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Active And Reactive Power Control By MMC For Grid Conncted Photo Voltaic Systems

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Abstract:
Aim at photovoltaic system or wind power system outputting constant DC voltage, research on the control strategy of grid-connected inverter suitable for such system is put forward in this paper. A novel dual-loop control structure that consists of power outer-loop and current inner- loop is proposed. The reference value of the outer-loop is provided by maximum power point tracking and integrative system operation status, and the active current component is given by the power outer-loop regulator. Finally, the stable operation under different power factor of the grid- connected inverter is realized by the current inter-loop regulator. Modeling and simulation research work based on MATLAB 7.1 is carried out in the paper. A prototype of 30kW rated grid- connected inverter is tested on developed wind simulation operation platform in the laboratory. Simulation and experimental results verified correctness and effectiveness of control structure and strategy of grid-connected inverter.

Keywords: Grid-connected inverter, outer-loop power control, modeling and simulation, power factor.

1. INTRODUCTION

Along with the continued consumption of fossil energy and fast growth of economy and population, the renewable-energy generation technology has received extensive attention worldwide The grid-connected inverter used in new energy grid-connected power generation systems are mostly three-phase voltage-source inverters with pulse width modulation (PWM) technology and have advantages such as sine current output, low harmonic content and adjustable power factor The grid-connected inverter using such control technology generally come with outer voltage loop and inner current loop, where the output of voltage loop serves as the active current reference of inner loop to control the output active power. It maintains the power factor to be 1 during proper operation, and regulates demand of reactive power during grid fault so that it runs in reactive compensation status. The research of grid-connected inverter with such control structure is very extensive and in-depth presently, particularly in the field of application in photovoltaic and wind power system scenarios and reactive compensation, harmonic suppression [10]. However, the grid-connected inverter with such control structure should have a certain fluctuation on the part of voltage outer loop, and otherwise adjustment of the active current is impossible. If the system has completed the close-loop regulation of DC-side bus voltage in the pre-stage of grid-connected inverter, and the constant DC voltage is sent to the DC-side of inverter, then grid-connected inverter with such control structure is no longer applicable and will cause system instability. Though DC-side voltage can keep stable during actual operation, DC- side current will present substantial fluctuation, causing failure of grid-connected inverter in outputting specified active power. Therefore, research on control strategy for grid-connected inverter without outer voltage loop control is of great significance. For photovoltaic or wind power system of outputting constant voltage in the front device, an applicable grid-connected inverter control scheme is proposed in this paper. A new double-loop control structure with outer power loop and inner current loop is used and modelling

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and simulation are realized. With the simulation and operation platforms of wind power generation in laboratory, the experiment on a prototype of 30 kW for grid-connected inverter is developed to verify the correctness and feasibility of such control scheme for grid-connected inverter.

2. RELATED WORK

For control strategy, the grid-connected inverter with outer power loop and inner current loop control structure differs from the general grid-connected inverters with outer voltage loop in the reference value of specific active current given by the regulator of power outer loop. On the other hand, the reference input of outer power loop regulator depends on the pre-stage input of system. Photovoltaic or wind power system is subject to track the maximum power, and operation state of current system is also taken into account, and thus eventually produces the reference input for outer power loop regulator.

