

Research on Active Control Strategy of Grid Connected Harmonic Current Based on Hierarchical Control for Microgrid

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Abstract. The micro grid connected in parallel with the traditional droop controlled voltage source inverter is easily affected by the disturbance of the harmonic component of the grid and the dot voltage when the equivalent output impedance is smaller. The total harmonic distortion rate of the grid connected current is raised. An active lifting control strategy for grid connected current power quality based on layered control is proposed. First, the Park transform is used to transform the error voltage between the node and the micro grid AC bus to the rotating coordinate system, and the error voltage compensation loop is added to the two layer control of the original microgrid, and the parallel connection in the compensation loop is used. The multiple resonant controller calculates the error voltage, obtains the harmonic voltage compensation of the underlying voltage source inverter, and uses the proportional integral and resonant hybrid controller based on the rotating coordinate system in the voltage and current inner loop of the inverter to improve the tracking ability of the inverter to the harmonic voltage compensation, and then reduce the micro grid. The harmonic voltage difference between the AC bus and the parallel node reduces the harmonic current injected into the grid by the microgrid. The analysis shows that the control strategy described in this paper can not only reduce the steady-state harmonic current injected into the power grid, but also reduce the harmonic current impact of the grid to the micro grid because of the closing of the grid switch. Finally, the effectiveness of the proposed control strategy is verified by simulation and experiments.

1. Introduction

The microgrid consisting of a droop controller has a small external equivalent output impedance, so the microgrid system can be equivalent to a controlled voltage source [1, 2] when the microgrid is in parallel with the grid. Although the related problems in parallel operation of microgrid and large power grid have been expounded in the existing literature, the parallel operation of the micro grid and the ideal power grid is the model. However, the voltage source grid connected inverter [3] has the same output impedance. Document describes the harmonic current suppression strategy in parallel operation with the distorted grid. The harmonic components in the dot voltage are extracted by the sliding discrete Fu Liye transform (Sliding Discrete Fourier Transform, SDFT), [4, 5] and the harmonic voltage is fed to the



inner loop of the voltage source grid connected inverter, and the multiple PR controller is adopted. The voltage source grid connected inverter is injected to inject harmonic current into the power grid. However, in large isolated power grids, frequency fluctuations will reduce the voltage tracking performance of the inverter. Therefore, in document [6], a hybrid voltage current control method is proposed to reduce the injection of harmonic current from the grid connected inverter to the grid when the frequency fluctuation of the power grid is fluctuated.

2. Active suppression strategy of harmonic current in micro grid

2.1. Principle analysis

The control block diagram of active control strategy for grid connected grid based on hierarchical control is shown in Figure 1. The bottom of the microgrid consists of a droop control voltage source inverter running in parallel. The two level control and three level control of microgrid are connected with the underlying inverters through communication. The microgrid AC bus is connected with the power grid PCC through the grid switch, so when the power grid fails, the microgrid can carry out the island operation to improve the reliability of the power supply to the sensitive load. When the power grid work is normal, the power and reactive power can be injected into the power grid to support the power grid. At the same time, the voltage, current base frequency and harmonic component needed in the two and three layer control are generated by the sampling signal which is different from the central resonant frequency.

