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고조파와 무효전력 보상기능을 가지는 Smart PCS의 새로운 제어 알고리즘

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Novel control algorithm for smart PCS with harmonics and reactive power compensation

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Abstract - A significant number of renewable energy systems have been connected to the grids as supplement power source. The renewable energy systems require control algorithm to maintain the power-supply reliability and quality. This paper proposes a novel control algorithm for smart Power Conditioning System (PCS) with harmonics and reactive power compensation. The smart PCS is used to feed Photovoltaic (PV) power to utility and compensate harmonics and reactive power at the same time. The experimentation is carried out on the proposed grid-connected PV generation system, and controlled by digital signal processor. The grid-connected PV generation system injects PV energy into the grid and performs as Active Filter (AF) and Static Synchronous Compensator (STATCOM) without additional devices. The experiment results show that the proposed control algorithm is effective for smart PCS with harmonics and reactive power compensation.

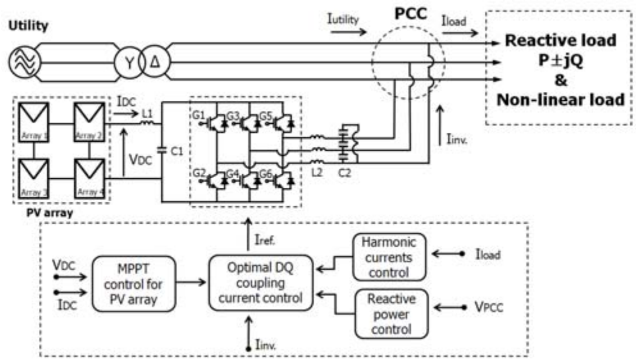
1. Introduction

The proliferation of nonlinear loads such as static power converters and arc furnaces results in a variety of undesirable phenomena in the operation of a power system. Therefore, compensation of these undesirable effects is extremely important. the static var compensators and shunt active filters have been developed in recent year. A shunt active filter can compensate only for the harmonic current of a selected nonlinear load, and can continuously track changes in its harmonic content. A STATCOM operated as a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage [1], [2]. The PV array cannot supply the power continuously 24 hours a day. To overcome the disadvantage of the grid-connected PV system, some multi-function inverters have been presented. The systems include just one additional function, active power filter or reactive power compensation [3].

This paper proposes a novel control algorithm for smart Power PCS with harmonics and reactive power compensation. The smart PCS is used to feed PV power to utility and compensate harmonics and reactive power at the same time.