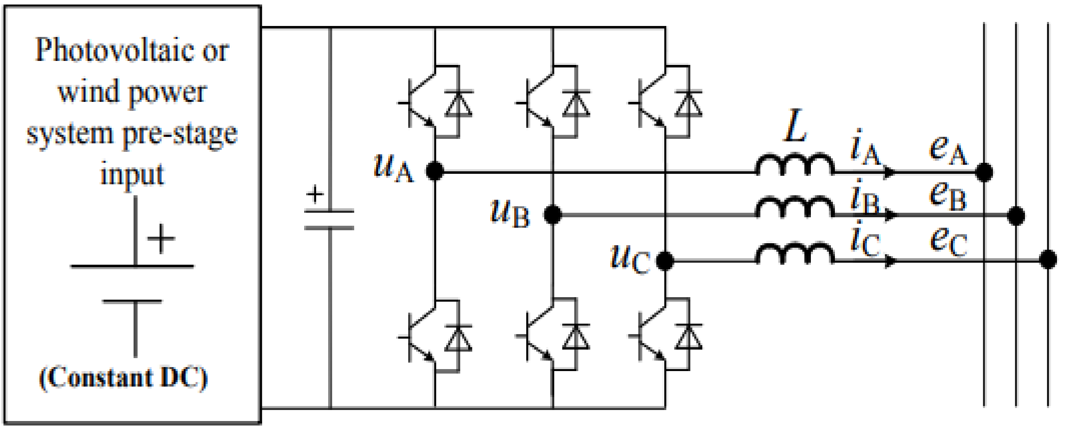

Fig.1.Grid Connected Inverter

It is compared with the actually detected power outputted from grid-connected inverters to power grid, and the given active current component is eventually obtained. In order to verify the correctness of the proposed control strategy of grid-connected inverter, The space vector pulse width modulation (SVPWM) is employed to obtain the drive signal of power electronic devices. The inner current loop regulators give the required voltage vector for SVPWM scheme, which is supplied by the voltage components in two-phase rotating coordinate. The reference input of outer power loop is provided by an integrated MPPT simulated module, which is realized by programming MPPT algorithm. Obviously, simulation results especially three-phase current at 30kW are superior to those at 10kW because the filtering effect is better when the output power is bigger. Simulation results during sharp load and unload are shown in Fig. 6. Although the output power increases suddenly, the output current can be regulated to reach target value rapidly after a short transient change process. All of these simulation results are carried out under the unity power factor.

3. PROPOSED SYSTEM

The simulation and operation platform of the wind power constructed in the laboratory is used for verifying the grid-connected inverters control strategy of outer voltage loop and inner current loop. To meet experimental conditions that the input DC voltage should be constant, output of wind turbine is adjusted by DSP.side voltage input to grid-connected inverters is constant 600 V DC. Rated power of grid- connected inverters is 30 kW. As the experiment aims to verify correctness and effectiveness of control strategy, L-type filter is used with inductance 4 mH instead of LCL filter. As the DC side voltage is only 600 V, which does not meet the voltage demand of full-power operation of grid- connected

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inverters, the isolation transformer with voltage ratio 1:1.42 is added to the grid side in this experiment. Firstly, the grid-connected inverters operation performance at unit power factor is tested. The wind turbine simulation system controls asynchronous motor to run on specified wind turbine characteristic curve, and thus change of wind speed and rotating speed will change its output power.

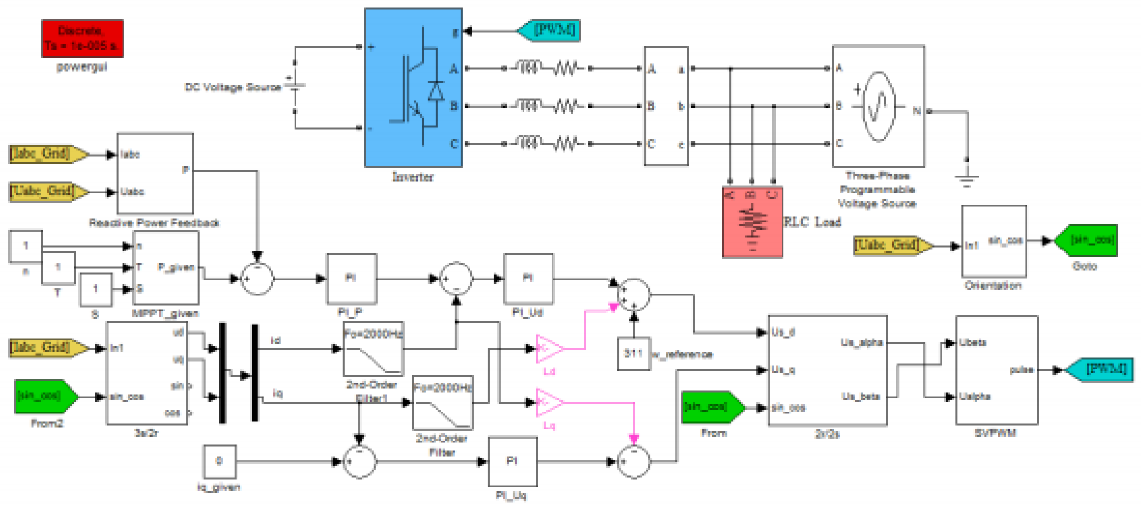

Fig.2.Block diagram

The reference input of outer power loop regulator is given by integrating the pre-stage maximum tracking algorithm. Fig. 9 and Fig. 10 are voltage and current waveforms of grid- connected inverters respectively when it outputs 10 kW and 30 kW active power, specifically including three-phase output current waveform, single-phase output current and grid-side voltage comparison waveform, and THD test diagram. The waveforms and data in these figures show that three-phase output current waveform features high sine degree, few harmonic content, accurate phase locking and high power factor and that use of L-type filter can meet the demand to have THD go below 5% with varied power.

