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An Advanced Current Control Strategy for Grid-Connected Distributed Generation under Non Linear Loads

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ABSTRACT

This paper introduces a new current control technique for distributed generation (DG). This current controller is implemented in the synchronous reference frame and composed of a proportional–integral controller and a repetitive controller (RC). An RC serves as a bank of resonant controllers, which can compensate a large number of harmonic components with a simple delay function. This proposed control method can be easily implemented into the traditional DG control system without any need of extra hardware. Despite the reduced number of sensors, the grid current quality is significantly improved compared with the traditional methods with the PI controller. The operation principle of the proposed control method is validated through simulated results

Keywords: *Distributed Generator, Grid-connected inverter, Harmonic compensation, nonlinear load, voltage distortion*

I. INTRODUCTION

The use of renewable energy sources, such as wind turbines, photovoltaic, and fuel cells, has greatly increased in recent decades to address concerns about the global energy crisis, depletion of fossil fuels, and environmental pollution problems. As a result, a large number of renewable energy sources have been integrated in power distribution systems in the form of distributed generation (DG). DG systems can offer many advantages over traditional power generation, such as small size, low cost, high efficiency, and clean electric power generation. A DG system is typically operated in a grid-connected mode where the maximum available power is extracted from energy sources and transferred to the utility grid In addition, to exploit full advantages of a DG system, the DG can be also equipped and operated with local loads, where the DG supplies power to the local load and transfers surplus power to the grid. In both configurations, i.e., with and without the local load, the prime objective of the DG system is to transfer a high-quality current (grid current) into the utility grid with the limited total harmonic distortion (THD) of the grid current at 5%, as recommended in the IEEE 1547 standards.

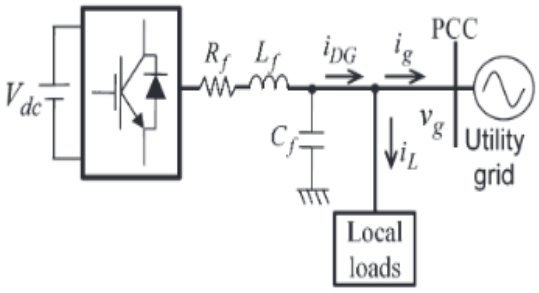


Fig 1. System configuration of a grid-connected DG system with local load

II. CONFIGURATION AND ANALYSIS OF SYSTEM

Fig 1 shows the system configuration of a three-phase Operating in grid-connected mode. The system consists of a dc power source, a voltage-source inverter (VSI), an output LC filter, local loads, and the utility grid. The purpose of the DG system is to supply power to its local load and to transfer surplus power to the utility grid at the PCC. To guarantee high-quality power, the current that the DG transfers to grid (i_g) should be balanced, sinusoidal, and have a low THD value. However, because of the distorted grid voltage and nonlinear local loads that typically exist in the power system, it is not easy to satisfy these requirements

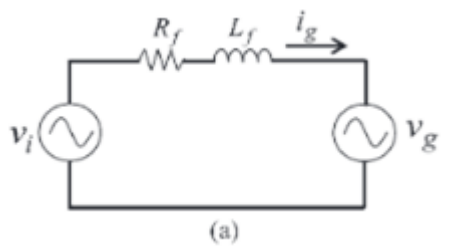
A Effect of Grid Voltage Distortion

To assess the impact of grid voltage distortion on the grid current performance of the DG, a model of the grid-connected DG system is developed, as shown in Fig. 2. In this model, the VSI of the DG is simplified as voltage source .The inverter transfers a grid current (ig) to the utility grid (v_g).For simplification purpose, it is assumed that the local load is not connected into the system.

