Delta P_c]$.

According to the importance of the local loads, the local loads are classified into three levels in this paper. The first level Load1 is the most important, the second level Load2 is second, and the third level Load3 is respectable load. In the case of active power deficit, the loads should be cut off according to the important level and granularity of the loads according to the predetermined optimization strategy, which firstly cut off the branch of the third level Load3, and make the optimal match between the total output of the DGs and the loads. After the load is removed, the power difference is within the range $[-\Delta P_c, \Delta P]$ to quickly achieve the power balance within the microgrid.

c. When $\Delta P < 0$ and $|\Delta P| > \Delta P_c$, the active power in the microgrid is surplus, it is necessary to adjust and control the output of DG. The range of the cutting machine is $[|\Delta P| - \Delta P_c, |\Delta P| + \Delta P_c]$.  

![Microgrid Schematic Diagram](image-url)
Developing the optimal regulation and cutting scheme, makes the optimal match between the DGs and the loads in the microgrid. After the cutting machine, the power difference is within the range $[-\Delta P_c, \Delta P_c]$ to complete the output adjustment.

(3) When the microgrid changes to the isolated island operation, power balance can be secondary adjusted through energy storage.

4. Simulation analysis

In order to verify the feasibility and effectiveness of the microgrid operation control strategy proposed in this paper, using matlab/simulink builds a simulation calculation example as shown in Fig.4.

![Fig.4 The model diagram of simulation example](image)

In the simulation, all DGs are replaced by DC power supply, DG1 is selected as the master DG, and it has two control modes: PQ control and V/f control, DG1 uses the selector to switch its control mode, while the slave DG2 and DG3 use PQ control. The loads in the microgrid are divided into three levels, numbered as Load1, Load2 and Load3. The first level load Load1 is the most important, the second level Load2 is second, and the third level Load3 is resealable load. Among them, Load2 and Load3 have branch loads, and the branch loads can be controlled by breaker.

**Example:** The parameters of the DGs and the loads are shown in Tab.1. When simulation time is 0.5s, the switch at PCC is open, so the microgrid will run in isolated island way, the master DG1 immediately change to V/f control by the selector, and using the power balance fast control technology quickly complete the regulation and control of DGs and loads, ensure the balance of power in the microgrid.

| Module        | Parameter                        |
|---------------|----------------------------------|
| Master DG1    | V/f control reference: $V_{ref}=380V, f_{ref}=50Hz$ |
|               | PQ control reference: $P_{ref}=20kW, Q_{ref}=0$ |
| Slave DG2 and DG3 | $P_{ref}=20kW, Q_{ref}=0$ |
|               | $P_{ref}=15kW, Q_{ref}=0$ |
| Load          | $P_{load}=100kW, Q_{load}=10kvar$ |
| Load1         | $P_{load}=20kW, Q_{load}=1kvar$ |
| Load2         | $P_{load}=10kW$, branch loads are respectively(kW): 1,2,3,4 $Q_{load}=1kvar$, branch loads are respectively(kvar): 0.1,0.2,0.3,0.4 |
| Load3         | $P_{load}=50kW$, branch loads are respectively(kW): 2,5,8,13,22 $Q_{load}=1kvar$, branch loads are respectively (kvar): 0.1,0.1,0.2,0.2,0.4 |
By simulation analysis, the power difference $\Delta P$ is 25$kW$, the total rated active power $P_{DG}$ of DG is 55$kW$, and threshold $\Delta P_c$ can be calculated by Eq. (2): $\Delta P_c = P_{DG} \times 10\% = 5.5kW$. Because of $\Delta P > 0$ and $\Delta P > \Delta P_c$, the active power deficit of the microgrid should be balanced by cutting off loads. The scope of excision is $[19.5, 30.5]$. To reduce the number of branches removed, select the 22$kW$ branch in Load3 to be removed. At this point, the power in the microgrid is balanced, the microgrid can run in isolated island way reliably. The voltage and frequency of the bus in the microgrid system are monitored. The simulation results are shown in Fig.5 and Fig.6.