4. ANALYSIS

The cascaded multilevel inverters are directly connected to the grid without big line-frequency transformer, and the synthesized output voltage from cascaded modules facilitates to be extended to meet high grid voltage requirement due to the modular structure. Each dc–dc converter module is interfaced with segmented PV arrays and therefore the independent MPPT can be achieved to harvest more solar energy. This paper is focused on active and reactive power distribution control of the cascaded multilevel inverters in the proposed PV system. The selected application is a 3-MW/12-kV PV system in this paper. The n is selected to be 4 considering the tradeoff among the cost, lifetime, passive components, switching devices and frequency selection, and power quality. As a result, power rating of each inverter module is 250 kW. The average dc voltage of each inverter module is 3000 V based on the requirement of inverter output voltage, power devices as well as power quality. The second-order voltage ripple on the dc side is allowed to 20% even higher. Hence, film capacitor with 400uF,Cm , is eligible to improve the system lifetime. In addition, the modular structure enables the high-voltage high-frequency SiC power devices for the HVHP PV application. The switching frequency for each power device is 5 kHz. Due to the phase-shift carrierbased phase-width modulation (PWM) control, the PV inverter will generate nine level output voltage and the equivalent output PWM frequency is 40 kHz for each phase. The current ripple of ac inductor is selected to be less than 20% of the rated output current. Therefore, the ac inductor with 0.8 mH, Lf, is acted as the filter. In each dc–dc converter module, Ldc1 and Ldc2 are dc inductors, and Ls is leakage inductor. CPV is high-frequency filter capacitor paralleled with PV arrays. High-frequency transformer with turn ration N is connected between low-voltage side.

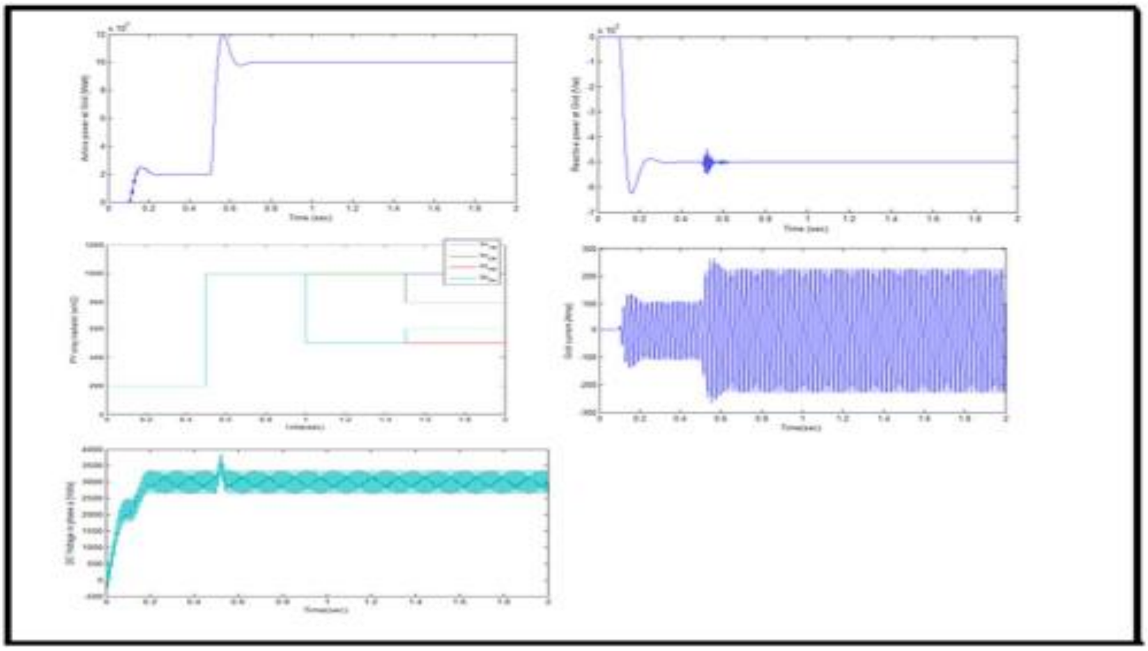

Fig.3.Output wave

The following simulation results provide the verification of the aforementioned analysis. The active and reactive power can be independently controlled. Although the solar irradiation on first and second inverter modules is different from one on third and fourth inverter modules after 1 s, the reactive power from them is controlled to be symmetrical. By this proper reactive power distribution, the over modulation caused by the active power mismatch is eliminated. Even when different active power is generated from the four inverter modules after 1.5 s, the effective reactive power compensation can ensure the system with good power quality and stability .It can be seen that THD of iga is only 2.532%.

CONCLUSION

The total reactive power to grid, Qg, is controlled to be −1.5 MVAR. At 1 s, solar irradiation appears on these PV inverter modules in phase b is different from ones in phases a and c. Therefore, different active power is generated from three phase. The dc voltages on these modules have good dynamic performance and are controlled to vary with 20% rated voltage. This paper gives the active and reactive power distribution among cascaded PV inverter modules and their impacts on power quality and system stability for the large-scale grid connected cascaded PV system. The output voltage for each module was separated based on grid current synchronization to achieve independent active and reactive power distribution. A decoupled active and reactive power control strategy was developed to enhance system operation performance. The proposed control strategy enabled the cascaded PV inverter modules.

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