Research on Harmonic Suppression Technology of new energy microgrid based on hybrid filter

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Abstract : Harmonic pollution and overshoot caused by the use of nonlinear load in microgrid. In order to solve this problem, the causes are analyzed and the suppression strategy is proposed. The method based on super-twisting sliding mode control algorithm combined with active and passive filter is adopted. The traditional PI controller is replaced by super-twisting sliding mode control. Through the SIMULINK simulation software in MATLAB, the voltage, FFT and THD waveforms of the method of combining super-twisting sliding mode control algorithm with active plus passive filter and the method of combining PI controller with active plus passive filter are compared and analyzed. The simulation results show that the method of combining the super-twisting sliding mode control algorithm with the active and passive filter reduces the harmonics in the microgrid, improves the robustness, and is not easy to cause overshoot in the control process, which ensures the continuity and stability of the microgrid grid connection.

Key words: Microgrid; Harmonic suppression; Sliding mode control

Introduction

With the increase of energy demand, it has become an inevitable trend to make full use of distributed power generation .Compared with traditional centralized power generation, distributed power generation has many advantages, such as reducing power loss, reducing greenhouse gas emissions, flexible voltage regulation, peak and voltage regulation, improving power quality and power supply reliability. Large-scale distributed power interconnection makes microgrid a powerful supplement and effective support for large-scale power grid. Therefore, one of the development trends of our electric power system is the construction of distributed power generation grid connected and micro-grid system.It is worth noting that the safe and reliable operation of distributed energy microgrid is an important prerequisite .However, the microgrid is close to the load, so it is easy to be affected by the load. The increase of unbalanced load and nonlinear load will affect the power quality of the whole microgrid. In severe cases, the microgrid system itself will collapse, causing the control system to lose control, and affecting the voltage and frequency of the distribution network. DG in microgrid requires various power electronic devices, especially inverters, to convert DC power to three-phase AC power. These power electronics produce considerable harmonic currents. At the same time, reactive load also exists in microgrid .More seriously, some DG devices also require inductive reactive power, such as wind turbines, which can lead to severe voltage fluctuations. These problems lead to the abnormal operation of sensitive equipment and the power quality of microgrid is not ideal. Sometimes the microgrid doesn't even work properly.

Therefore, improving the power quality of the microgrid is a key issue. Traditionally, microgrids use power filters. Wave (PF) or static var compensator (SVC) to improve power quality. Filters are used to screen harmonic signals, mainly using active and passive types, namely APF and PPF . In Reference , the traditional PI control of APF has poor tracking ability for harmonic signals and cannot obtain better compensation effect. Reference proposed the improvement of active filter and PPF power quality. Reference proposed a combination of neural network and PID algorithm to improve the anti-interference ability and adaptive ability. As one of the commonly used control methods, the sliding mode control method is characterized by nonlinearity and independence. Independence means that the method is not affected by the mathematical model of the object, and the parameter recording efficiency of the performance is high, and its robustness has obvious outstanding characteristics .

Considering the actual situation, for the filter system, this paper adopts a hybrid filter usage scheme . In this new combined system, based on the mathematical model of hybrid filter, a control strategy based on super-twisting sliding mode control algorithm is designed. The super-twisting method is used to reduce the influence of jitter, and the wavelet packet transform is used to realize the detection of specific harmonic current . The improved hybrid filter mainly alleviates the harmonics of the load and compensates the reactive power of the load to maintain the voltage stability near the load, thereby reducing the power loss of the transmission line.

1. The basic structure and harmonic detection analysis of microgrid

1.1 basic structure of microgrid

In the microgrid system, the most important part is the distributed generation device and a variety of energy storage, protection, converter and other devices, and the distributed generation such as photovoltaic cells, fuel cells and other components of the microgrid is also important. The microgrid of the system is composed of distributed power and loads, in which distributed power includes photovoltaic cells and wind turbines. The photovoltaic array is connected to the distribution network through photovoltaic inverter, and the direct drive wind turbine is connected to the power frequency AC bus through rectifier inverter device and transformer. Its topology is shown in Figure 1. These different components and components jointly supply power to different loads. Compared with the large grid, the microgrid is an independent overall network. Generally, it is connected with the large grid through a circuit breaker, which can improve power quality and contribute to power peak shaving.