The voltage equation of the system is given as

$$v_i - v_g - L_f \frac{di_g}{dt} - R_f i_g = 0 \qquad (1)$$

Where R_f and L_f are the equivalent resistance and inductance of the inductor L_f, respectively



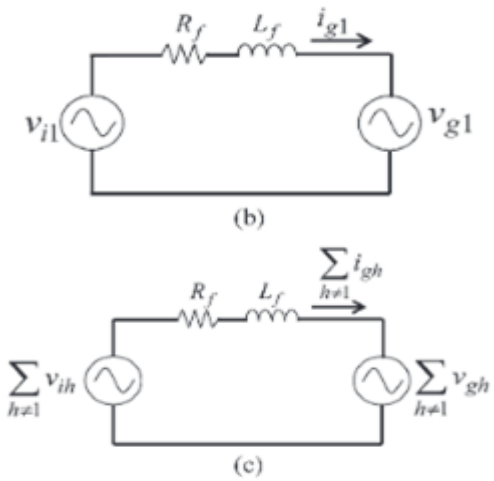


Fig 2. Model of grid-connected DG system under distorted grid voltage condition. (a) General condition; (b) at the fundamental frequency; and (c) at harmonic frequencies.

If both the inverter voltage and the grid voltage are composed of the fundamental and harmonic components as (2), the voltage equation of (1) can be decomposed into (3) and (4), and the system model shown in Fig. 2(a) can be expressed as Fig. 2(b) and (c), respectively.

$$v_i = v_{i1} + \sum_{h\neq1} v_{ih}$$
$$v_g = v_{g1} + \sum_{h\neq1} v_{gh} \qquad (2)$$

$$v_{i1} - v_{g1} - L_f \frac{di_{g1}}{dt} - R_f i_{g1} = 0 \qquad (3)$$

$$\sum_{h\neq1} v_{ih} - \sum_{h\neq1} v_{gh} - L_f \frac{d\left(\sum_{h\neq1} i_{gh}\right)}{dt} - R_f \sum_{h\neq1} i_{gh} = 0. \qquad (4)$$

Effect of Nonlinear Local Load

Fig. 3 shows the model of a grid-connected DG system witha local load, whereby the local load is represented as a current source i_L, and the DG is represented as a controlled current source i_{DG}. According to Fig. 3, the relationship of DG current i_{DG} , load current i_L, and grid current ig is described as

$$i_{DG} = i_L + i_g. \qquad (5)$$

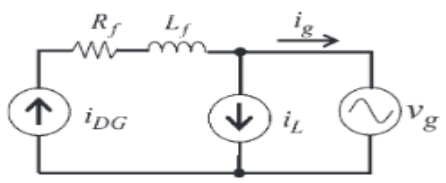


Fig. 3. Model of grid-connected DG system with nonlinear local load

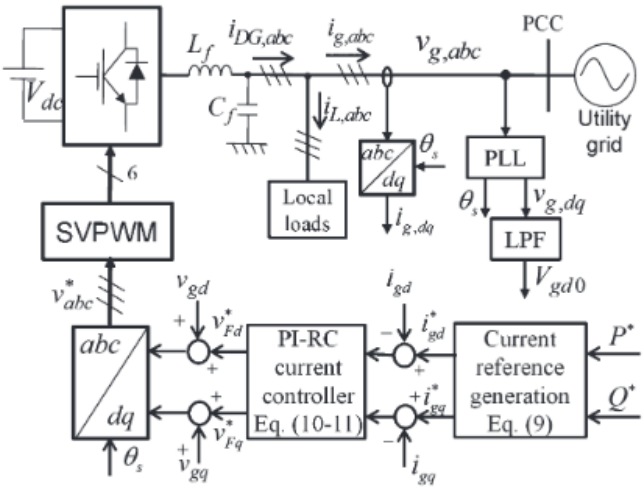


Fig 4: Overall block diagram of the proposed control strategy.

