분산 전원 시스템을 위한 계통연계 인버터의 간단한 고조파 보상 기법

라이 녹 바오, 김경화†
서울과학기술대학교

Simple Harmonic Compensation Scheme for a Grid-connected Inverter in Distributed Generation Systems

Ngoc Bao Lai, Kyeong-Hwa Kim
Seoul National University of Science and Technology

ABSTRACT

A new simple and effective scheme to improve power quality for a grid-connected inverter in distributed generation systems under distorted grid voltages will be presented. The proposed scheme is constructed with two controllers to regulate fundamental and harmonic components separately. In order to accomplish the proposed control scheme, the fourth order band pass filter is used to extract harmonic components from distorted gird voltages. Then, the undesired harmonic components are excellently suppressed by proportional decoupling controller. Experimental results are presented to verify the simplicity and effectiveness of proposed scheme.

1. Introduction

The steady growth in electricity demand, and the depletion of fossil energy have created increased interest in renewable energy resources. Because of the economy and stability of distributed generation (DG) systems, the injected renewable energy into the grid by mean of the DG system has been rapidly increasing in the last decade[1]. One of the demands present in all standards regarding a grid-tied system such as the grid-connected inverter in photovoltaic and wind turbine is the quality of distributed power. The total harmonic distortion in injected current needs to be met certain standards such as IEEE-519 or IEC 61000-3-2 in order to satisfy gird integration requirements[2][3].

For the purpose of improving power quality of DG systems, this paper proposes a novel simple and effective harmonic compensation scheme for a grid-connected inverter in DG systems. The proposed control strategy is based on the fact that the distorted grid voltages are expressed as fundamental and harmonic components, therefore the current controller may be designed individually in order to achieve the best control performance of each component.

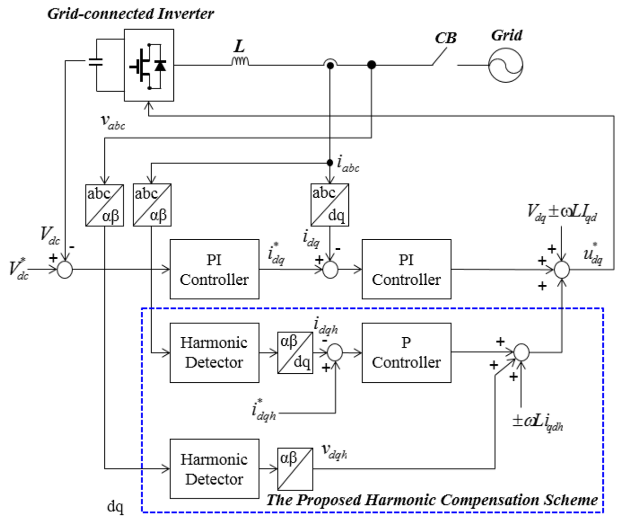


그림 1 제안된 기법의 블록선도
Fig. 1 The block diagram of the proposed control scheme.

2. Proposed Harmonic Compensation Scheme

Fig. 1 illustrates the block diagram of the proposed harmonic compensation scheme. The overall control scheme comprises the DC-link voltage controller, harmonic detector, and current controller. The current controller is composed of the conventional PI decoupling controller for the fundamental model and P decoupling controller for the harmonic model. The voltage equations expressed in dq-frame which is synchronized with the grid voltages are expressed as

$$v_{qs} = R\, i_{qs} + L\frac{d\, i_{qs}}{dt} + \omega L\, i_{ds} + e_{qs} \tag{1}$$

$$v_{ds} = R\, i_{ds} + L\frac{d\, i_{ds}}{dt} - \omega L\, i_{qs} + e_{ds} \tag{2}$$