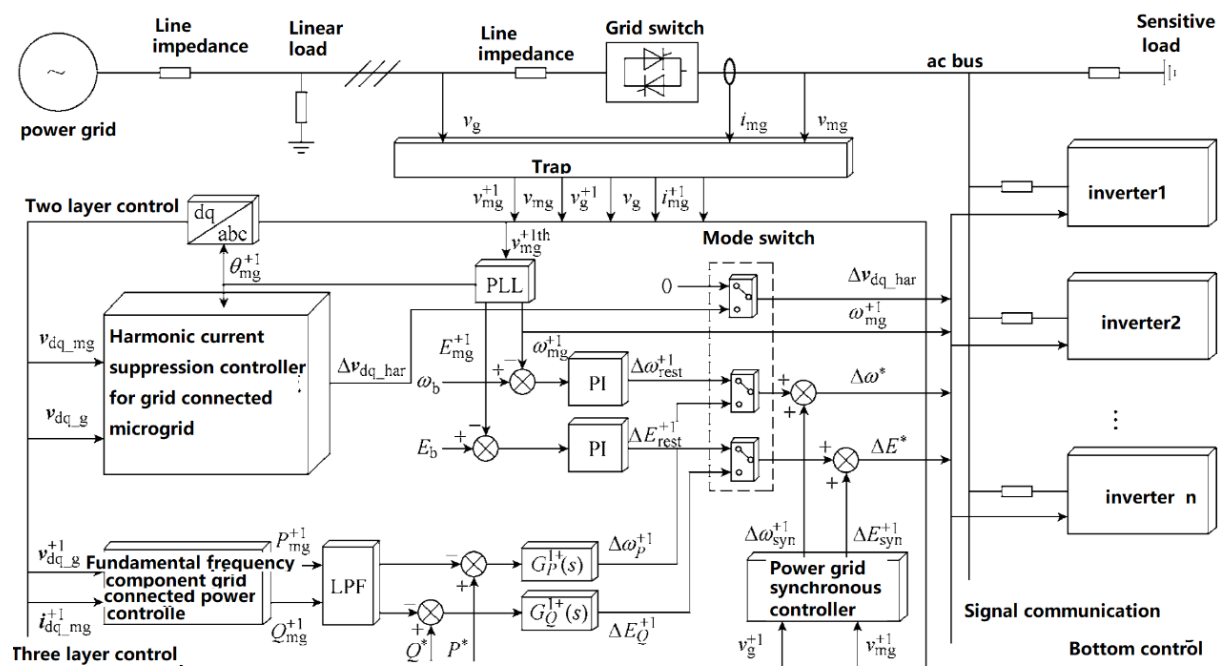


Figure 1. The control scheme of the proposed strategy based on the hierarchical control

One of the main functions of the two layer control of the traditional microgrid is to restore the voltage frequency and amplitude deviation of the AC bus voltage of the micro grid caused by the droop control of the bottom inverter, and the other function of the two layer control is before the parallel operation of the microgrid and the power grid.

The AC bus voltage of the microgrid is synchronized with the PCC voltage of the power grid. The two basic functions of the above two levels of control have been discussed in detail in the relevant literature. However, when microgrid and malfunction

When the power grid is operated in parallel, the type (3) can know that the transient response of the grid connected current after the closing of the grid switch, or when the parallel operation of the microgrid and the grid reaches steady state, the communication of the microgrid.

The harmonic voltage difference between bus and PCC will affect the grid connected current of microgrid. When the grid switch is closed, the harmonic voltage

The harmonic impact current $i_{inrush}^{\pm n}(t)$ of microgrid caused by difference is estimated.

$$R_{equ} i_{inrush}^{\pm n}(t) = -I_m \sin \varphi_i e^{\frac{R_{equ}}{L_{equ}} t} + I_m \cos(\omega_{har}^{\pm n} L_{equ}) \quad (1)$$

In the formula, R_{equ} and L_{equ} are equivalent line impedance; $V_g^{\pm n}$ is n sub harmonic voltage peak; $\omega_{har}^{\pm n}$ is the angular frequency of n sub harmonic component.

After the parallel operation of the microgrid and the distorted grid reaches steady state, the gain of the voltage transfer function at the harmonic frequency component can be enhanced even if the conventional multiple proportional resonance (PR) controller is adopted in the outer voltage loop of the underlying inverter. However, because of the traditional microgrid bottom control only sampling the local voltage, the PCC harmonic voltage information of the power grid cannot be obtained. Therefore, the current distortion of grid connected microgrid is still difficult to avoid. To solve the above problems, a microgrid AC bus and PCC harmonic error voltage controller can be added to the two level control of the original microgrid, as shown in Figure 2.

The voltage components of the N secondary positive or negative sequence harmonic components are converted to n-1 or n+1 sub harmonic components after the Park conversion of ω_b frequency. Therefore, in the proposed control, the parallel resonant controller with resonant frequency of $2\omega_b$, $4\omega_b$ and $8\omega_b$ is used to calculate the basic frequency negative sequence, the 5 positive sequence and the 7 negative sequence components in the power grid, and the resonant frequency is A, and the 5 negative sequence and the 7 positive sequence components are performed at the same time.

$$G_{r_sec}(s) = \sum_{n=2k} G_{r_sec}^n(s) = \sum_{n=2k} \frac{k_{r_sec}^n s}{s^2 + (n\omega_0)^2} \quad (2)$$

3. Simulation and experimental verification

3.1. Experimental verification

In order to verify the effectiveness of the proposed control strategy, a microgrid experimental platform based on real-time dSPACE controller is built. The platform consists of two 2.2kW three-phase inverters, LfCf filters, line impedance and load.