Assuming that the local load is nonlinear, e.g., a three-phase diode rectifier, the load current is composed of the fundamental and harmonic components as

$$i_L = i_{L1} + \sum_{h \neq 1} i_{Lh} \qquad (6)$$

Where iL1and iLh are the fundamental and harmonic compo
nents of the load current, respectively

substituting (6) into (5), we have

$$i_g = i_{DG} - \left(i_{L1} + \sum_{h \neq 1} i_{Lh} \right). \qquad (7)$$

III. PROPOSED CONTROL SCHEME

To enhance grid current quality, an advanced current Control strategy, as shown in Fig. 4, is introduced. Although there are several approaches to avoid the grid voltage sensors and a phase-locked loop (PLL), It contains the grid voltage sensor and a PLL for simple and effective implementing of the proposed algorithm, which is developed in the d–q reference frame. The proposed control scheme is composed of three main parts: the PLL, the current reference generation scheme, and the current controller. The control strategy operates without the local load current measurement and harmonic voltage analysis on the grid voltage. Therefore, it can be developed without requiring additional hardware. Moreover, it can simultaneously address the effect of nonlinear local load and distorted grid voltage on the grid current quality

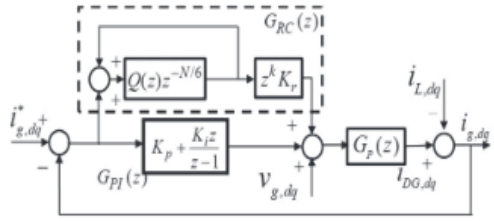


Fig. 5. Block diagram of the current controller.

IV.SIMULATION RESULTS

A simulation model of the DG system is built by PSIM simulation software to verify the effectiveness of the proposed control method. The system parameters are given in Table I. In the simulation, three cases are taken into count.

1) Case I: The grid voltage is sinusoidal and the linear local
load is used.
2) Case II: The grid voltage is sinusoidal and the nonlinear
local load is used.
3) Case III: The grid voltage is distorted and the nonlinear
local load is used.

harmonic, 3% 7th harmonic, 1% 11th harmonic, and 1% 13th harmonic.The THD of grid voltage is about 4.82%. This grid voltage condition complies with the IEEE 519-1992 harmonic restriction standards, where the THD of grid voltage is less than 5%.In all test cases, the reference grid current is set at i∗gd=10A and i∗gq=0, and the conventional PI current controller and the proposed current controller are investigated to compare their
control performances.

Fig. 6. depicts the steady-state performance of the grid-connected DG by using the conventional PI current controller, in which the waveforms of grid voltage (vg,abc), grid current (ig,abc), local load current (iL,abc), and DG current (iDG,abc) are plotted. As shown in Fig. 11, the PI current controller is able to offer a good performance only in Case I, when the grid voltage is ideal sinusoidal and the local load is linear. In the other circumstances, due to the effect of distorted grid voltageand the nonlinear local load, the PI current controller is unable to transfer a sinusoidal grid current to the utility grid. In fact, because of the popular use of nonlinear loads in the DG local load and distribution system, the ideal sinusoidal

condition of the grid voltage is very rare. On the other hand, the conditions, as given in Cases II and III, frequentlcontroller is insufficient to offer a good quality of the grid current.y occur in practice. As a result, the conventional PI

