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Influence and Research of Distributed Power Grid-connected on Power System Relay Protection Performance

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Abstract

With the rapid increase in the population of human social development, energy problems have become increasingly prominent. Among the various energy sources that can be used, solar energy is increasingly valued by researchers and governments because of its pollution-free and renewable characteristics. In our country, solar energy resources are very rich, the potential of solar energy resources exploitation and utilization is very broad. In order to make full use of solar energy combined with the various preferential policies of photovoltaic power generation, scholars from all over the world have conducted a lot of research on photovoltaic power generation. This paper has studied photovoltaic connected inverters. Compared to L-type and LC type filters, the LCL filter has better harmonic current and voltage suppression effects. However, the LCL filter is a low-damping third-order system and is prone to resonance. The key difficulty in the control of LCL grid-connected inverter is its stability. By analyzing the working principle of the LCL inverter, the mechanism of resonance current generation is studied. Based on the analysis of the characteristics of the LCL filter, the influence of different parameters and incoming current on the resonant current is derived, and the inductive capacitance is selected according to the index and the working process. Make its resonant current as small as possible in the parameter selection process.

Keywords

LCL Grid-connected Inverter; Quasi-proportional Integral; Active Damping; Resonant Peak Suppression.

1. Introduction

Converting solar energy into electricity is an effective way to utilize solar energy, and the stability of photovoltaic power generation system is needed to ensure normal operation. Compared with stand-alone PV system, grid-connected PV system does not need energy storage, lower investment and more soil pollution. The grid-connected structure can be divided into single-stage and two-stage structure. The single-stage grid-connected PV structure does not need a converter, and its maximum power point tracking control and grid-connected control are all realized by controlling the solar inverter. Single-stage structure is simple, but the system control is more complex, reducing the stability of the system. The two-stage grid-connected PV system uses the front stage for maximum power point tracking control and the rear stage for solar inverter control. The two links of the two-stage Power Generation System have independent control objectives and methods. The control links are easy to design and realize, which improves the reliability of operation. Unlike conventional inverters, the solar inverter requires that the current output from the solar inverter be in sync with the

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grid voltage and that the grid-connected current be of good quality, to reduce the impact on the large power grid.Organization of the Text.

In this paper, a current control strategy combining quasi-proportional integral control and active damping control is proposed, and the principle of the control method is derived, the process of suppressing the resonant current and reducing the influence of frequency change on the system is analyzed, and the overall steady-state and dynamic response are improved by limiting the required parameters within a reasonable range.

2. Control of the Solar Inverter

Because there are many parameters in the two-degree-of-freedom single-current grid-connected control method, these parameters need to be pieced together for a long time, which makes the design more difficult. Therefore, this section first needs to satisfy the parameters of the conditions such as system stability, from the control system stability margin, dynamic response and steady-state error, etc. , then, appropriate parameter values are selected to simplify the parameter design process and improve the steady and dynamic performance of LCL inverter.

AC side filter is responsible for filtering the high-frequency voltage and current ripple caused by switching on and off. The selection of filter topology and parameters has a direct impact on the ripple size. In addition, the filter will affect the output impedance, according to the requirements should have a strong ripple suppression ability and smaller output impedance.

