

Research on Virtual Impedance Anti Sag Control Technology Based On Multi Micro Source Low Voltage Microgrid

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Abstract. For low-voltage micro-grid systems with multiple micro-sources with different rated capacities, the performance of load power distribution in proportion to the capacity of micro-sources is very important to the stability and efficient operation of the system. The inverse droop control strategy has the problem of active power distribution error due to the unbalanced line impedance of micro-grid. The virtual impedance can suppress this error, but the traditional virtual impedance method will lead to large voltage sag. Therefore, a novel inverse droop control method with virtual impedance is proposed, which can realize the power distribution in proportion to capacity and ensure the stability of voltage and frequency. Finally, a low-voltage micro-grid system with six specific micro-sources is built on the PSCAD / EMTDC platform to simulate the multi-mode operation under Island / grid-connected mode, and the effectiveness of the control strategy is verified comprehensively.

1. Introduction

Microgrid is a small-scale power distribution system composed of a variety of distributed generators, energy storage systems, energy conversion devices, load and monitoring, protection devices. The micro-grid is an independent autonomous system which can realize self-control, protection and management.^[1] It can be connected to the grid system as a whole through the common connection point (PCC) and operates in two modes of islanding and grid-connected according to the demand of the grid system and user load^[2].

[3] A virtual negative impedance is introduced to make the total output impedance pure inductance, to counteract the resistive component of the system impedance and suppress the circulating current of the system. [4] Dynamic virtual impedance is used to improve the power quality with the variation of load current and voltage drop, but the unbalanced impedance is neglected. [5] A virtual impedance optimization method based on global reactive power equalization error minimization is proposed to solve the reactive power equalization problem in traditional droop control. However, the optimization calculation of the error function is complicated and the influence of virtual impedance on the output voltage is not considered. [6] Through the combination of voltage coarse-tuning and fine-tuning links to adapt to load power changes, so as to achieve power sharing and better power quality, but the paper does not consider the inverter rated capacity of different circumstances.



A novel inverse droop control method based on virtual impedance is proposed for a low voltage microgrid system with multiple microsources of different rated capacities, in which the load power is distributed proportionally according to the capacity and the output power quality is guaranteed under unbalanced circuit impedance. Based on the inverse droop control, a bus voltage amplitude feedback compensation term is introduced, which is also a virtual impedance method and can guarantee the power quality. Finally, a microgrid system is built on PSCAD / EMTDC platform, and the effectiveness of the proposed control method is verified by simulation analysis.

2. Structure and parameters of multi micro source microgrid system

For the simulation study of micro-grid control strategy, two inverters are usually used to equivalent the specific micro-source, and the capacity of the inverters is usually the same value. Such simulation system is too ideal and simplistic, which is not consistent with reality. In practical application, the micro-grid system contains many kinds of micro-sources with different capacities. The control between micro-sources needs to coordinate each other to make the system run stably as a whole. Therefore, a low-voltage microgrid system with six microsources and different capacities is constructed as shown in Fig. 1. The parameters in the system are shown in Table 1.

Table 1 Model parameters of microgrid system

ac bus	The rated line voltage is 380V, the phase voltage is 220V the rated working frequency is 50Hz
Photovoltaic micro source	PV1: capacity is 4kW PV2: capacity is 5kW PV3: capacity is 6kW
Battery micro source	BT1: capacity is 4kVAh (120V 58.4Ah). BT2: capacity is 4kVAh (120V 66.7Ah). BT3: capacity is 4kVAh (120V 75.0Ah).
Line impedance	380V, $R_L=0.642\Omega/km$, $X_L=0.083\Omega/km$ 10V, $R_L=0.06\Omega/km$, $X_L=0.191\Omega/km$
load	LOAD1:P=10kW,cos ϕ =0.90(Perceptual) LOAD1:P=10kW,cos ϕ =0.85(Perceptual) LOAD1:P=10kW,cos ϕ =0.92(Perceptual)

In this paper, photovoltaic devices with intermittent energy sources and batteries with stable energy sources are selected as micro-sources. Each micro-source adopts two-stage grid-connected mode, photovoltaic cell-connected DC/DC converter adopts MPPT control method, battery-connected DC/DC converter adopts constant voltage control method. Because we want to study the peer-to-peer control strategy, all the micro-source DC / AC inverters adopt the proposed anti-droop control method in Island / grid-connected operation mode. The specific parameters required for anti sag control are shown in Table 2. In order to verify that the proposed control method can solve the power allocation problem caused by unbalanced line impedance, the line length between each micro-source and PCC is different.

