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Basic Research on Microgrid switching method

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ABSTRACT. *This paper proposes a seamless transfer method of microgrid in grid connected and islanded mode based on the master-slave control strategy considering the variety of distributed generations. The control model is also illustrated. The problem of power deficit during islanded operation can be solved by power error calibration in slave control. The proposed master-slave seamless transfer method of microgrid between grid-connected and islanded operation modes was simulated based on DIgSILENT software. The simulation results verified the effectiveness of proposed control method.*

KEYWORDS: *distributed generation; microgrid; islanded operation; master-slave control; seamless transfer*

1. Introduction

By adjusting the power output from the power supply to compensate for the power shortage generated during the island operation, the power support pressure when the micro network main power source is switched from the grid-connected operation mode to the island operation mode is alleviated. This paper details the master-slave control DG controller model, including seamless switching control of the main power supply, power error control from the power supply, and synchronous control before the island is connected to the grid. Finally, the simulation was carried out by DIgSILENT software, and the results verified the effectiveness of the proposed control method[1-4].

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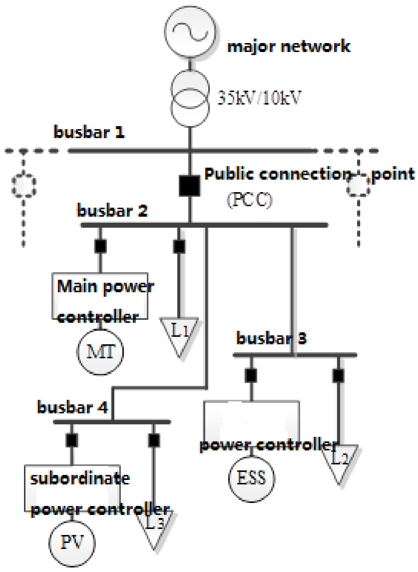

Fig.1 Typical master-slave microgrid

2. master-slave microgrid architecture

As the island main power source in the master-slave control mode, the voltage and frequency in the island are maintained. The other DG will operate as a slave from the power supply. After the main network resumes stability, the MT adjusts the operating point to synchronize with the main network. After the voltages at both ends of the PCC are synchronized, the islands are connected to the grid by closing the PCC, and the MT is switched back to the PQ control by the V/f control[5-7].

2.1. Control system modeling

In this paper, all DG inverter control adopts double loop control mode (as shown in Figure 2), the outer loop is the power control loop, and the inner loop is the current control loop. The power control of the DG is done by changing the input of the power outer loop (including variables and reference quantities). The control variable is acquired by the measurement acquisition module in real time; the reference quantity is set by the operation reference point control module. After the power outer loop is controlled by PQ or V/f, the output current reference value (and) is given to the current inner loop, and the latter will control the inner loop current (and) according to the current reference value to control the incoming voltage control reference signal for the PWM (with).

The DGs in the master-slave mode are modeled using the control framework shown in Figure 2. The control modules are slightly different for different types of

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DGs. For example, for the MT, as the island main power source, its operation reference point includes voltage and frequency, and the synchronization between the island and the main network can be completed by the synchronous controller; for the ESS, as the controllable slave power source, the operation reference point is received by the main power source. The power output changes and does not have the ability to synchronize control; for PV, as the uncontrollable slave, its operational reference point is controlled by MPPT and runs in PQ control mode during the entire island operation[8-10].

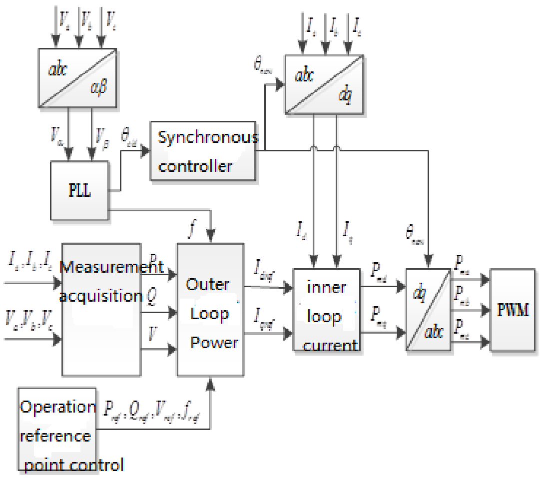

Fig.2 Framework of PWM/power-current double loop control

2.2. Main power control

The main power inverter control model is shown in Figure 3. The power outer loop provides the inner loop current reference value (and) to the current inner loop based on the input control variable and its reference value. The current inner loop is based on the reference value and the actual the inner loop current value (and) is made worse, and the PI link and the limiter link are sequentially passed, and the reference signal (and) of the phase angle of the control terminal and the voltage output of the terminal is input to the PWM. The seamless switching between the main power PQ control and the V/f control is achieved by the value switching of the four first-order proportional links (), as shown in equation

$$\begin{cases} (S_1, S_2, S_3, S_4) = (0,1,1,0) & \text{PQ} \\ (S_1, S_2, S_3, S_4) = (1,0,0,1) & \text{V/f} \end{cases} \quad (1)$$