2. PV-AF-STATCOM system

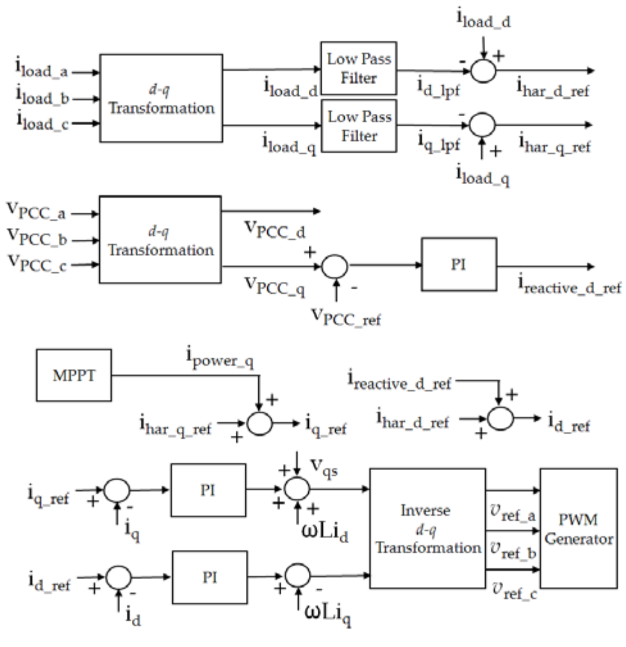
2.1 Concept of the PV-AF-STATCOM system



<Fig. 1> Configuration of the proposed system

Fig. 1 shows the configuration of the proposed system. The system is composed of a PV module, DC/AC inverter, voltage sensors, current sensors and DSP controller. The detection variables in the inverter circuit are the DC link voltage Vdc, the phase-voltage V_{PCC} at the point of common coupling (PCC), the inverter current $I_{inv.}$ and the load current I_{load}. The main purpose of the inverter is DC/AC power conversion with Maximum Power Point Tracking (MPPT), it was designed for compensating harmonic currents and reactive power caused by customer loads in this work. The proposed system has three current references. One is the current reference of the PV output power control, and others are the current references of active filter and static var compensator function.

2.2 Proposed control method



<Fig. 2> Control block diagram of the proposed system

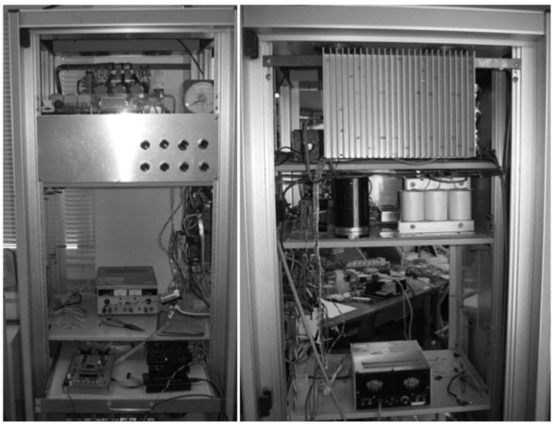
As shown in Fig. 2, load currents (i_{load_a}, i_{load_b}, i_{load_c}) are transformed into *d-q* axis load current components (i_{load_d}, i_{load_q}). The *d-q* load current components are filtered by Low Pass Filter (LPF) and remained as the *d*-axis positive-sequence component (i_{d_lpf}) and *q*-axis positive-sequence component (i_{q_lpf}) of loads harmonic current, respectively. As a result, the fundamental frequency of load current is transformed into dc-component. Thus, the difference between *d-q* axis components of load current and dc-component becomes the current references of the *d-q* axis components ($i_{har\_d\_ref}$, $i_{har\_q\_ref}$) for harmonics compensation.

The phase-voltages (V_{PCC_a}, V_{PCC_b}, V_{PCC_c}) at PCC are transformed into d-q axis components. The difference between q-axis component of phase-voltage (V_{PCC_q}) and the phase-voltage reference (V_{PCC_ref}) becomes the d-axis current reference component ($i_{reactive\_d\_ref}$) for reactive power compensation.

The summation of *q*-axis component of harmonic current and *q*-axis reference current of MPPT ($i_{har\_q\_ref}$ + i_{power_q}) is total q-axis reference of inverter output current. The summation of d-axis component of harmonic current and d-axis current reference of reactive power compensation ($i_{reactive\_d\_ref}$ + $i_{har\_d\_ref}$) is total d-axis reference of inverter output current. Consequently, the PWM reference voltages (v_{ref_a}, v_{ref_b}, v_{ref_c}) of PV-AF-STATCOM system are obtained by the inverse d-q transformation.

3. Experiments and results

A voltage source PWM inverter was used as the power conversion system of the PV-AF-STATCOM system, and its control was realized with Digital Signal Processor (DSP). The PWM converter should have a high switching frequency in order to supply accurate compensating currents. The switching frequency of the PV-AF-STATCOM system is 10kHz. Experiments were carried out to confirm the proposed operating principle. The PWM inverter is controlled with the feedback loops of the output current and voltage of inverter, and optimal values of PI gains and filter constants are tuned to obtain proper responses. Harmonic currents were generated by a three-phase diode rectifier with a capacitive load. Table 1 describes the specification of real built-in hardware used for the experiment.