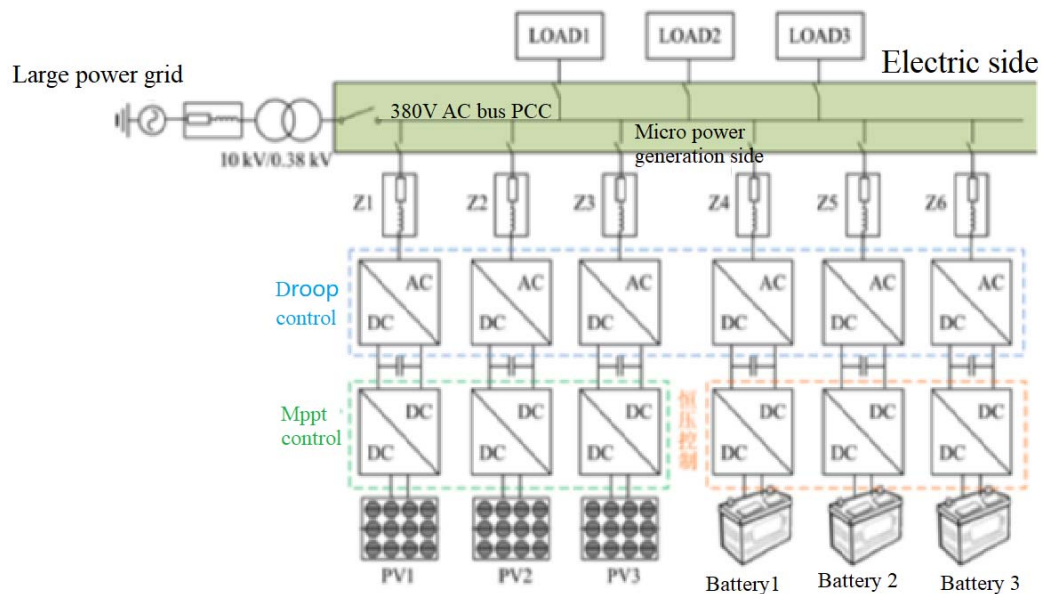


Fig. 1 System structure of microgrid with multiple micro sources

Table 2 Droop control parameters of each DG

Micro source	Capacity ratio	P_i^*/kW	$P_{pi}/(kV/kW)$	$Q_i^*/k\text{ var}$	$k_{qi}/(Hz/k\text{ var})$	Line length
PV1	4	2.051	0.0024	1.132	0.006	0.6
PV2	5	2.564	0.00192	1.415	0.0048	2.0
PV3	6	3.077	0.0016	1.698	0.004	1.2
BT1	7	3.590	0.00137	1.982	0.00343	0.8
BT2	8	4.103	0.0012	2.265	0.003	1.6
BT3	9	4.615	0.001067	2.548	0.00267	1.0
Total rated power		$P = 20kW, Q = 11.04k\text{ var}$ (That is the sum of <i>LOAD1</i>				
V_i^*, f_i^*		380V, 50Hz				

3. Simulation and analysis

3.1. Simulation and comparison of load variation based on isolated island mode

In island mode, the microgrid is disconnected from the large power grid and operates independently. It is necessary for the microgrid to automatically participate in the output power distribution according to its capacity and provide voltage and frequency support.

The improved inverse droop control method in this paper and the traditional virtual impedance method in reference are used to simulate and compare. The simulation process is as follows: Load *LOAD1* and *LOAD2* are put into operation in 0-2 s, Load *LOAD3* is added in 2 s, Load *LOAD3* is removed in 3 s, and the total simulation time is 4 s.

