AN OPTIMAL CONTROL OF GRID CONNECTED MULTILEVEL INVERTER

K. Ravi[1], G. Balram[2]

[1] Student, EEE Department, Avanthi Institute of Engineering & technology, Telangana, India
[2] Asst.Prof, EEE Department, Avanthi Institute of Engineering & technology, Telangana, India

ABSTRACT

In this work a unified control strategy that enables both islanded and grid-tied operations of three-phase three-level inverter in distributed generation controlled by using multilevel space vector pulse width modulation technique, with no need for switching between two corresponding controllers or critical islanding detection. The proposed control strategy composes of an inner inductor current loop, and a novel voltage loop in the synchronous reference frame. The inverter is regulated as a current source just by the inner inductor current loop in grid-tied operation, and the voltage controller is automatically activated to regulate the load voltage upon the occurrence of islanding. Furthermore, the waveforms of the grid current in the grid-tied mode and the load voltage in the islanding mode are distorted under nonlinear local load with the conventional strategy. A unified load current feed forward with proposed control presents the detailed analysis and the proposed system. The effectiveness of the proposed control strategy is simulated by using MATLAB/Simulink software results.

Keyword: *- Multilevel inverter, DG, Grid*

1. INTRODUCTION

Now a days the Distributed generation (DG) is emerging as a viable alternative when renewable or nonconventional energy resources are available, such as wind turbines, photovoltaic arrays, fuel cells, micro turbines [1]. Most of these resources are connected to the utility through power electronic interfacing converters, i.e., three-phase inverter. Moreover, DG is a suitable form to offer high reliable electrical power supply, as it is able to operate either in the grid-tied mode or in the islanded mode [2]. In the grid-tied operation, DG deliveries power to the utility and the local critical load. Upon the occurrence of utility outage, the islanding is formed. Under this circumstance, the DG must be tripped and cease to energize the portion of utility as soon as possible according to IEEE Standard 929-2000 [4]. However, in order to improve the power reliability of some local critical load, the DG should disconnect to the utility and continue to feed the local critical load [5]. In this situation, the inverter is always regulated as a voltage source by the voltage loop, and the quality of the load voltage can be guaranteed during the transition of operation modes. However, the limitation of this approach is that the dynamic performance is poor, because the bandwidth of the external power loop, realizing droop control, is much lower than the voltage loop. Moreover, the grid current is not controlled directly, and the issue of the inrush grid current during the transition from the islanded mode to the grid-tied mode always exists, even though phase-locked loop (PLL) and the virtual inductance are adopted [15]. The hybrid voltage and current mode control is a popular alternative for DG, in which two distinct sets of controllers are employed [17]–[40]. The inverter is controlled as a current source by one sets of a controller in the grid-tied mode, while as a voltage source by the other sets of controller in the islanded mode. As the voltage loop or current loop is just utilized in this approach, a nice dynamic performance can be achieved. Besides, the output current is directly controlled in the grid-tied mode, and the inrush grid current is almost eliminated. In the hybrid voltage and current mode control, there is a need to switch the controller when the operation mode of DG is changed. During the interval from the occurrence of utility outage and switching the controller to voltage mode, the load voltage is neither fixed by the utility, nor regulated by the DG, and the length of the time interval is determined by the islanding detection process. Therefore, the main issue in this approach is that it makes the quality of the load voltage heavily reliant on the speed and accuracy of the islanding detection method [6]–[10]. Another issue associated with the aforementioned approaches is the waveform quality of the grid current and the load voltage under nonlinear local load. In the grid-tied mode, the output current of DG is generally desired to be pure sinusoidal [18]. When the nonlinear local load is fed, the harmonic component of the load current will fully flow into the utility. A single-phase DG, which injects harmonic current into the utility for mitigating the harmonic component of the grid current, is presented.

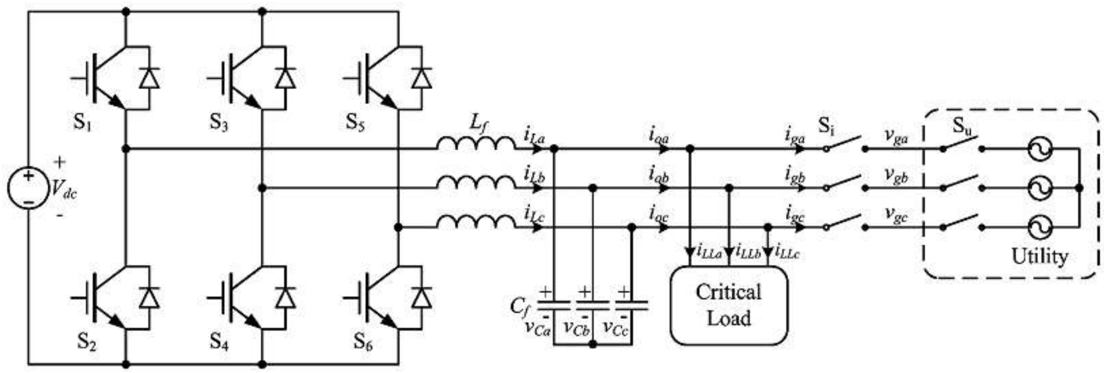

Fig.1.Schematic diagram of the DG based on the proposed control strategy.