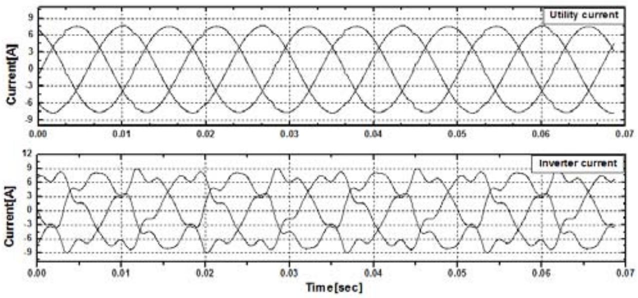


<Fig. 3> Real built-in full hardware of the PV-AF-STATCOM system used for experiment

<Table 1> Specifications of the experimental system

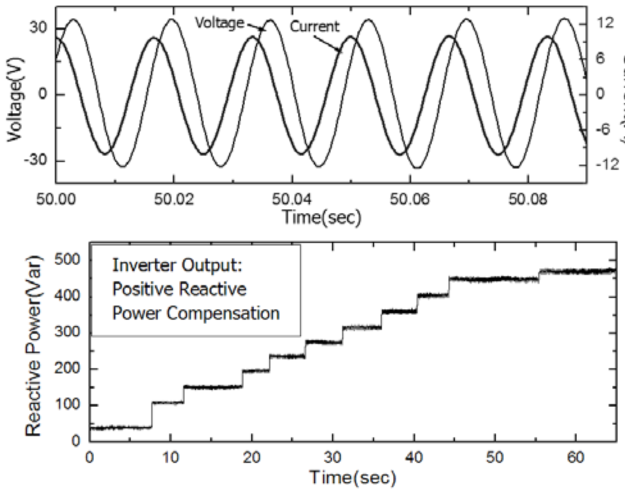
L 1	L 2	C 1	C 2	G	Trans.	Utility
6mH	5mH	10000μF	5μF	IGBT	3 phase Δ-Y type 380/50	220V 60Hz

As shown in Fig. 4, the system injects real power into the grid, operating the PV arrays at its maximum power point while simultaneously compensating harmonic currents and reactive power.

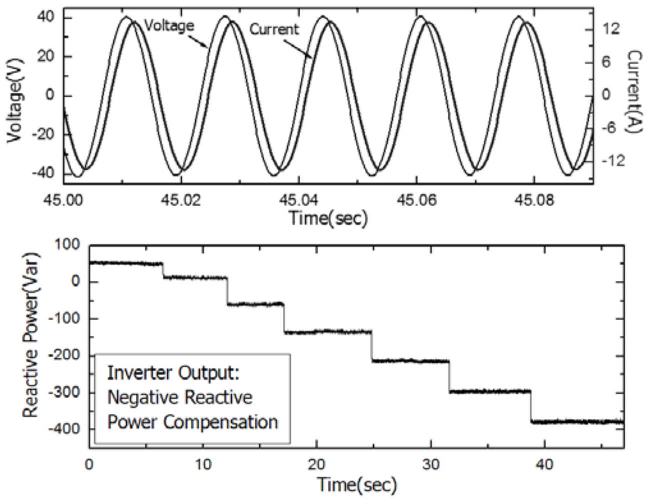


<Fig. 4> Test result of active power control and harmonic compensation

Fig. 5(a) shows the inverter output voltages and currents with positive reactive power compensation. Fig. 5(b) depicts the inverter output voltage and currents with negative reactive power compensation.



(a)



(b)

<Fig. 5> Experimental waveforms of the proposed system

4. Conclusions

This paper presents harmonics and reactive power compensation method by grid-connected PV generation system. It provides both active filter and reactive power compensation function. The implementation results demonstrate the effectiveness of the proposed system and control algorithm, which will contribute to effective operation of power distribution system.

Acknowledgements

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