The simulation results under the two methods are shown in figures 2 and 3. Comparing the two diagrams, it can be found that: 1) when adopting the improved inverse droop control method, the active power and reactive power of the micro-source can be output according to the set capacity ratio of 4:5:6:7:8:9, which is not affected by unbalanced line length. When the traditional virtual impedance method is used, the reactive power can be output in proportion to the capacity, but the output proportion of the active power does not conform to the capacity ratio. 2) The frequency, voltage

amplitude and load power of the two methods are in accordance with the inverse droop control equation (eq. (3)). When the load power increases, the frequency rises while the voltage amplitude decreases. When the load decreases, the situation is opposite. 3) The operating frequency of the traditional virtual impedance method fluctuates more than that of the improved inverse droop control, both of which are within a reasonable range of variation. 4) Because of the extra voltage drop caused by the virtual impedance, the voltage amplitude at the PCC is far less than the rated value, so it is necessary to raise the voltage by modifying the sag characteristic curve. The voltage amplitude of the improved anti sag control can meet the requirements of power quality.

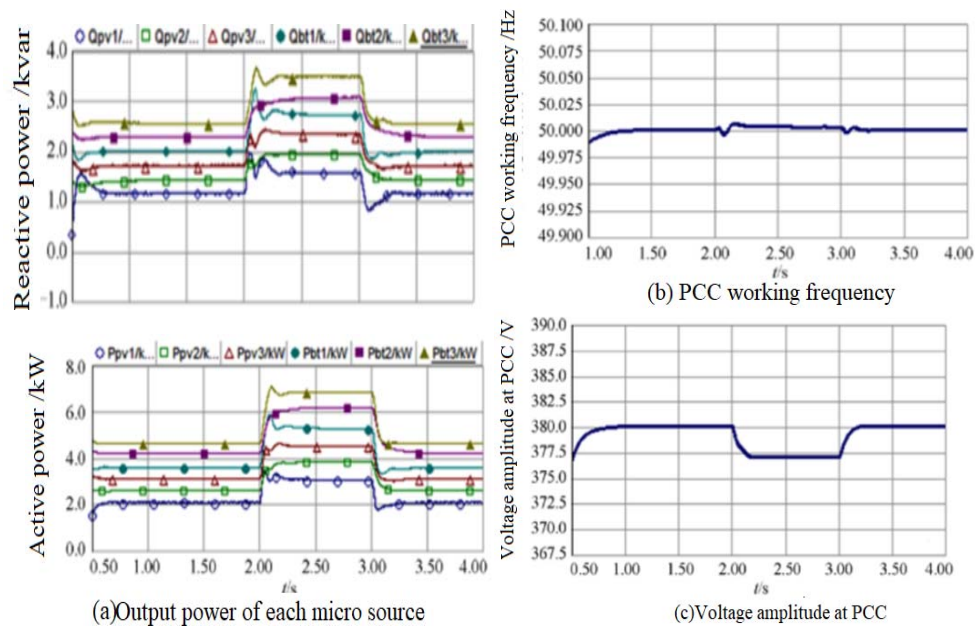


Fig. 2 Simulation results of loads changes in the islanding mode (under improved droop control method)

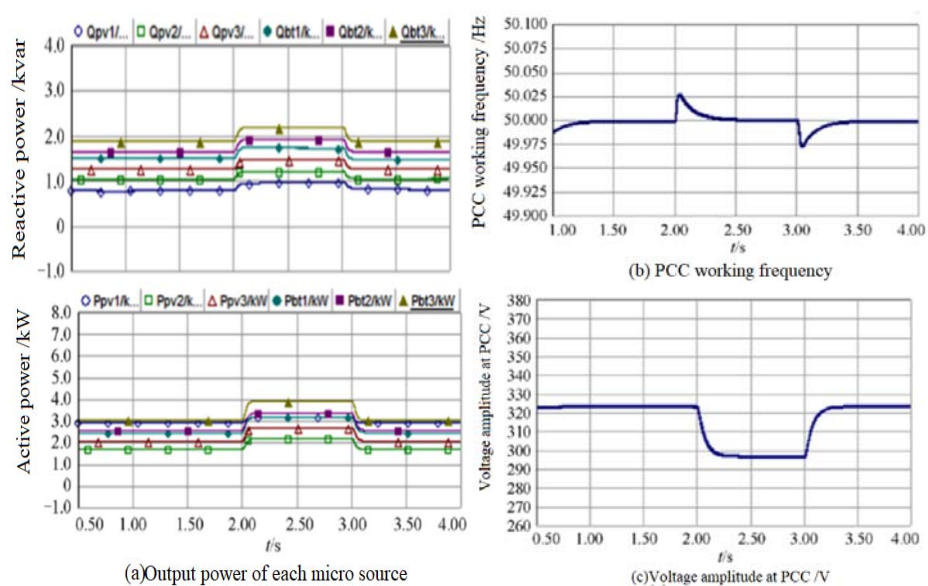


Fig. 3 Simulation results of loads changes in the islanding mode (under traditional virtual impedance method)

The simulation results show the effectiveness of the improved anti droop control method under load variation conditions. Compared with the traditional virtual impedance method, the improved control method can realize load power distribution according to capacity proportion under unbalanced line impedance, and ensure certain power quality and frequency stability.