Fig.5 The frequency of microgrid

![Frequency vs Time](image)

Fig.6 The busbar voltage of microgrid

![Voltage vs Time](image)

It is obvious from the simulation Fig.5 that, when simulation time is 0.5s, the microgrid run in isolated island way, the frequency fluctuates, but the fluctuation range is small, and it tends to be stable after about 0.1s. And it is obvious from the simulation Fig.6 that, when simulation time is 0.5s, the microgrid run in isolated island way, the busbar voltage of microgrid changes temporarily, but it stabilizes rapidly due to the V/f control. The power balance fast control technology can quickly realize the power balance in the microgrid, and the V/f control can quickly maintain the stability of voltage and frequency in the microgrid to ensure the normal operation of the microgrid after switching to isolated island. Therefore, the feasibility and effectiveness of the operation control strategy proposed in this paper are verified.

5. Conclusions
The access of DG has a lot of adverse effects on the power grid, in order to solve the contradiction between power grid and DG, this paper proposes a microgrid operation control strategy based on wide
area information. Using wide area information to get the following data: the switching power and the
breaker state of the Point of Common Coupling (PCC); the output of the DG; the loads and so on.
When the microgrid will run in isolated island way, using the power balance fast control technology
makes the power of microgrid balanced. In addition, the control mode of the master DG is controlled;
PQ control is adopted in the grid-connected operation, while V/f control is adopted in the isolated
island operation, which ensures that the voltage and frequency in the microgrid system meet the
operating standards, and ensures that important loads in the microgrid system can operate steadily and
reliably. Finally, the feasibility and effectiveness of the proposed control strategy are verified by the
simulation of matlab/simulink model.

Acknowledgments
This study was supported by the Scientific Research Fund of Education Department of Yunnan
Province.

References
[1] Liang CH, Duan XZ. (2001) Distributed generation and its impact on power systems. Power
System Automation, 25(12):53-56.
[2] Ackermann T, Andersson G, Soder L. (2001) Distributed generation: a definition. Electric Power
Systems Research, 57 (3): 195-204.
[3] Dugan, R.C., McDermott T.E. (2002) Distributed generation. IEEE Industry Applications
Magazine, 8 (2): 19-25.
[4] Yang WJ. Research on photovoltaic grid connection and microgrid operation control, Doctor,
Southwest Jiaotong University, Chengdu, 2010-05-01.
[5] Zhang CZ. Research and design of photovoltaic grid-connected inverter, Doctor, Jiangnan
university, 2009.
[6] Lu ZX, Wang CX, Min Y. Summary of microgrid research. (2007) Power System and Automation,
31(19):100-107.
[7] Lasseter R H. Piagi P. Microgrid: A Conceptual Solution. (2004) Proceeding of IEEE 35th Annual
Power Electronics Specialists Conference. Aachen, Germany, 1(1):4285-4290.
[8] Lasseter R. H, Paigi P. Microgrid: A Conceptual Solution. (2002) IEEE 35th Annual Power
Electronics Specialists Conference PESC.
[9] BARSAL I S, CERAOLO M, PELACCHI P. (2002) Control techniques of dispersed generators to
improve the continuity of electricity supply. In: Proceedings of Power Engineering Society
Winter Meeting. New York, USA: 789-794.
[10] Lopes J A P, Moreira C L, Madureira A G. (2006) Defining Control Strategies for Microgrids
Islanded Operation. IEEE Transactions on Power Systems, 21(2): 916-924.
[11] Huang W, Niu M. (2011) Analysis on control Strategy of non-planned isolated network in
microgrid. Automation of Electric Power System, 35(9): 42-46.
[12] Chen L. Design and research of distributed generation control system. Doctor, Zhejiang
University, Zhejiang, 2006.
[13] Wu ZP. Control and Analysis of micro grid based on micro gas turbine power generation system.
Doctor, North China Electric Power University, Beijing, 2009.
[14] GB/T12325 -- 2008. Power quality allowable deviation of supply voltage $[S]$. 