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Direct Grid Current Control of LCL Filtered Grid Connected Inverter Mitigated Grid Voltage Disturbances.



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ABSTRACT

The grid-connected inverter is usually used as the interface between the green power source and the utility grid .To reduce the switch ripples and improve the quality of the grid current; an LCL output filter is always used between the inverter and the grid. Compared with L filter, LCL filter has better attenuation capacity of high-order harmonics and better dynamic characteristic. Nevertheless, because LCL filter is a three-order system and it has resonance problem, the current control strategies of the LCL-filtered inverter are more difficult and susceptible to interference hazards and the lower harmonic impedance presented to the grid A direct grid current control strategy for LCL-filtered grid-connected inverters is proposed in this paper. The conventional current control strategies are analyzed and compared, and then the necessity of direct grid current control is presented to mitigate the grid voltage disturbance. In the proposed control strategy, the virtual resistance based on the capacitance current is used to realize active damping, zero compensation is brought in to enhance the stability, and the proportional resonant (PR) controller is also proposed. (PR+HC) structure is adopted to restrain the distortion of the grid current. Finally, the proposed control strategy is verified by the simulation results.

Index Terms—distributed generation (DG), distribution system, grid interconnection, power quality (PQ).

INTRODUCTION

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers. Power stations may be located near a fuel source, at a dam site, or to take advantage of renewable energy sources, and are often located away from heavily populated areas. They are usually quite large to take advantage of the economies of scale. The electric power which is generated is stepped up to a higher voltage-at which it connects to the transmission network.

The transmission network will move the power long distances, sometimes across international boundaries, until it reaches its wholesale customer (usually the company that owns the local distribution network).

GRID INTERCONNECTION

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of three main components: 1) generating plants that produce electricity from combustible fuels (coal, natural gas, biomass) or non-combustible fuels (wind,

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solar, nuclear, hydro power); 2) transmission lines that carry electricity from power plants to demand centers; and 3) transformers that reduce voltage so distribution lines carry power for final delivery.

PROPOSED SYSTEM

GRID-TIED INVERTER

A grid-tie inverter (GTI) or grid interfacing inverter is a special type of inverter that converts direct current (DC) electricity into alternating current (AC) electricity and feeds it into an existing electrical grid. GTIs are often used to convert direct current produced by many renewable energy sources, such as solar panels or small wind turbines, into the alternating current used to power homes and businesses. The technical name for a grid-tie inverter is "grid-interactive inverter". They may also be called synchronous inverters. Grid-interactive inverters typically cannot be used in standalone applications where utility power is not available.

Residences and businesses that have a grid-tied electrical system are permitted in many countries to sell their energy to the utility grid. Electricity delivered to the grid can be compensated in several ways. "Net metering", is where the entity that owns the renewable energy power source receives compensation from the utility for its net outflow of power. So for example, if during a given month a power system feeds 500 kilowatt-hours into the grid and uses 100 kilowatt-hours from the grid, it would receive compensation for 400 kilowatt-hours. In the US, net metering policies vary by jurisdiction. Another policy is a feed-in tariff, where the producer is paid for every kilowatt hour delivered to the grid by a special tariff based on a contract with Distribution Company or other power authority.

This paper proposes A Novel Control Strategy Inspired by the structure diagram of the passive damping method, the virtual resistance based on capacitance current is used to realize active damping, so the grid current loop can be stable.

Then, the zero compensation on the corner frequency is brought in to enhance the stability. For three-phase *LCL*-filtered inverter, if coordinate transformation is adopted, the coupling between *d* and *q*-axis is more complex than *L* filter, so the outer proportional resonant (PR) controller under two-phase static coordinate is designed to track the ac reference current as well as to avoid the strong coupling.

Moreover, the disturbance caused by grid voltage harmonics is investigated by determining the harmonic impedance of the current controller in [5], and tuning the current controller parameters is used to mitigate this distortion, but the effect is limited. In this paper, PR + HC structure is adopted to increase the typical harmonic impedance, and power quality.

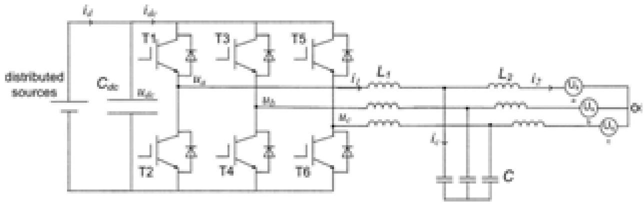

Fig. 1. Three-phase grid-connected inverters with *LCL* filter.

CONTROL STRATEGY

Adoption of PR Controller

Since PI controller cannot track the ac reference without error under static coordinate, it is replaced by a PR controller, considering *Kr* = *Ki*. To investigate the characteristic of the regulation, the open-loop Bode plot of the system using PI and PR controllers ,where the high-frequency band of them coincide including the cutoff frequency, so the replacement of PR to PI does not affect the stability of the system.