3.2. Simulation of micro source exit under isolated island mode

When the photovoltaic micro-source is affected by external factors can not work normally and the battery discharge is complete, it is necessary to withdraw from the micro-grid in order to prevent the impact on the overall operation. The operation of improving anti sag control under this working condition is the following simulation contents.

The simulation process is as follows: all six micro-sources are put into operation within 0-2 s, BT1 micro-sources exit at 2 s, PV2 micro-sources exit at 3 s, and the total simulation time is 4 s.

The simulation results are shown in Figure 4. As shown in Figure 4 (a), when a micro-source exits, the power part it should bear will be allocated to the remaining micro-source, and the remaining micro-source will redistribute the output power according to the original set capacity ratio. As shown in Fig. 4 (b) and Fig. 4 (c), the variation of frequency, voltage amplitude and load power still conforms to the inverse droop control equation, and the variation range of frequency and voltage amplitude still meets the requirements of power quality.

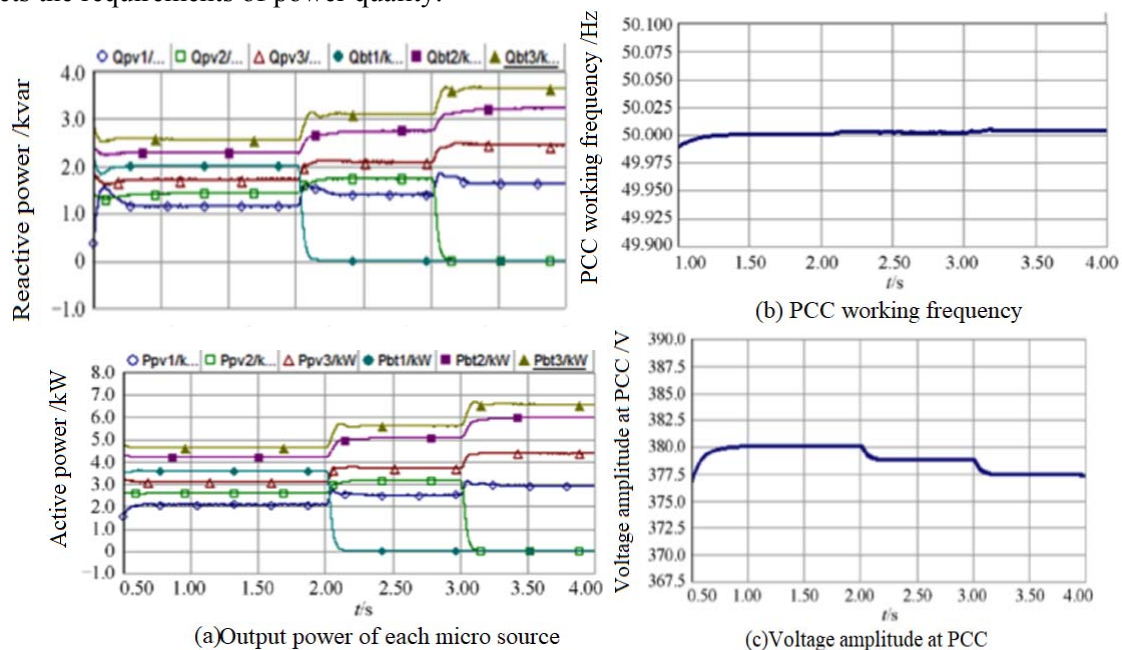


Fig.4 Simulation results of DGs excision in the islanding mode (under improved droop control method)

The simulation results show that the improved inverse droop control method allows the micro-source to exit halfway without affecting the overall normal operation. It shows that the peer to peer control strategy has the function of plug and play.

