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A New Hybrid Power Filter Based Grid Connected System with Power Quality Improvement



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ABSTRACT

As to the concrete topology of three-phase LCL type grid-connected inverter with damping resistance, mathematical model was deduced in detail, using method of equivalent transformation to the structure diagram, damping resistance was virtualized, mathematical model under the DQ frame that can realize decoupling control was established, a dual-loop control strategy for grid-connected inverter with LCL filter was proposed, the system stability was analyzed and the design method of controller was given. The proposed method overcame the flaws of loss increase, efficiency reduce and cost increase which were caused by damping resistance in LCL type grid-connected inverter, the system efficiency and power supply quality of the output were improved. Feasibility and effectiveness of the new method were validated by simulation results.

Index Terms—Active damping, direct grid current control, grid connected inverter, harmonic distortion, LCL filter.

INTRODUCTION

LCL filter compared with the traditional L filter, it needs smaller inductance value and it is more effective for re-straining higher harmonic when they achieve the same filtering effect, but resonance problem exists in LCL fil-ter itself, it will cause system instability [1-3]. There are two common methods to solve it [4, 5]: one is passive damping, that is, a damping resistance is connected with the capacitor branch in series to inhibit resonance [6,7]. This method is simple and reliable, but the LCL filter's ability of restraining higher harmonic was reduced, it will also bring extra system loss for the damping resistor; another one is active damping, namely the modified con-trol algorithm was adopted to inhibit resonance and make sure the system stability [8, 9].

According to the principle of inhibiting resonance by using damping resistance, and using equivalent transfor-mation, a dual-loop control strategy for grid-connected inverter with LCL filter was proposed in this paper, this new method was used to inhibit resonance, ensure system stability. A detailed description about the process of proposing control strategy, mathematical modeling and decoupling control of grid-connected inverter in the DQ coordinate system, and the design method of controller parameter was given in this paper. Then system stability was analyzed, finally, the effectiveness and feasibility of the new method have been verified by simulate results.

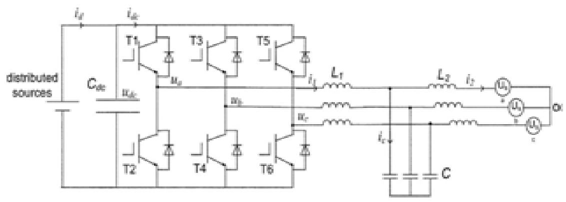

Fig. 1. Three-phase grid-connected inverters with *LCL* filter.

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Fig. 1 shows the topology of three-phase grid-connected inverter with *LCL* filter, where the parasitic resistances are ignored. The *LCL* filter is designed.

PROPOSED SYSTEM

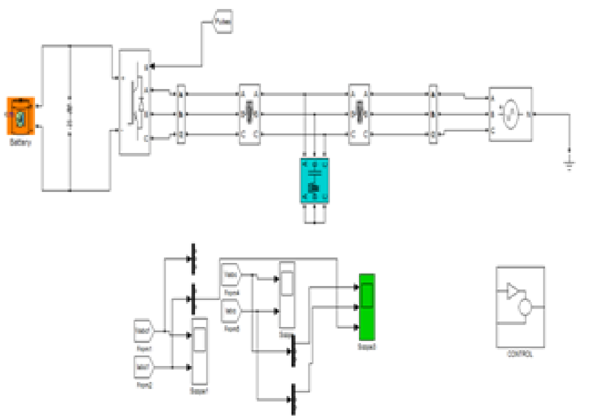

Fig. 2. Proposed Circuit

Fig. 2 shows the topology of three-phase grid-connected inverter with LCL filter, where the parasitic resistances are ignored.

If the dc capacitance is large enough, it's reasonable to assume that the dc side is a dc voltage source. The switching frequency is sufficiently high, so the pulsewidth modulated (PWM) element can be simplified as proportional element using average switching model (ASM).