When in the V/f control mode, the collected frequency is poorer than its reference value, and is used as a new d-axis active control reference value after the PI link. When the frequency decreases, it starts to increase, so that the active output

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of the inverter increases, achieving the purpose of frequency control. For q-axis control, the difference between the voltage and its reference voltage is used instead of the reactive power difference as the input to the q-axis PI control.

2.3. From power control

In the master-slave control mode, the slave power supply is still PQ controlled under the island operation, which is the same as the grid-connected operation mode. From the power supply can be divided into two categories, one is a controllable DG, as shown in Figure 1 ESS; the otherFor intermittent DG, as shown in Figure 1 PV. Since PV operates in MPPT mode, its output power changes with the change of illumination intensity, which is equivalent to a load of power change under island operation; while ESS is a controllable DG, under the coordination of the power controller, it can be based on the main power supply. The output power is varied to adjust the output power to provide power support for the island's island operation. This section presents a slave power reference point control model based on the mains output power variation (shown in Figure 3).

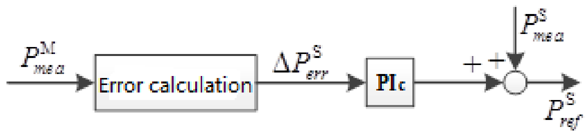

Fig.3 Block diagram of slave power reference control.

From the power supply power reference point control model, the power output of the current main power source is used as an input of error calculation, and the active power reference point of the slave power source is adjusted according to the real-time power output of the main power source. The error calculation is as shown in equations (11) and (12).

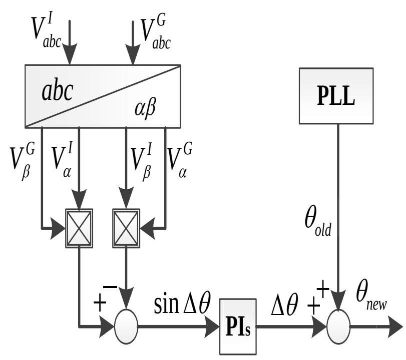

Fig.4 Block diagram of phase synchronization control.

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$$\Delta P_{err}^{\mathrm{S}} = \begin{cases} P_{mea}^{\mathrm{M}} - P_{trig}, P_{mea}^{\mathrm{M}} > P_{trig} \\ 0, P_{mea}^{\mathrm{M}} < P_{trig} \end{cases} \quad (2)$$

$$P_{trig} = k \cdot P_{\max}^{\mathrm{M}} \quad (3)$$

The significance of the control from the power supply reference point is: when the micro-network is connected to the island for switching, and the maximum output power of the main power cannot meet the power shortage of the island, the controllable power supply can adjust the power output to provide power to the main power supply in time support.

3. Case Analysis

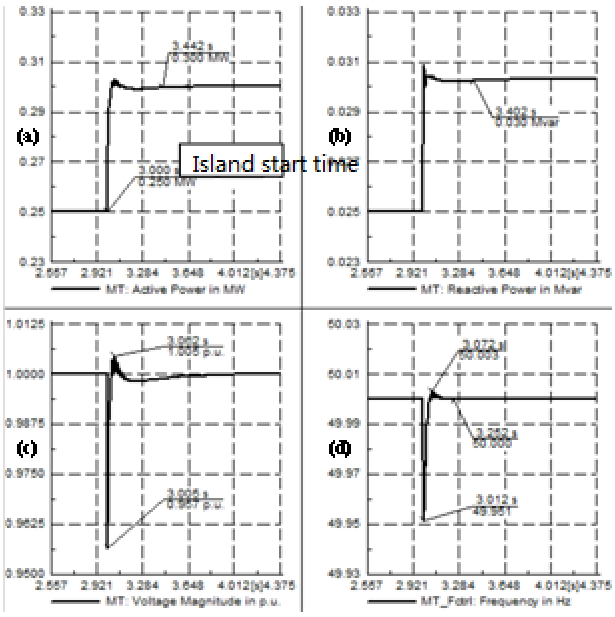

Fig.5 Seamless transient of MT from grid-connected operation to islanding operation: (a) Active power output of MT. (b) Reactive power output of MT. (c) Voltage output of MT. (d) Frequency of MT.