3.3. Simulation in grid connected mode

In the grid-connected mode, the large grid provides voltage and frequency support to undertake the power changes of the system; as an auxiliary unit, the micro-grid meets certain power supply requirements through coordinated control of the micro-sources under its jurisdiction.

In order to facilitate the study, the load change, micro-source exit and light intensity change are placed in the same grid-connected simulation process: 0-1 s is pre-processing before grid-connected, 1 s is grid-connected; 0-2.5 s light intensity is 1000W/m², load LOAD 1 and LOAD2 are put into operation, 2.5 s light intensity is reduced to 800W/m²; 3 s is added load LOAD3. At 4 S, the load is

LOAD3; when the battery is 4.5 s, the battery BT1 and the PV cell PV2 are removed. The total simulation time is 5.5 s.

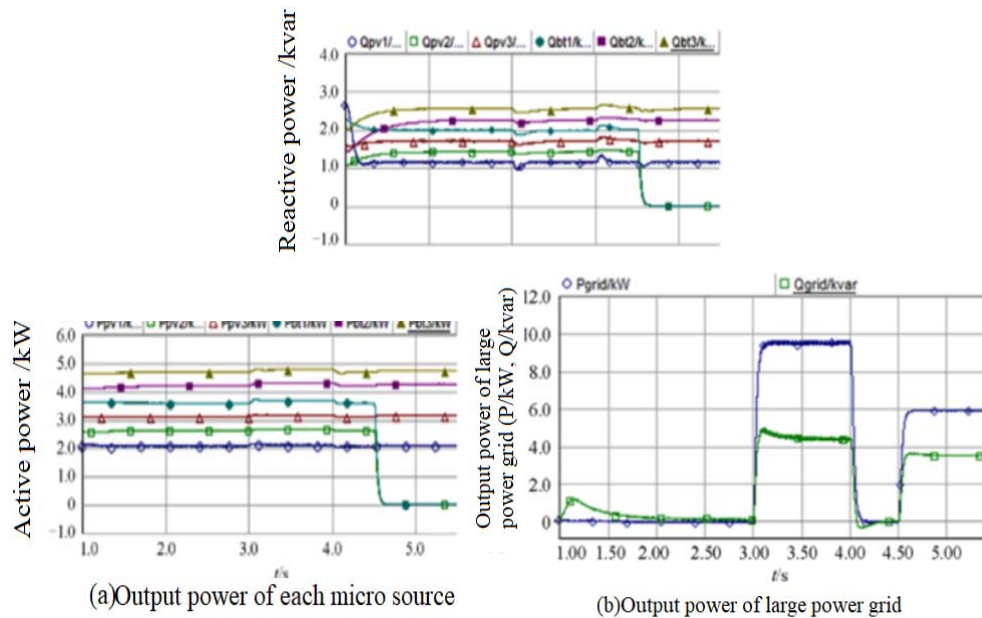


Fig. 5 Simulation results from the grid-connected mode under improved droop control method

The simulation results are shown in Figure 5. Figure 5(a) shows that all the micro-sources operate near the rated power in the grid-connected operation mode, and are not affected by light intensity and load changes, except for the output power of the exiting micro-sources drops to zero. Figure 5 (b) shows that when the output power of the micro-grid meets the load demand, the output power of the large power grid is zero, and the power fluctuation caused by load variation and micro-source withdrawal is assumed by the large power grid. The simulation results show that the improved inverse droop control method is effective in grid-connected mode, which can ensure the output power of each micro-source to be carried out according to a given operation plan (set rated power), and share a certain amount of power output. The part beyond the plan will be borne by the large power grid, thus reducing the power burden of the large power grid.

4. Conclusions and Prospects

A novel inverse droop control method with virtual impedance is proposed for a low voltage microgrid system with multiple microsources of different rated capacities. Based on the inverse droop control, the bus voltage amplitude feedback compensation term is introduced, which solves the problem of active power proportional distribution caused by unbalanced line impedance and ensures the stable control of voltage and frequency. Simulation results show that the proposed control strategy has certain reliability in island mode (load change, micro-source exit) and grid-connected mode. But the inverse droop control is essentially a kind of difference control method. It still needs two or more adjustments of voltage and frequency to achieve voltage and frequency stability, which is a further research task.

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