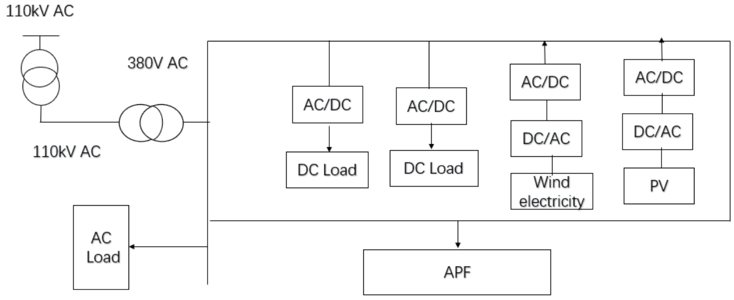

Figure 1 microgrid topology structure

1.2 harmonic detection and analysis

The harmonic of the system needs to be detected and managed to ensure the stable transmission of the system signal. In this paper, the instantaneous reactive power detection method is used to detect the harmonic. Its detection principle is to use the instantaneous harmonic to $i_p - i_q$ Check as shown in Figure 2.

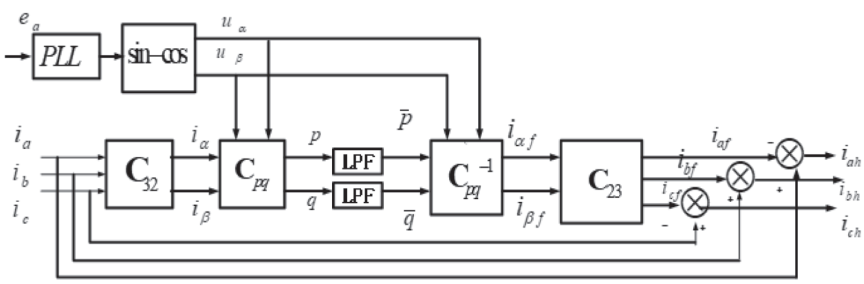

Figure 2 $i_p - i_q$ Schematic diagram of detection method

Figure 2 is based on the method of instantaneous reactive power theory $i_p - i_q$ .The phase of the a-phase voltage of the power grid is obtained by the phase-locked loop (PLL) module, and the conversion value of the three-phase input current signal is calculated by combining the corresponding sine parameters and cosine parameters. The coordinate conversion method is adopted for calculation, and the conversion coordinate is $\mathbf{C}_{32}$ 、 $\mathbf{C}_{pq}$ .Finally get i_p 、 i_q ,That is, instantaneous active current and reactive current. Using LPF module to filter out high-order harmonics and obtain basic components $i_{p\_}$ 、 $i_{q\_}$, and finally through inverse coordinate transformation $\mathbf{C}_{pq}^{-1}$ 、 $\mathbf{C}_{23}$ After that, the component size of the fundamental current of the transformed phase number is counted, and the harmonic current is obtained by subtracting the total current and the fundamental current parameters.

2 Harmonic suppression of microgrid based on hybrid filter

2.1 structure analysis of hybrid filter

As mentioned above, considering the actual situation, this paper adopts a hybrid filter usage scheme for the filter system. The components of the system mainly include filter HPF, harmonic detection, control circuit , buffer circuit and other multi-functional modules. In the four modules, the harmonic detection and control circuit is the most important part. The RLC passive filter is connected to the input of the active filter, and its schematic diagram is shown in Figure 3.