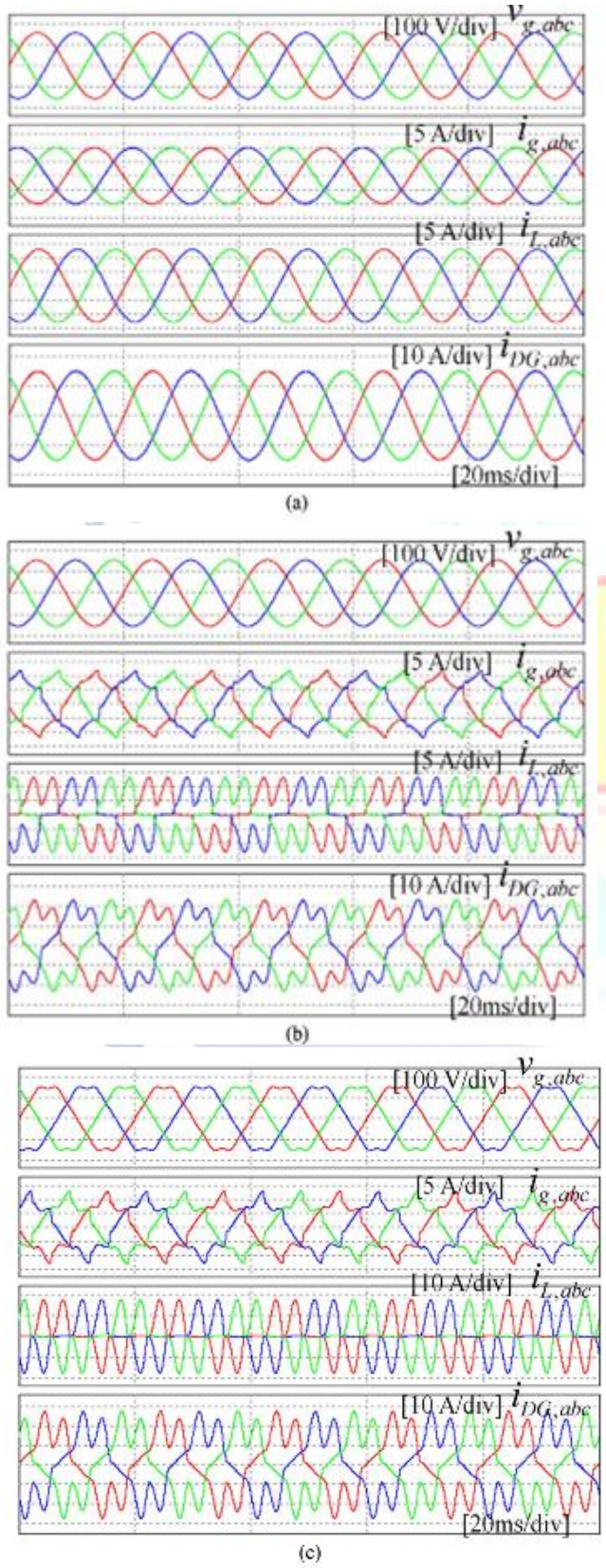


Fig.6. Simulation results with the PI current controller: (a) Case I;(b) Case II; and (c) Case III

In Cases I and II, the grid voltage is assumed as a pure sinusoidal waveform. In Case III, the distorted grid voltage is supplied with the harmonic components: 3.5% 5th harmonic, 3% 7th harmonic, 1% 11th harmonic, and 1% 13th harmonic.The THD of grid voltage is about 4.82%. This grid voltage condition complies with the IEEE 519-1992 harmonic restriction standards, where the THD of grid voltage is less than 5%.In all test cases, the reference grid current is set at i∗gd=10A and i∗gq=0, and the conventional PI current controller and the proposed current controller are investigated to compare their control performances.

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To demonstrate the superiority of the proposed current controller over the traditional PI controller, the DG system with the proposed current controller is also simulated, and the results are shown. As shown in the results, the proposed control strategy can provide a good quality grid current, i.e., sinusoidal grid currents, despite the distorted grid voltage and nonlinear local load conditions. Therefore, with the aid of the RC in the proposed current controller, the distorted grid voltage and nonlinear load current no longer affect the grid current quality.

Moreover, the proposed control method can bring the THD of the grid current to less than 2% in all cases, as given in Table II, which complies completely with IEEE 1547 standards. These results obviously validate the effectiveness of the proposed control approach