† 교신저자

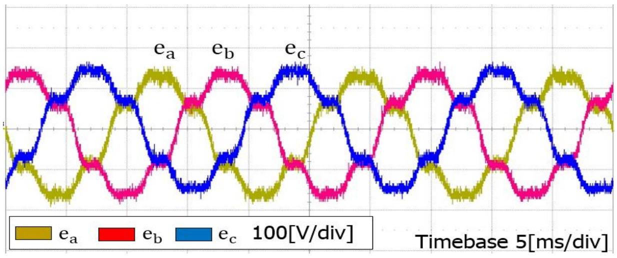


그림 2 왜곡된 3상 계통전압 파형
Fig. 2 Three-phase distorted grid voltages.

where $v_{qs} = V_{qs} + v_{qsh}$ and $v_{ds} = V_{ds} + v_{dsh}$ are inverter output fundamental and harmonic voltages in q-axis and d-axis, $i_{qs} = I_{qs} + i_{qsh}$ and $i_{ds} = I_{ds} + i_{dsh}$ are inverter output fundamental and harmonic currents in q-axis and d-axis, $e_{qs} = E_{qs} + e_{qsh}$ and $e_{ds} = E_{ds} + e_{dsh}$ are grid fundamental and harmonic voltages in q-axis and d-axis, ω is grid angular frequency, L is output filter inductance, and R is filter resistance.

The fundamental component of output inverter currents which is in charge of delivering the power from renewable resources to the grid is controlled by the PI decoupling controller because of its stability and accuracy. In order to overcome the poor disturbance rejection capability of the PI controller, a high gain P controller is introduced to provide fast dynamic response to periodic disturbance which is due to the distorted or unbalanced grid voltage. For the purpose of extracting harmonic components of the distorted grid voltage accurately without delay, the fourth order band pass filter is implemented in digital manner.

3. Experimental Results

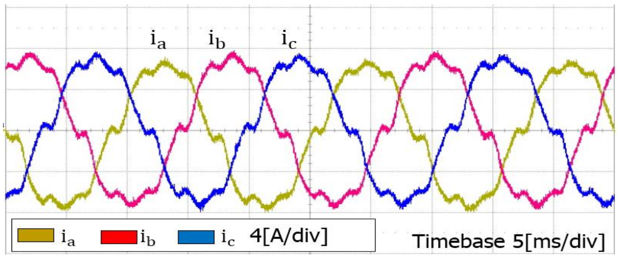
To prove the performance of the proposed control scheme, the experiments have been carried out. The overall DG system comprises a DSP-based controller, 2 kVA prototype of three-phase grid-connected inverter with an L filter, a transformer, and magnetic contactor for grid-connection.

Fig. 2 shows the distorted grid voltages with 10% of the fifth and seventh harmonics, respectively, 5% of the eleventh and thirteenth harmonics, respectively.

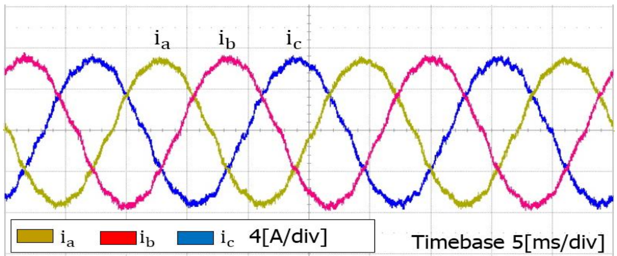
Fig. 3 shows the inverter output currents under the distorted grid voltages. As a result of an effective suppression of harmonic components by the proposed scheme, the inverter output currents in Fig. 3(b) is more sinusoidal than those in Fig. 3(a).

4. Conclusion

This paper has presented a simple harmonic compensation scheme for a grid-connected inverter.



(a)



(b)

그림 3 왜곡 계통전압 하에서 인버터의 출력전류 특성. a) 보상기법 적용 전. b) 보상기법 적용 후.
Fig. 3 Inverter output currents under distorted grid voltage condition. a) without harmonic compensation. b) with harmonic compensation.

The proposed scheme divides measured grid voltage into the fundamental and harmonic components by using the fourth order digital band pass filter in order to control the fundamental and harmonic components of inverter currents separately. The comparative experimental results have demonstrated the performance of the proposed scheme as well as its simplicity. Thus, the proposed scheme can be an attractive solution to improve the power quality of DG systems.

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