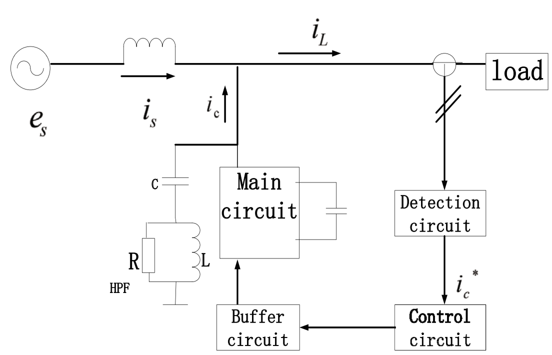

Fig. 3 working principle of hybrid filter

It can be seen from figure 3, e_s represents the potential of AC power supply, i_s represents the current of AC power supply, and the load is a harmonic source, which reduces the power factor of the system and generates harmonics, i_L is the load current. i_c for compensation current, i_c^* HPF is the command signal of compensation current, and HPF is the high pass filter. Firstly, RLC filter is used to filter the micro grid harmonics, and then APF is used to filter the remaining harmonics, which can reduce the capacity of energy storage unit C1 in APF, reduce the volume of APF part, and have better harmonic control effect. Among them, harmonic detection and current tracking monitoring are designed, current hysteresis control measures are adopted to realize current signal monitoring, and harmonic compensation current is controlled through signal conversion device and transformation process.

2.2 active power filter control

2.2.1 DC side voltage control strategy

In this paper, the control scheme of the converter is designed to control the voltage parameters of the DC side. When the compensation current is generated in the converter, the active current will be supplied at the capacitor to ensure that the voltage and capacitance of the circuit maintain the corresponding balance . Given voltage value at DC side of active power filter U_{dc}^* subtract actual value U_{dc} .The difference is sent to the PI regulator, and the result is the change of instantaneous active current, as shown in Figure 4. The operation principle of PI controller is relatively simple, and the accuracy of test operation meets the requirements. However, compared with the test of uncertain system, its robustness is not outstanding. To solve this problem, this paper tests the uncertain system by setting the system overshoot and using the super spiral sliding mode control algorithm to replace the PI controller. As shown in Figure 5, this method has fast response speed, good robustness and is not easy to cause overshoot in the control process.

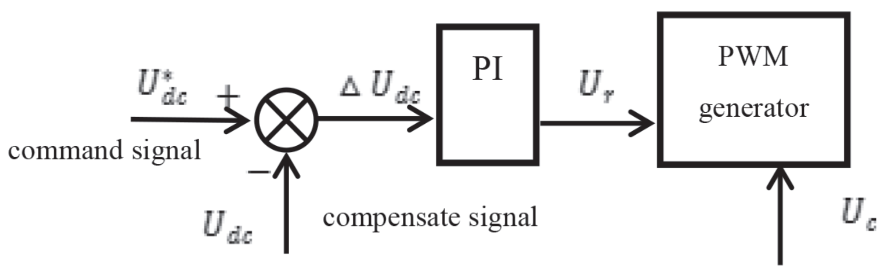

Figure 4 control by PI

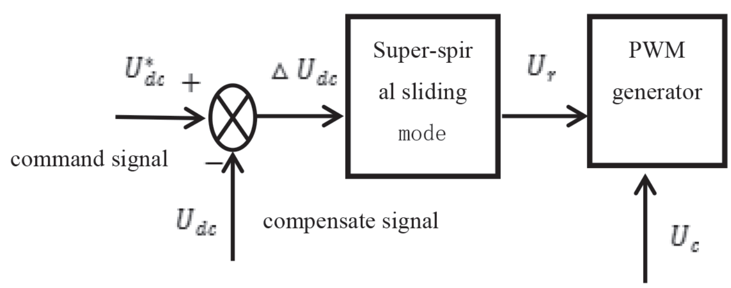

Fig. 5 control using super spiral sliding mode algorithm

According to the note in the figure: given a signal U_{dc}^* 、 actual voltage value U_{dc} 、 voltage difference U_{dc} 、 input voltage values U_r 、 output voltage value U_c .

2.2.2 super spiral sliding mode control

Sliding mode control virtualizes the differential signal of the actual input as a new control variable, integrates the virtual control variable to the actual control input, which is continuous. The sliding mode variable is ensured by virtual control s .It can converge to zero, so as to effectively weaken the chattering of the system.