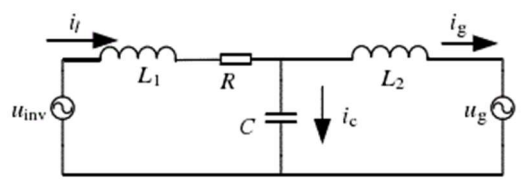

Fig.1 Inductance L1 series resistance

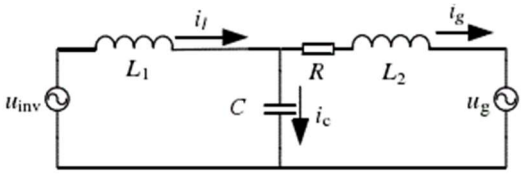

Fig.2 Inductance L2 series resistance

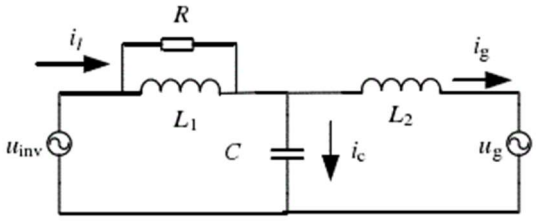

Fig.3 Inductance L1 parallel resistor

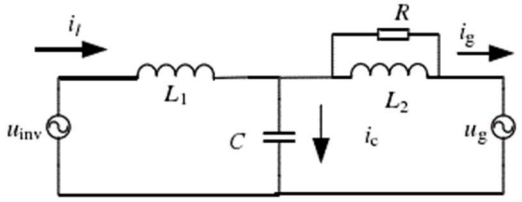

Fig.4 Inductance L2 parallel resistor

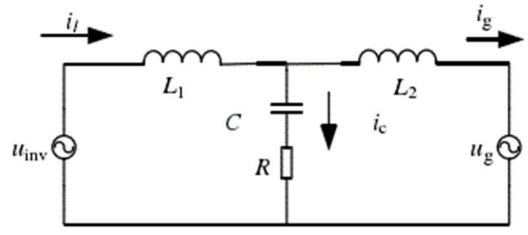

Fig.5 Capacitance C series resistance

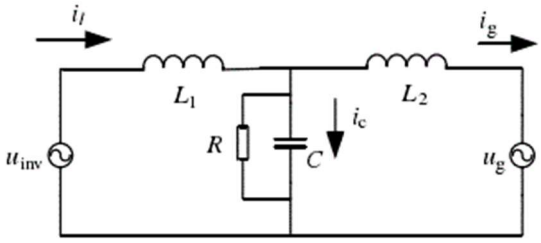

Fig.6 Capacitance C parallel resistance

Passive damping is the traditional method to reduce the resonance spike using damping technology. The method adds passive devices to the filter, such as series or parallel resistors in the inductor or capacitor branch, depending on the location of the added resistor, it can be divided into the following basic modes [18] : inductance-l1 branch series resistance (fig. 1) , inductance-l1 two-side parallel resistance (fig. 2) , inductance-l2 branch series resistance (fig. 3) , inductance-l2 two-side parallel

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resistance (fig. 4) , filter capacitor C branch series resistance (fig. 5) , filter capacitor c two-side parallel resistance (fig. 6) . In practice, the loss of the damping resistance is large, resulting in lower efficiency, and its heat dissipation requirements in the selection of resistance and cooling system is more limited.

3. Analysis of the Basic Characteristics of LCL Filters

The switching state of the switching tubes of the LCL grid-connected inverter transitions very quickly, the switching frequency is high, and the high-frequency harmonics in the output current of the inverter are also mainly concentrated near the switching frequency. One of the research focuses of this paper is to suppress the effect of resonance spikes on the incoming current of the grid-connected inverter, so the resonance characteristics of the LCL filter are analyzed in this section.

The LCL filter mathematical model is of third order, referring to the block diagram of the grid-connected inverter system and the loop equations in the previous section, and temporarily ignoring the resistors R1 and R2, the block diagram of the LCL filter system is introduced as shown.

LCL filter (due to the equivalent resistor resistance value is very small, the frequency range of the low-frequency band is small, after omitting the resistance is not taken into account) in the middle band of the slope of -20dB/dec, the larger the frequency range of the band, the larger the bandwidth, the faster the dynamic response of the system; high-frequency band of -60dB/dec, high-frequency attenuation is fast, the ability to anti-jamming is strong, which means that it itself has a better ability to inhibit high-frequency harmonics. Ability; the two frequency bands of the turning point that resonance frequency, the point of resonance spike, amplitude and frequency gain is very large, but the phase lag is also very large, easy to cause the system is not stable, so should focus on reducing the resonance frequency point of the impact of the system.

It is seen that the equivalent impedance of the inverter is equal to the capacitive impedance XC at high frequencies, and is connected in parallel with the inductor impedance XL2 on the grid side, and then in series with the inverter side inductor XL1. Firstly, assuming that the capacitor impedance $1/j\omega XC$ is much smaller than the inductor impedance $j\omega XL2$ on the grid side, then the impedance value of capacitor C and the grid side inductor L2 in parallel will be less than these two values, becoming smaller, and then connected in series with the inverter side inductor L1, the effect of filtering out the current ripple will be mainly responsible for the inverter side inductor L1; In addition, the capacitor is through the high frequency resistance low frequency, and the inductor is through the low frequency resistance high frequency, because the capacitive impedance is much smaller than the grid side inductor impedance, the high-frequency component of the current flowing through L1 will mainly flow from the capacitor branch, that is, the capacitor and the grid side inductance form a filter channel, which can be used to filter out higher harmonics. The choice of L1 size is mainly based on the current ripple requirements, and the capacitive impedance should be much smaller than the L2 impedance.