The voltage mode control is enhanced by controlling the DG to emulate a resistance at the harmonic frequency, and then the harmonic current flowing into utility can be mitigated. In the islanded mode, the nonlinear load may distort the load voltage [43], and many control schemes have been proposed to improve the quality of the load voltage, including a multi loop control method, resonant controllers, sliding mode control. However, existing control strategies, dealing with the nonlinear local load in DG, mainly focus on either the quality of the grid current in the grid-tied mode or the one of the load voltage in the islanded mode, and improving both of them by a unified control strategy is seldom. This paper proposes a unified control strategy that avoids the aforementioned shortcomings. First, the traditional inductor current loop is employed to control the three-phase inverter in DG to act as a current source with a given reference in the synchronous reference frame (SRF). Second, a novel voltage controller is presented to supply reference for the inner inductor current loop, where a proportional-plus-integral (PI) compensator and a proportional (P) compensator are employed in D-axis and Q-axis, respectively. In the grid-tied operation, the load voltage is dominated by the utility, and the voltage compensator in D-axis is saturated, while the output of the voltage compensator in Q-axis is forced to be zero by the PLL. Therefore, the reference of the inner current loop cannot regulated by the voltage loop, and the DG is controlled as a current source just by the inner current loop. Upon the occurrence of the grid outage, the load voltage is no more determined by the utility, and the voltage controller is automatically activated to regulate the load voltage. These happen naturally, and, thus the proposed control strategy does not need a forced switching between two distinct sets of controllers. Further, there is no need to detect the islanding quickly and accurately, and the islanding detection method is no more critical in this approach. Moreover, the proposed control strategy, benefiting from just utilizing the current and voltage feedback control, endows a better dynamic performance, compared to the voltage mode control. Third, the proposed control strategy is enhanced by introducing a unified load current feed forward, in order to deal with the issue caused by the nonlinear local load, and this scheme is implemented by adding the load current into the reference of the inner current loop. In the grid-tied mode, the DG injects harmonic current into the grid for compensating the harmonic component of the grid current, and thus, the harmonic component of the grid current will be mitigated. Moreover, the benefit of the proposed load current feed forward can be extended into the islanded operation mode, due to the improved quality of the load voltage.

2. THREE-PHASE THREE-LEVEL NEUTRAL POINT CLAMPED MULTI-LEVEL INVERTER

The three phase diode clamped multi-level inverter topology shown in Fig. 2 is invented by Nabae et al will have the space vector modulation diagram of three level as shown in Fig. 3. There are six sectors (S_1 to S_6) in which again each sector is having four regions A_i, B_i, C_i and D_i where $i=1.2\dots6$ corresponding to all sectors and total of 27 i.e. 3^3 switching states are available in this space vector diagram. As the level n increase the number of regions in each sector, switching states and on-time calculations will increase. This can be little complex when moving to the higher level. [12]

Fig.2 Three-level NPC inverter

The most effective strategies to control the multilevel inverters are the PWM. The SVPWM technique is the preferred method which includes reduced power loss. Three-level NPC inverter is shown in Fig. 2. In each leg, there are four active switches (S_1 to S_4) along with four anti-parallel diodes (D_1 to D_4). The capacitors split the DC input on the DC side and also provide a neutral point *N*. When switches S_2 and S_3 are ON, the neutral point connect to the output terminal 'A' through one of the clamping diodes. The voltage applied to the capacitors is E, which is V_{dc}.

TABLE 1 THREE-LEVEL INVERTER SWITCHING STATES

Fig. 1. **Switc hing state**	**Device switching state (phase A)**				**Output pole Voltage**
	S_1	**S_2**	**S_3**	**S_4**	
2	on	on	off	off	+E
1	off	on	on	off	0
0	off	off	on	on	-E

3 MODELING AND CONTROL OF INVERTER INTERFACED DG UNITS

Basically each DG unit may have DC type or rectified generation unit (Fuel cell, solar cell, wind turbine, micro turbine…), storage devices, DC-DC converter, DC-AC inverter, filter, and transformer for connecting to loads or utility in order to exchange power. Model and dynamic of each of this part may have influence in system operation. But here for simplification it is considered that DC side of the units has sufficient storage and considered as a constant DC source. Hence only DC-AC inverter modeling and control investigated in this paper.