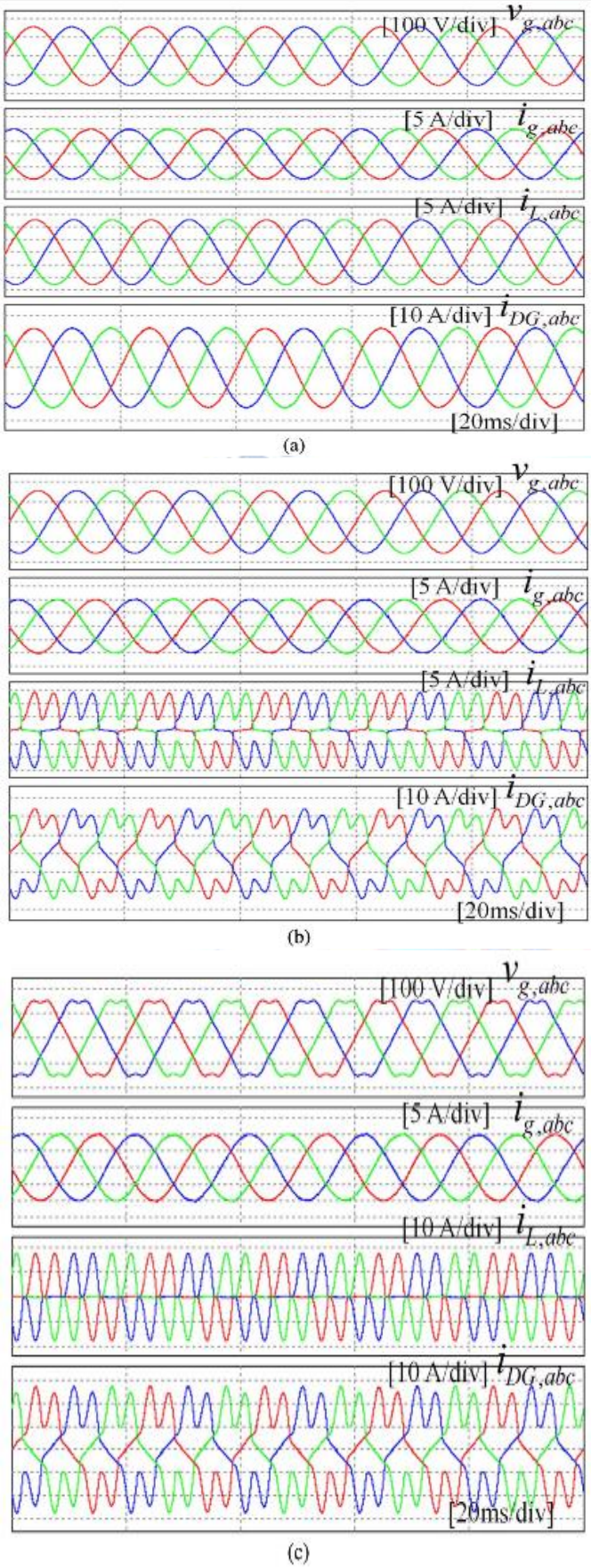
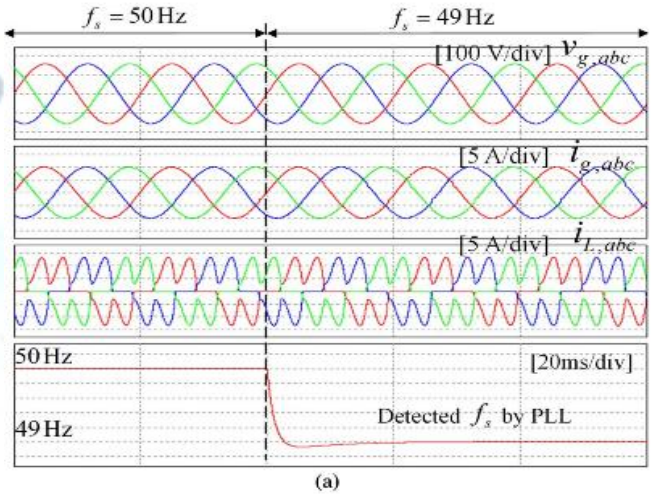


Fig 7. Simulation results with the proposed PI-RC current controller:(a) Case I; (b) Case II; and (c) Case III.

TABLE II
SUMMARY OF THD VALUES OF GRID CURRENT WITH PI AND PROPOSED CURRENT CONTROLLER

	PI current controller			Proposed current controller		
	Case I	Case II	Case III	Case I	Case II	Case III
THD of i_g	1.57%	11.9%	18.6%	1.57%	1.76%	1.85%



In addition, to assess the feasibility of the proposed current controller under grid frequency variations, simulation results of the proposed PI-RC current controller, when the grid frequency changes from 50 to 49 Hz and from 50 to 51 Hz, are illustrated in Fig. 8 (a) and (b), respectively. In Fig.8, the PLL quickly detects the grid frequency variation and accurately compensates it within a short period of time, i.e., less than 10 ms without any influence on the grid current. Therefore, we can say that the proposed current controller is able to maintain a high-quality grid current even under the grid frequency variations.