In addition, because PR controller has big magnitude at fundamental frequency, it can track the reference without error. When applied in $\alpha\beta$ coordinate, the control structure is shown in Fig. 2. To verify the aforementioned analysis, simulation is

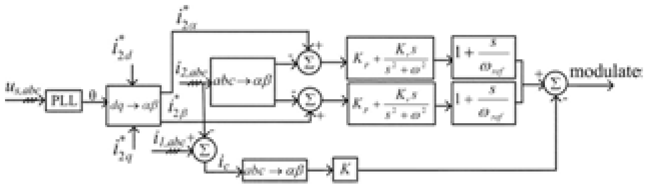

Fig. 2. Control structure applied under $\alpha\beta$ coordinate.

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done in Simulink using PI and PR controllers, respectively, and the result is given in Fig. 14, where the dotted line is the reference command current. From the simulation result, it's seenthat when a PI controller is used, the grid current has a staticerror to the reference; when a PR controller is used, the grid current tracks the reference current accurately. Moreover, when the reference current has mutation, dynamic response of the two controllers is similar. It's verified that PR controller has a better performance to track the ac reference command.

PR+HC Control Structure

In order to investigate the stability of the control system after HC part brought in, the Bode plots of PR controller , which can be seen that except some new harmonic peaks, the Bode plot of PR +HC controller coincides with the PR controller, so the stability margins of them are the same.

When applied under $\alpha\beta$ coordinate, the control structure is shown in Fig.3. Simulations are done to verify the antiinterference function of the HC part. For comparison, simulations are done using PR controller and PR + HC controller. In which the total harmonic distortion (THD)of grid voltage is set to be 5%, by adding some typical odd harmonic.

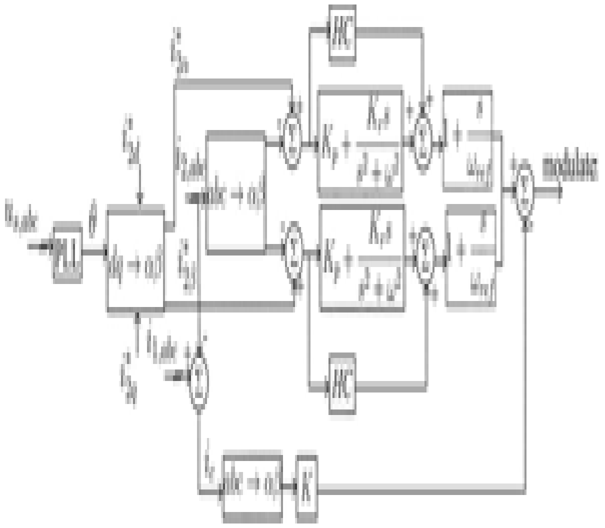

Fig.3. Control structure of PR+HC applied under $\alpha\beta$ coordinate

IV.SIMULATION RESULTS

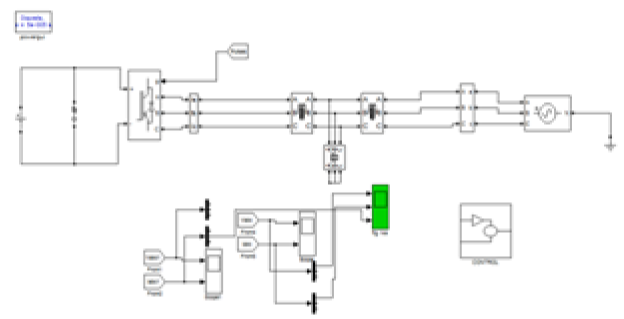

Fig.4simulation circuit

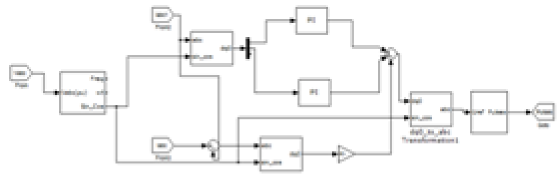

Fig.5. control strategy for PI controller used.

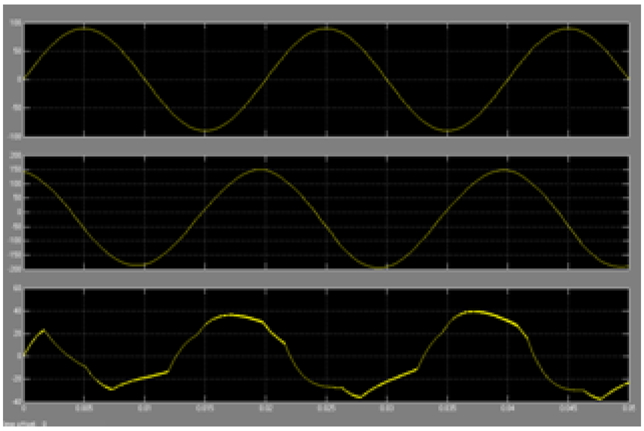

Fig.6 pi control waveforms, grid voltage, grid current, inverter current.