A circuit model of a three-phase DC to AC inverter with LC output filter is further described in Figure As shown in the figure, the system consists of a DC voltage source (Vdc), a three- phase PWM inverter, an output filter (Lf and C with considering parasitic resistance of filter- Rf). Sometimes a transformer may be used for stepping up the output voltage and hence Lf can be transformer inductance.

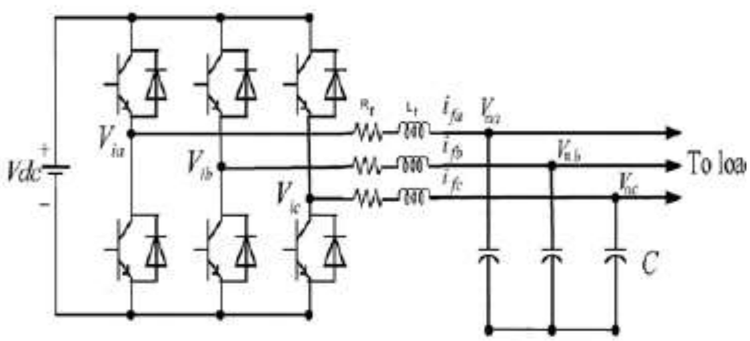

Fig.3 PWM inverter diagram

There are two ways for controlling an inverter in a distributed generation system

A. PQ Inverter Control

This type of control is adopted when the DG unit system is connected to an external grid or to an island of loads and more generators. In this situation, the variables controlled by the inverter are the active and reactive power injected into the grid, which have to follow the setpoints Pref and Qref, respectively. These set points can be chosen by the customer or by a central controller. The PQ control of an inverter can be performed using a current control technique in qd reference frame which the inverter current is controlled in amplitude and phase to meet the desired set-points of active and reactive power .With the aim of Park transform and equations between inverter input and output, the inverter controller block diagram for supplying reference value of Pref and Qref is as figures. For the current controller, two Proportional-Integral (PI) regulators have been chosen in order to meet the requirements of stability of the system and to make the steady state error be zero. With this control scheme, it is possible to control the inverter in such way that injects reference value of Pref, Qref into other part of stand-alone network. When the output voltage is needed to be regulated, the PV control scheme that is similar to PQ mode with feedback of voltage used to adjust Qref.

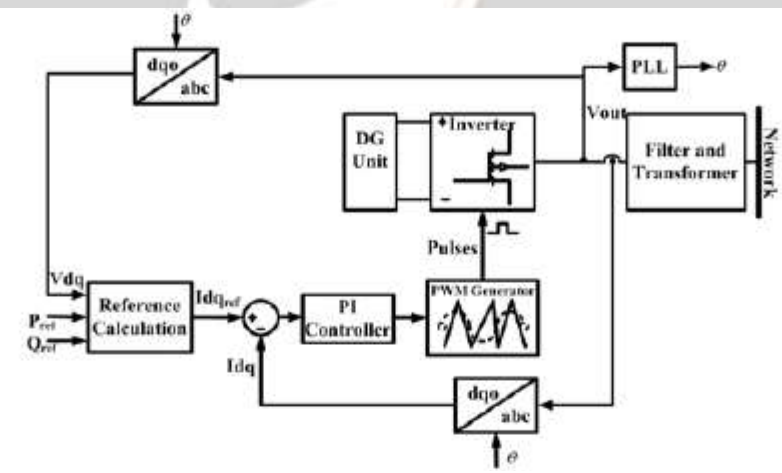

Fig.4 PQ control scheme of inverter

B. Vf Inverter Control

This controller has to act on the inverter whenever the system is in stand-alone mode of operation. In fact in this case it must regulate the voltage value at a reference bus bar and the frequency of the whole grid. A regulators work in order to keep the measured voltages upon the setpoints. Moreover the frequency is imposed through the modulating signals of the inverter PWM control by mean of an oscillator. A simple PI controller can regulate bus voltage in reference value with getting feedback of real bus voltage. Figure outlines this control strategy. In this case it is obvious that the DG unit should have storage device in order to regulate the power and voltage.