Figure 2 is a distorted grid voltage test waveform. The harmonic analysis of the sampled data of the three-phase voltage shows that the negative sequence, the 5 positive and negative sequence and the 7 positive and negative order harmonic components are also included in the analog distorted grid except the positive sequence component of the fundamental frequency, as shown in Figure 3.

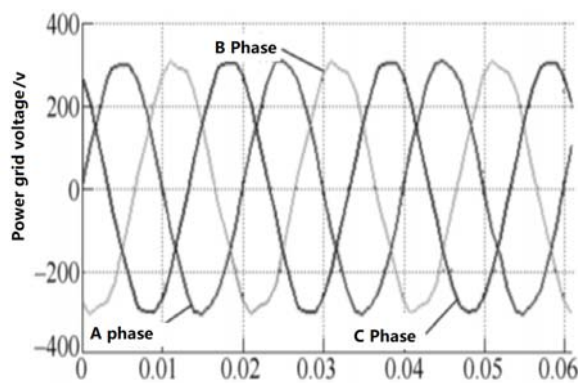


Figure 2. The experimental waveforms of grid voltage at PCC

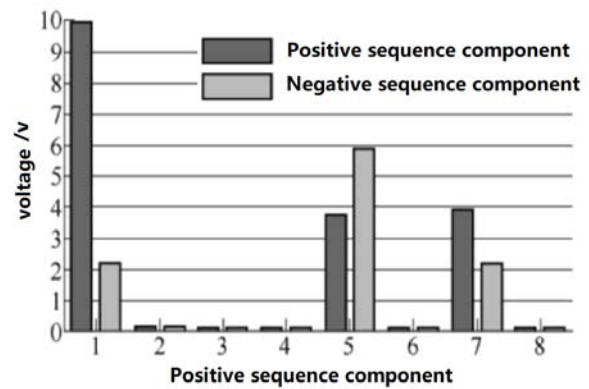


Figure 3. The harmonic analysis of PCC's voltage

In Figure 4, after the synchronous control loop in the two layer control of the microgrid and the active suppression loop of the harmonic current, the voltage error of the PCC in the microgrid AC bus and the analog power grid can be measured. It can be seen from the diagram that the harmonic voltage components on both sides of the grid switch are also synchronized, so that the voltage components on both sides of the grid switch are also synchronized. The harmonic current impact caused by the closing of the grid connected switch is less than that of the microgrid.

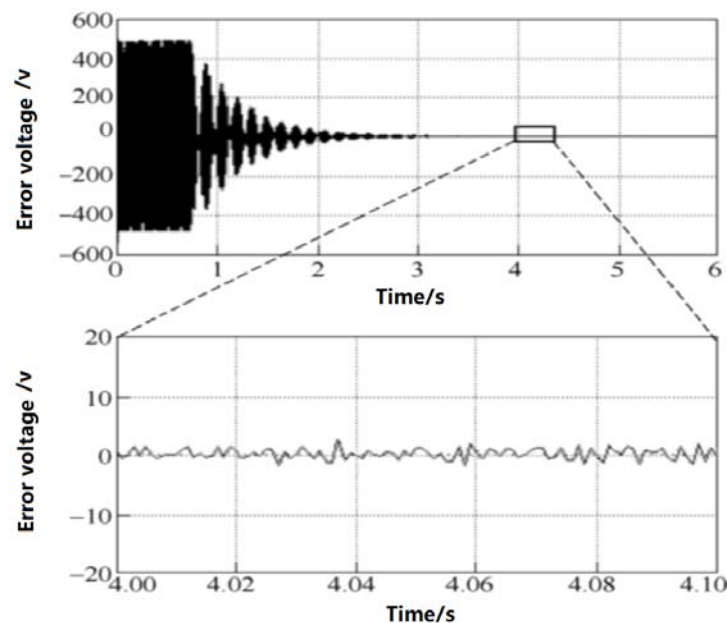


Figure 4. The experimental waveforms of error voltage between PCC and the bus of microgrid (improved)

The analysis of the current waveform and harmonic current of the system is shown in Figure 15 when the micro grid and the distorted grid are in parallel with the traditional hierarchical control strategy and reach the steady state.