Battery:-- An electric battery is a device consisting of two or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell has a positive terminal, or cathode, and a negative terminal, or anode. The terminal marked positive is at a higher electrical potential energy than is the terminal marked negative. The terminal marked positive is the source of electrons that when connected to an external circuit will flow and deliver energy to an external device. When a battery is connected to an external circuit, Electrolytes are able to move as ions within, allowing the chemical reactions to be completed at the separate terminals and so deliver energy to the external circuit. It is the movement of those ions within the battery which allows current to flow out of the battery to perform work.[1] Although the term *battery* technically means a device with multiple cells, single cells are also popularly called batteries.

Primary (single-use or "disposable") batteries are used once and discarded; the electrode materials are irreversibly changed during discharge. Common examples are the alkaline battery used for flashlights and a multitude of portable devices. Secondary (rechargeable batteries) can be discharged and recharged multiple times; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium ion batteries used for portable electronics.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to battery banks the size of rooms that provide standby power for telephone exchanges and computer data centers.

ACTIVE POWER FILTER:-- An active filter is a type of analog electronic filter that uses active components such as an amplifier. Amplifiers included in a filter design can be used to improve the performance and predictability of a filter,[1] while avoiding the need for inductors (which are typically expensive compared to other components). An amplifier prevents the load impedance of the following stage from affecting the characteristics of the filter. An active filter can have complex poles and zeros without using a bulky or expensive inductor. The shape of the response, the Q (quality factor), and the tuned frequency can often be set with inexpensive variable resistors. In some active filter circuits, one parameter can be adjusted without affecting the others.Using active elements has some limitations. Basic filter design equations neglect the finite bandwidth of amplifiers. Available active devices have limited bandwidth, so they are often impractical at high frequencies. Amplifiers consume power and inject noise into a system. Certain circuit topologies may be impractical if

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no DC path is provided for bias current to the amplifier elements. Power handling capability is limited by the amplifier stages.[2]

CONTROL STRATEGY

The output current of three-phase grid-connected inverter with LCL filter will have higher quality, but it demands higher requirement of control. The system is unstable if using typical grid-connected current direct feedback closed loop control. Conclusion that is obtained from the block diagram in the above paragraphs is that: it can achieve the same effect of inhibiting resonance as using a damping resistance in the filter capacitor branch in series by adopting the filter capacitor current feedback as well as proper control strategy. If "virtual damping resistance" that is from the equiv-alent transformation is directly used in controlling, due to the order of its transfer function numerator is higher thancapacitor current, the current harmonic is high and the control is more difficult, it is difficult to achieve the ef-fect of inhibiting resonance and system stability and this is verified by simulation result.

Now that the control effect is not good by using "vir-tual damping resistance" directly that is from the equiva-lent transformation, only the feedback quantity is taken in the control that is simplified in this paper. Current double closed loop control strategy is used in three-phase grid-connected inverter with LCL filter and the feedback quantity is the filter capacitor current *CI* and the grid- connected current 2*I* on the grid side. A P control is applied in the filter capacitor current inner loop and a PI control is applied in the grid-connected current outer loop.
Current double closed loop control for grid-connected inverter consists of capacitor current inner loop and grid- connected current outer loop. Voltage-current double closed loop control for grid-connected inverter consists of grid-connected current inner loop and grid voltage outer loop. Because the control principle is different be-tween the two, it cannot adopt a similar method to the latter to design current double closed loop controller in this paper [10]. The setting value of the current double closed loop control in this paper is current instruction, the reference current of the capacitor current inner loop will be obtained after flowing through outer PI controller, then, the voltage instruction will be obtained after flow-ing through inner P controller and it will be sent to in-verter. The inner or outer loop cannot be designed inde-pendently because of the interdependence between the two, only the inner and outer loop controllers were de-signed synchronously in order to ensure system per-formance.