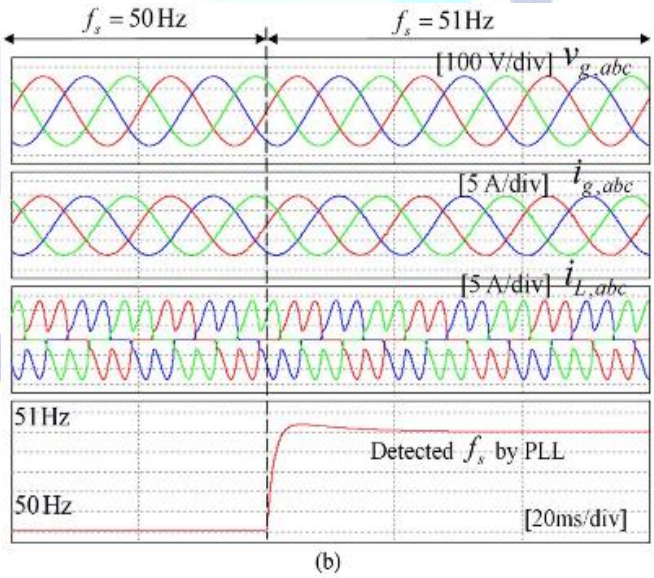


Fig. 8. Simulation results of the proposed PI-RC current controller under grid frequency variations (a) from 50 to 49 Hz and (b) from 50 to 51 Hz

In addition, to assess the feasibility of the proposed current controller under grid frequency variations, simulation results of the proposed PI-RC current controller, when the grid frequency changes from 50 to 49 Hz and from 50 to 51 Hz, are illustrated in Fig. 8 (a) and (b), respectively. In Fig.8, the PLL quickly detects the grid frequency variation and accurately compensates it within a short period of time, i.e., less than 10 ms without any influence on the grid current. Therefore, we can say that the proposed current controller is able to maintain a high-quality grid current even under the grid frequency variations.