In this section, according to the microgrid structure of Fig. 5, the corresponding master-slave microgrid control model is built in DIgSILENT software, and the control effects of the controller model shown in the previous section are verified by three typical examples. Example 1 simulates the seamless switching process of the microgrid's grid-connected islands when the island power shortage can be completely borne by the main power source. The second example studies the

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seamless switching process of the grid-connected islands in the microgrid. When the island power shortage cannot be independently assumed by the main power source, the power supply from the power source to the main power source is supported. Example 3 shows the synchronization process of the island with the main network before the grid connection. The initial power of each DG and load in the calculation examples 1 and 2 are shown in Table 1 and Table 2, respectively.

3.1 Power support from the power supply

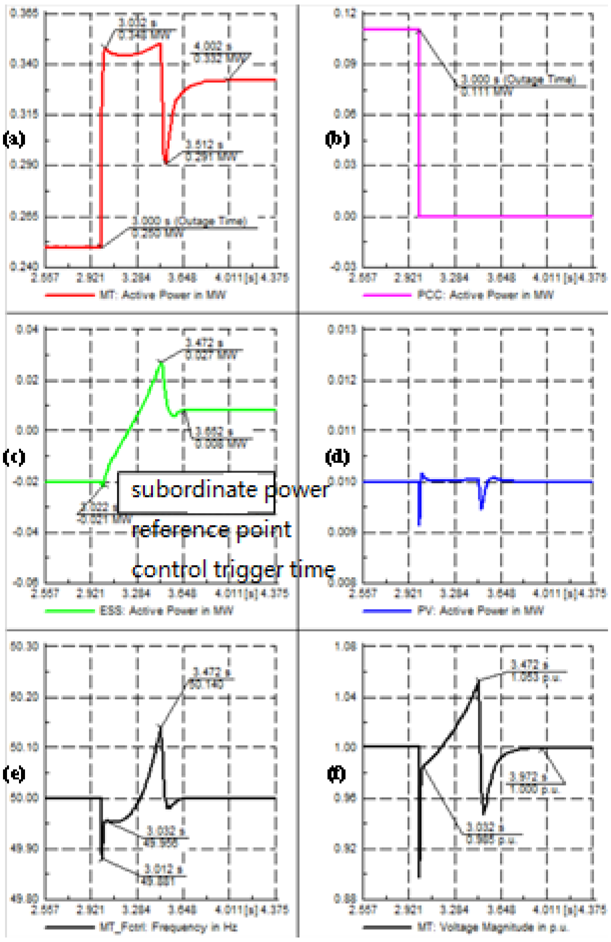

Fig.6 Islanding transient with slave power reference control: (a) Active power output of MT. (b) Exchange power on PCC. (c) Active power output of ESS. (d) Active power output of PV. (e) Frequency of MT. (f) Voltage output of MT.

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It can be calculated from Table 2 that the net load on the feeder has reached 0.36 MW, which exceeds the maximum rated output power of the MT (0.35 MW). If the microgrid is switched from an on-grid operation to an island operation at this time, the MT cannot fully assume the power shortage in the island, and the system will not be able to continue to operate stably, which may trigger the DG exit and load shedding protection. According to the power supply support strategy proposed in this paper, the ESS is a controllable DG. When the output power of the MT exceeds the set threshold, the ESS will trigger the power reference point control, and the output power will be changed at the moment of the island off-grid to assist the MT to make up. The current power shortage in the island. In the process of grid-connected islands of the microgrid, the power support effect of the ESS on the MT is shown in Fig. 6.

4. Conclusion

In this paper, the structure of master-slave microgrid power generation system with MT, ESS and PV is constructed. A reasonable seamless switching control strategy is designed for the problems encountered by the master-slave microgrid in switching between grid-connected operation and island operation. The following conclusions were drawn:

(1) Based on the master-slave microgrid system structure and MT as the island power source, this paper designs a seamless switching control strategy of MT from grid-connected operation to island operation. The simulation results show the built-in MT inverter control module. It has good dynamic response capability, can maintain system voltage and frequency stability after the formation of islands, and minimize the impact of micro-network operation mode switching on power quality.

(2) In view of the problem that the traditional master-slave microgrid has insufficient power support capability under the island operation, a power source reference point control method is proposed. When the main power supply cannot fully satisfy the island power shortage, the dynamic adjustment can be controlled. The power reference point of the power supply (such as ESS) can make up for the shortage of island power.

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