4. System Structure and Control Method of LCL Solar Inverter

Fig.7 is the grid-connected PV LCL inverter system structure diagram. It can be seen from the diagram that the inverter consists of inverter circuit, LCL filter, driver protection circuit and control circuit. Where UDC for DC power, the value of UDC (photovoltaic components will absorb solar energy into electrical energy, after voltage conversion into the inverter input, here with DC power said) ; The inductor, the capacitor, and the inductor together form the LCL filter, with R1 and R2 representing the Equivalent series resistance of the inductors respectively , and the voltage of each phase of the power grid, and the current flowing through each phase when connected to the power grid, respectively, are the pre-filter voltage, and the corresponding A, B, c-phase filter capacitor voltage, respectively; And respectively are the acquisition current and acquisition voltage needed for control.

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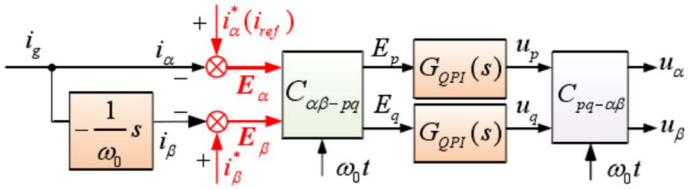

Fig. 7 Photovoltaic grid-connected LCL inverter system structure

The error values EP and EQ can be obtained by converting E α and E β in the stationary coordinate system, as shown in the figure. E α and E β are the error values of two orthogonal currents on the αβ axis respectively, and E α is also the difference between the measured value of grid-connected current IG and the set current reference contrast iref.

The active damping control strategy can be considered as a parallel connection of a resistor and a capacitor at both ends of the filter, which means that the response speed of the system will become slower, it may also have adverse effects on the overall stability of the operation. Therefore, it is necessary to discuss the possible consequences of sampling frequency on overall stability in order to set a better switching frequency.

5. Conclusion

In the diagram, the control method is mainly divided into two parts: quasi-proportional integral control and grid-connected current feedback active damping control. The quasi-proportional integral controller can obviously reduce the negative effect of the grid frequency variation on the grid-connected current, and the active damping control uses the high frequency component of the grid-connected current as an additional variable to introduce the loop, the damping of the system is increased and the dynamic response of the system is improved. This control method only needs to sample the grid-connected current and voltage, and does not need to use too many sensors, thus reducing the cost of manufacturing and increasing the reliability of the system. In figure 3-2, IREF is the current contrast value set to adjust the current; UD is the signal measured during the mediation process; and Kinv is the equivalent gain.

Acknowledgments

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References

[1] Luo A, Chen Y., et al. An Improved Reactive Current Detection and Power Control Method for Single-Phase Photovoltaic Grid-Connected DG System[J].IEEE Transactions on Energy Conversion, 2016, 28(4): 823-831.

[2] Chen Y, Luo A, et al.Robust predictive dual-loop control strategy with reactive power compensation for single-phase grid-connected DG system[J].IET Power Electronics, 2015, 6(7): 1320-1328.

[3] Peng S, Luo A, Chen Y, et al.Dual Loop power control for single-phase grid-Connected converters with LCL filter[J].Journal of Power Electronics, 2017, 11(4): 1-8.

[4] .Blaabjerg F, Teodorescu R, Liserre M, et al. Overview of control and grid synchronization for distributed power systems[J].IEEE Trans.on Industrial Electronics, 2016, 53(5): 1398-1409.

[5] Li Y, Wang M.Control stratories for grid-connected and island dualmode operated inverter under unbalanced grid volatage conditions[C]. 2012 IEEE 7th International Power Electron. And Motion control Conference-ECCE Asia, Harbin, China.2016: 2152-2556.