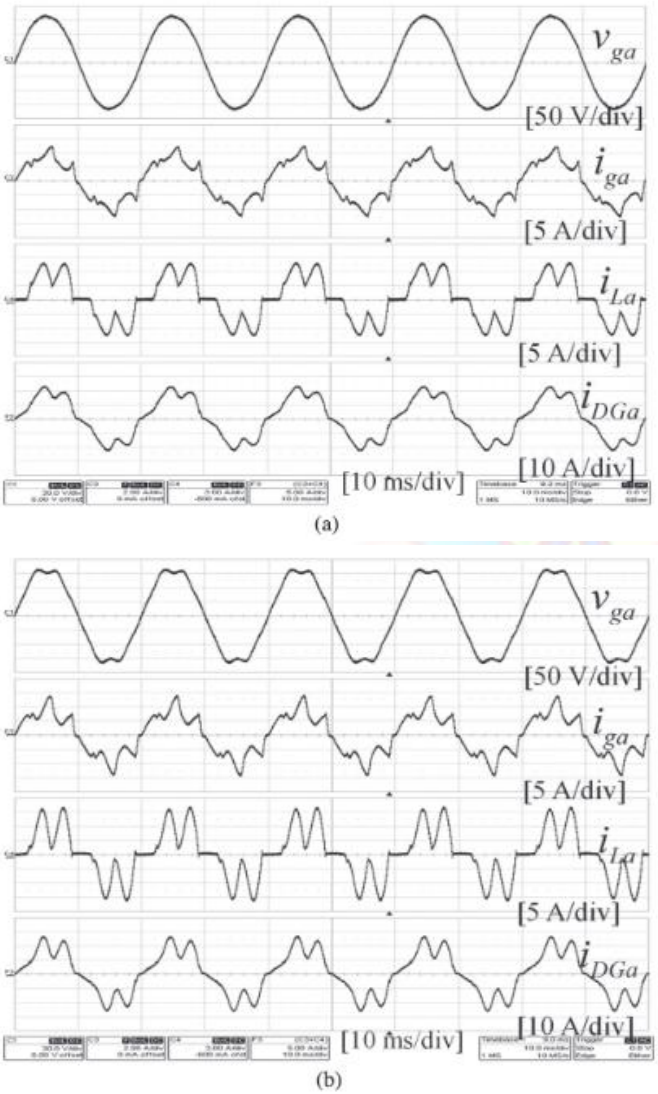


Fig. 9. Experimental results of the grid-connected DG with the conventional PI current controller: (a) Case II; and (b) Case III

V.CONCLUSION

The proposed advanced current control strategy for the grid-connected DG to simultaneously eliminate the effect of grid voltage distortion and nonlinear local load on the grid current. The simulation results established that the DG with the proposed current controller can sufficiently transfer a sinusoidal current to the utility grid, de-spite the nonlinear local load and distorted grid voltage conditions. The proposed current control scheme can be implemented without the local load current sensor and harmonic analysis of the grid voltage. Despite the reduced number of current sensors, the quality of the grid current is significantly improved: the THD value of the grid current is decreased considerably compared with that achieved by using the conventional PI current controller. In addition, the proposed current controller also maintained a good quality of grid current under grid frequency variations. Moreover, the dynamic response of the grid current controller was also greatly enhanced compared with that of the traditional RC, due to the PI and RC combination and the reduced RC delay time.

REFERENCES

[1] R. C. Dugan and T. E. McDermott, "Distributed generation," IEEE Ind. Appl. Mag, vol. 8, no. 2, pp. 19–25, Mar./Apr. 2002.

[2] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, Overview of control and grid synchronization for distributed power generation systems," IEEE Trans. Ind. Electron. , vol. 53, no. 5, pp. 1398–1409, Oct. 2006.

[3] J. A. Suul, K. Ljokelsoy, T. Midtsund, and T. Undeland, "Synchronous reference frame hysteresis current control for grid converter applications," IEEE Trans. Ind. Appl. , vol. 47, no. 5, pp. 2183–2194, Sep./Oct. 2011.

[4] Q. Zeng and L. Chang, "An advanced SVPWM-based predictive current controller for three-phase inverters in distributed generation systems,"IEEE Trans. Ind. Electron., vol. 55, no. 3, pp. 1235–1246, Mar. 2008.

[5] S. Buso and P. Mattavelli, "Digital control in power electronics," in Synthesis Lectures on Power Electronics . San Rafael, CA, USA: organ & Claypool, 2006.

[6] C. A. Busada, S. Gomez Jorge, A. E. Leon, and J. A. Solsona, "Current controller based on reduced order generalized integrators for distributed generation systems," IEEE Trans. Ind. Electron., vol. 59, no. 7, pp. 2898–2909, Jul. 2012.

[7] M. Liserre, R. Teodorescu, and F. Blaabjerg, "Multiple harmonics control for three-phase grid converter systems with the use of PI-RES current controller in a rotating frame,"IEEE Trans. Power Electron. vol. 21,no. 3, pp. 836–841, May 2006.

[8] M. Castilla, J. Miret, A. Camacho, J. Matas, and L. G. de Vicuna, "Reduc-tion of current harmonic distortion in three-phase grid-connected photo-voltaic inverters via resonant current control,"

IEEE Trans. Ind. Electron.,vol. 60, no. 4, pp. 1464–1472, Apr. 2013.

[9] R.-J. Wai, C.-Y. Lin, Y.-C. Huang, and Y.-R. Chang, "Design of high-performance stand-alone and grid-connected inverter for distributed generation applications,"IEEE Trans. Ind. Electron., vol. 60, no. pp. 1542–1555, Apr. 2013.

[10] I. J. Balaguer, Q. Lei, S. Yang, U. Supatti, and F. Z. Peng, "Control for grid-connected and intentional islanding operations of distributed power generation," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 147–157,Jan. 2011.