Due to the duality between D-axis and Q-axis, only taking D-axis controller design for example in what fol-lows. The system control block diagram is shown in figure3

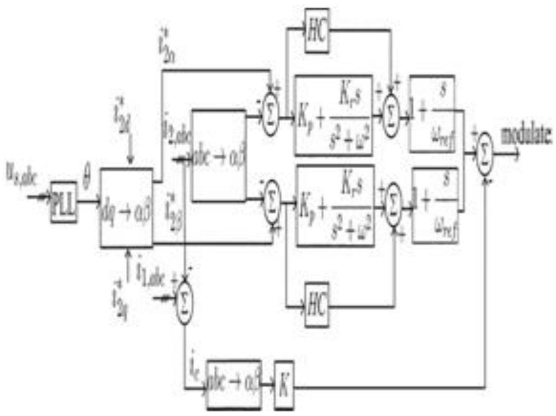

Fig. 3. Control structure of PR+HC applied under *αβ* coordinate.

SIMULATION RESULTS

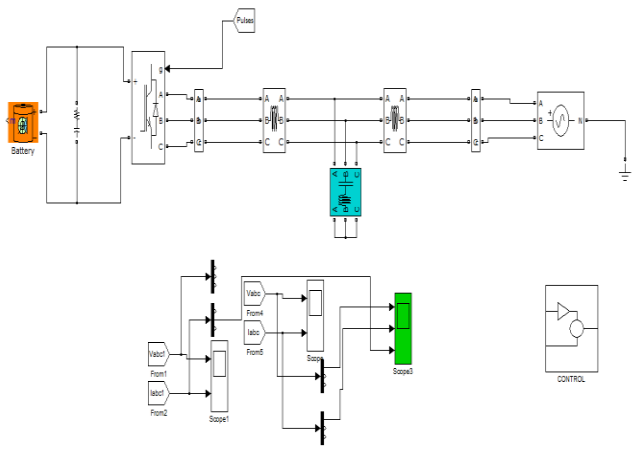

Fig4.simulation circuit

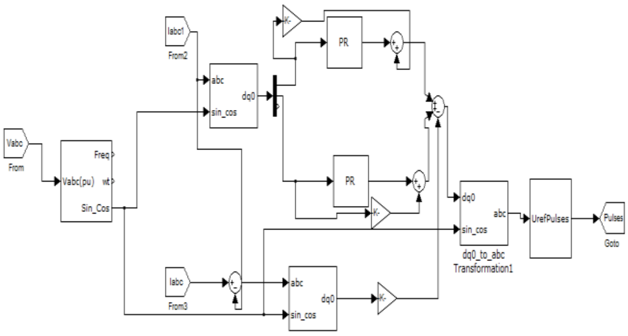

Fig.5 Control unit block

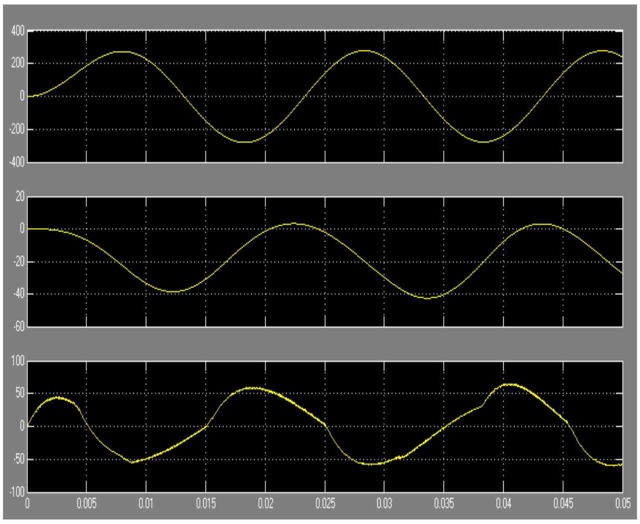

Fig.6 Grid Voltage,Grid Current & Inverter Current

CONCLUSION

In this paper, a direct grid current control strategy is proposed.The virtual resistance based on the capacitance current feedbackis used to realize active damping, zero compensation is broughtin to enhance the stability, and PR controller in stationary $\alpha\beta$coordinate is designed to track the reference current as wellas to avoid the strong coupling brought in by the coordinatetransformation. Under the distortion grid voltage, the PR+HC structure is adopted to restrain the distortion of the grid current.The feasibility of the control strategy is verified by simulation results.

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