The controller equation is:

$$\begin{cases} \dot{u}(t) = -\varepsilon sign(s) \\ u(t) = u_1(t) + u_2(t) \\ u_1(t) = -\int \varepsilon sign(s) dt \\ u_2(t) = -k|s|^{\rho} \end{cases} \quad (1)$$

Where k、ε ρ is the parameter of the controller, s is the sliding mode variable, where $\rho = \frac{1}{2}$,The super spiral sliding mode control law is obtained:

$$u(t) = k|s|^{1/2} sign(s) + \int \varepsilon sign(s)dt \qquad (2)$$

3 Simulation Analysis

In order to verify the control effect of hybrid filter using super spiral sliding mode control, the relevant parameters are shown in Table 1:

Table 1 relevant parameters

Basic parameters of photovoltaic system model	Basic parameters of PMSG model for permanent magnet direct drive wind turbine
Rated voltage: $P_N = 30KW$	Rated voltage: $P_N = 30KW$
Peak power: $P_m = 103.4W$ Short circuit current: $I_{SC} = 63.3A$ Maximum power point current: $I_m = 59.1A$ Open circuit voltage: $I_m = 59.1A$ In boost $L = 9e-5H$、$C_1 = 0.5mF$ $C_2 = 20e-6F$、$R = 10\Omega$ Ambient temperature: $T = 25$℃ Initial light intensity: $S = 600W/m^2$ when t=0.5s , S=1000W/m^2	Wind turbine parameters: wind wheel radius: R=4m, moment of inertia: $J = 12kg \cdot m^2$,air density: $\rho = 1.29kg / m^3$ Rated wind speed: $V = 12m / s$ Stator axis d and q, inductance: $L = 1000mH$, stator winding: $R_S = 0.02\Omega$, polar pairs: $n_p = 6$ Rated speed: $\omega = 6.075rad / s$ Initial wind speed: $V = 6m / s$, When t=0.5s, $V = 12m / s$ Some parameters of inverter: DC bus voltage: $U_{dc} = 700V$, DC side capacitance: $C = 1700 \times 10^{-6} F$ Parameters of power grid: rated voltage: $U_{abc} = 380V$ Rated frequency: $f = 50Hz$, filter inductance: $L = 6mH$

In order to verify the effectiveness of the hybrid filter using super spiral sliding mode control, a photovoltaic wind microgrid simulation model is built in MATLAB, and the harmonic compensation effect of hybrid filter with PI control and super spiral sliding mode control is simulated and analyzed. Figure 6 shows the DC phase voltage compensated by the PI control method, and Figure 7 shows the DC phase voltage compensated by the super spiral sliding mode control method. The overshoot of the latter is small and the voltage near the load is kept stable.