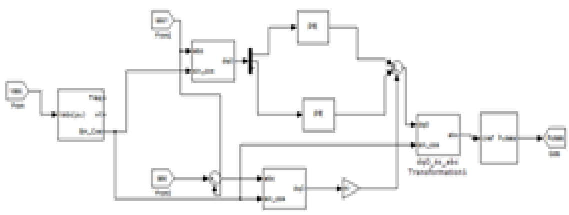

Fig.7. control strategy for pr

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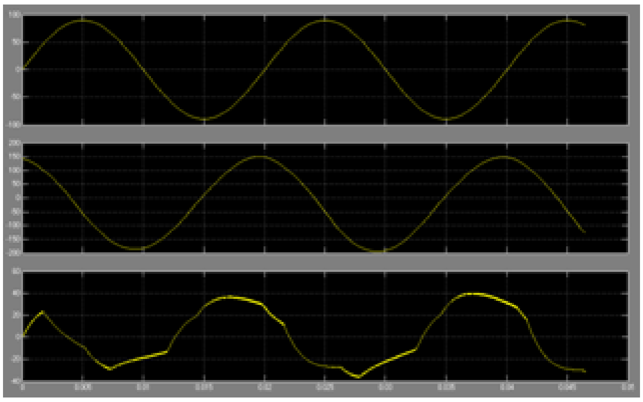

Fig.8 PRcontrol waveforms, grid voltage, grid current, inverter current.

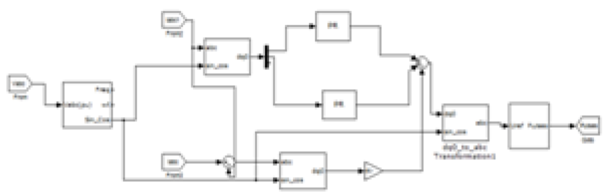

Fig.9 PR controller control strategy

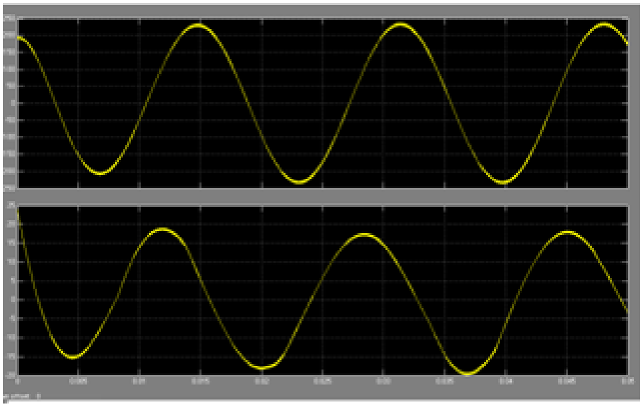

Fig.10. PR control waveforms, grid voltage, grid current,

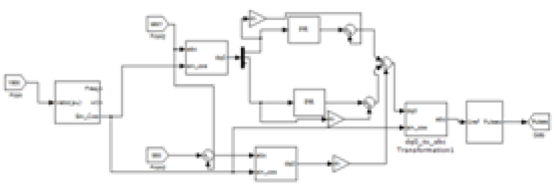

Fig.11 PR+HC controller control strategy

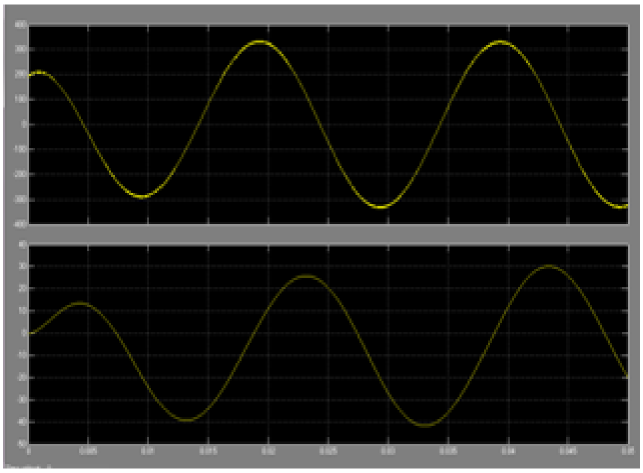

Fig.11 PR+HC waveforms, grid voltage, grid current,

V.CONCLUSION

In this paper, a direct grid current control strategy is proposed. The virtual resistance based on the capacitance current feedback is used to realize active damping, zero compensation is brought in to enhance the stability, and PR controller in stationary $\alpha\beta$ coordinate is designed to track the reference current as well as to avoid the strong coupling brought in by the coordinate transformation. 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 experimental results. The quality of grid current can be guaranteed even when the grid voltage is not ideal.

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