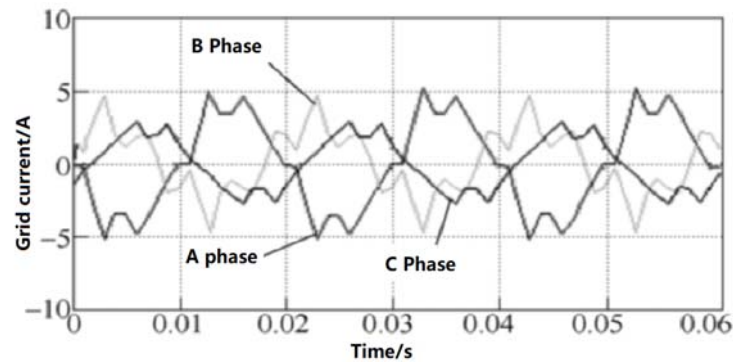


Figure 5. The experimental waveforms of grid-connecting current (conventional)

As can be seen from Figure 5, the harmonic content in the grid current of the microgrid is high. By analysing the harmonic content in the grid current, the negative sequence of the fundamental wave, the 5 positive and negative sequence and the 7 positive and negative harmonic currents in the grid current can be obtained, as shown in Figure 6.

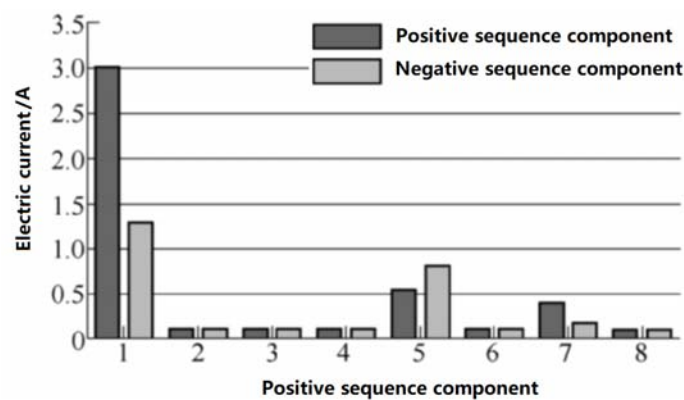


Figure 6. The harmonic analysis of grid-connecting current (conventional)

Table 1. The harmonic analysis based on experimental result

Harmonic	Net side voltage/V	Pre improvement		After improvement	
		Bus voltage /V	Grid current /A	Bus voltage /V	Grid current /A
Positive sequence of fundamental wave	310.02	311.89	3.03	311.89	3.02
Fundamental negative sequence	2.22	1.26	1.28	2.78	0.29
5order positive sequence	3.78	0.45	0.54	3.79	0.02
5order negative sequence	5.87	0.71	0.81	5.83	0.01
7order positive sequence	3.9	0.26	0.4	3.97	0.01
7order negative sequence	2.21	0.75	24.86	3.1	0.01
THD (%)	3.09	0.75	24.86	3.1	4.28

Similar to the simulation results, when the active grid harmonic current control strategy proposed in this paper is adopted in this paper, the sine degree of the grid connected current is obviously improved and the harmonic content is reduced, the detailed experimental data and analysis are shown in Table 1.

4. Conclusion

In this paper, a hierarchical control strategy based harmonic current suppression strategy based on hierarchical control strategy is proposed for the microgrid grid connected system composed of droop parallel voltage source inverters. This strategy adds a micro grid bus voltage and PCC error voltage control loop to the two layer control of the original microgrid, and uses multiple PR controllers to calculate the error voltage. The harmonic voltage compensation of the bottom inverter is obtained, and the harmonic voltage is tracked by the voltage loop of the underlying inverter. After reducing the voltage difference between the bus voltage and the PCC point harmonic voltage, the harmonic current content of the microgrid is reduced to the grid under the voltage distortion of the power grid. The theoretical analysis shows that the proposed control strategy can not only reduce the harmonic current content of the grid connected system when the grid connected system reaches the steady state, but also reduce the opening of the grid connected to the grid. Finally, the impact of harmonic current on the microgrid after closing the power grid is closed. Finally, the effectiveness of the proposed control strategy is verified by simulation and experiment.

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