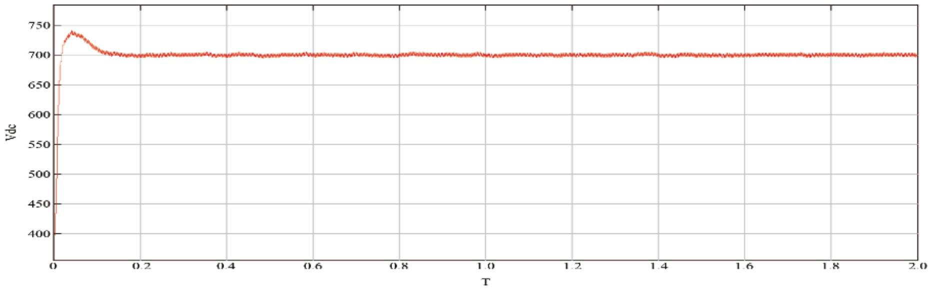

Figure 6 DC phase voltage after PI control compensation

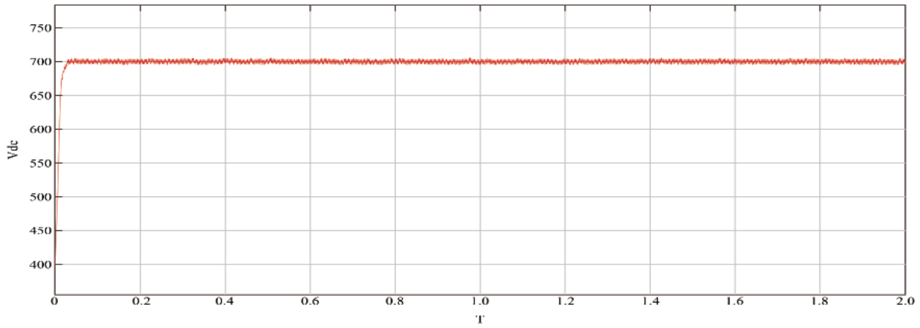

Fig. 7 DC phase voltage compensated by super spiral sliding mode control

Figure 8 shows the FFT analysis using PI control method, and Figure 9 shows the FFT analysis using super spiral sliding mode control method, THD of the former is 24.72% and THD of the latter is 7.64%, which is obviously better than the compensation effect of the former, has a good inhibition effect, improves the robustness and efficiency, and ensures the sustainability and stability of the microgrid grid connection.

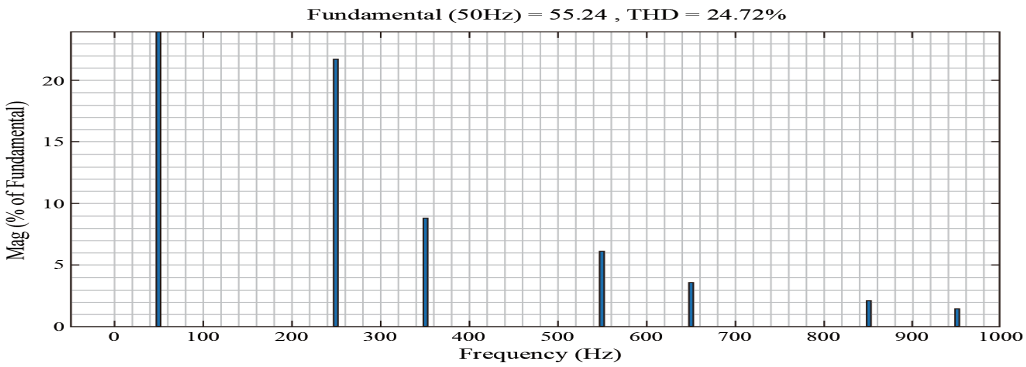

Fig. 8 FFT analysis using PI control

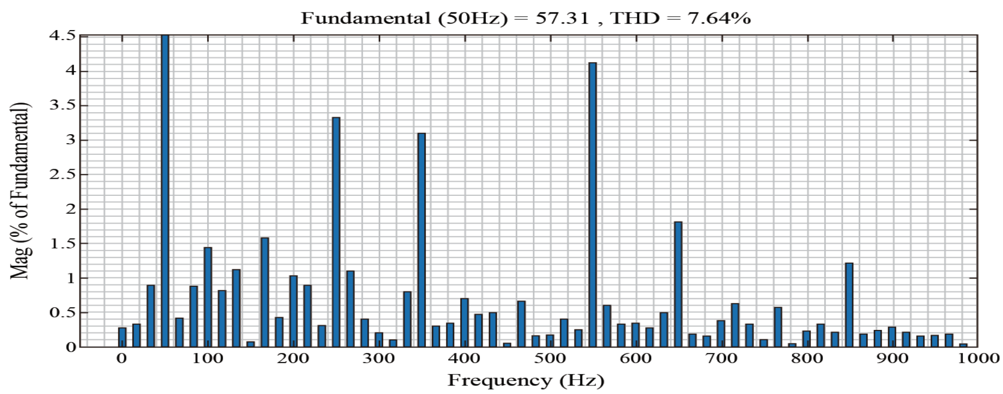

Fig. 9 FFT analysis using super spiral sliding mode control

4 Conclusion

In order to suppress the influence of harmonics in the microgrid on the power system, this paper uses the active plus passive filter based on the super spiral sliding mode control algorithm to suppress the harmonics in the microgrid. Firstly, the structure of the microgrid and the structure of the hybrid filter are introduced, and then, the hybrid filter based on the super spiral sliding mode control strategy is used. Finally, the simulation model is built in MATLAB, By comparing and analyzing the hybrid filter of PI control strategy and super spiral sliding mode control strategy, it can be found that the super spiral sliding mode control strategy reduces the harmonics in the microgrid, improves the robustness, effectively weakens the chattering of the system, reduces the overshoot, and ensures the sustainability and stability of the microgrid grid connection.

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