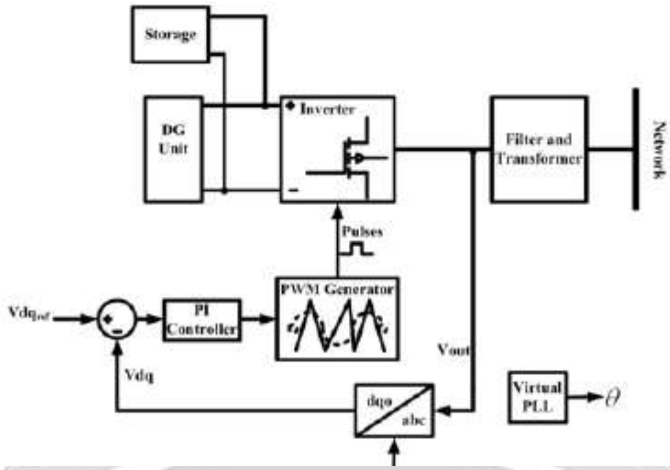

Fig.5 Vf control scheme of inverter

4. PROPOSEDCONTROLSTRATEGY

A. Power Stage

This paper presents a unified control strategy for a three phase inverter in DG to operate in both islanded and grid-tied modes. The schematic diagram of the DG based on the proposed control strategy is shown by Fig. 1. The DG is equipped with a three-phase interface inverter terminated with a LC filter. The primary energy is converted to the electrical energy, which is then converted to dc by the front-end power converter, and the output dc voltage is regulated by it. Therefore, they can be represented by the dc voltage source Vdc in Fig. 1. In the ac side of inverter, the local critical load is connected directly. It should be noted that there are two switches, denoted by Su and Si , respectively, in Fig. 1, and their functions are different. The inverter transfer switch Si is controlled by the DG, and the utility protection switch Suis governed by the utility. When the utility is normal, both switches Si and Suare ON, and the DG in the grid-tied mode injects power to the utility. When the utility is in fault, the switch Suis tripped by the utility instantly, and then the islanding is formed. When the utility is restored, the DG should be resynchronized with the utility first, and then the switch Si is turned ON to connect the DG with the grid.

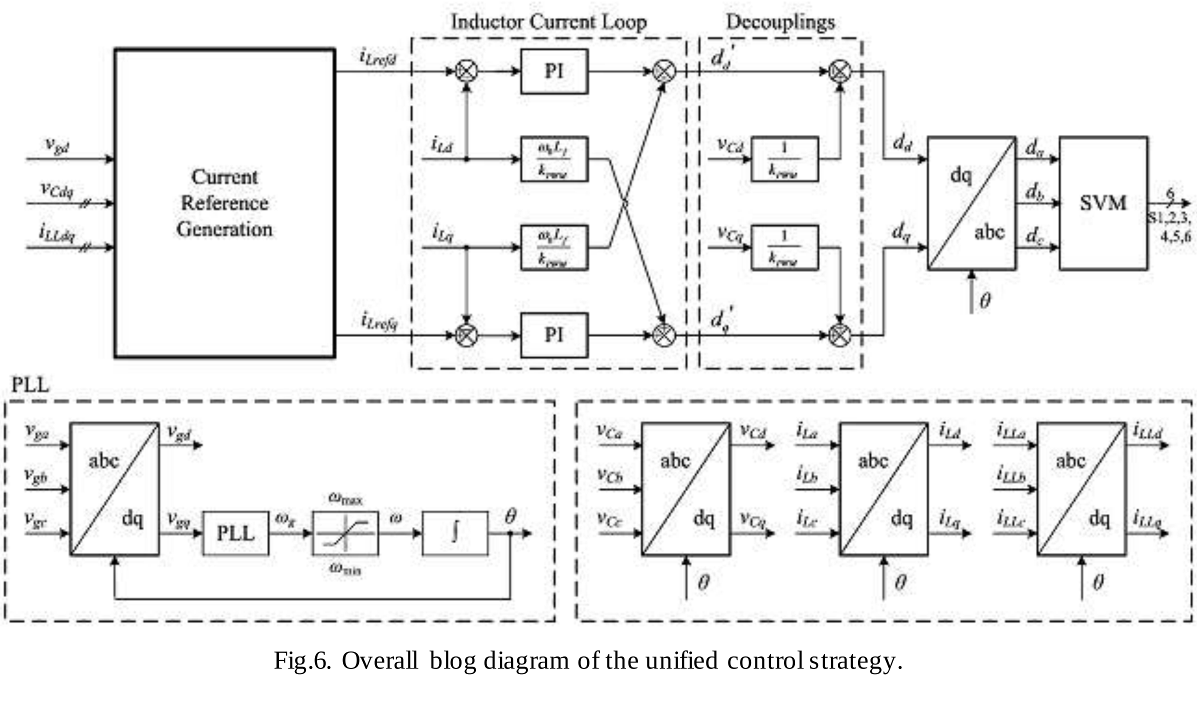

Fig.6. Overall blog diagram of the unified control strategy.

B. Basic Idea

With the hybrid voltage and current mode control [17]–[40], the inverter is controlled as a current source to generate the reference power PDG+jQDG in the grid-tied mode. And its output power PDG+jQDG should be the sum of the power injected to the grid Pg +jQg and the load demand Pload + jQload, which can be expressed as follows by assuming that the load is represented as a parallel RLC circuit

$$P_{\mathrm{load}} = \frac{3}{2} \cdot \frac{V_m^2}{R} \qquad (1)$$

$$Q_{\mathrm{load}} = \frac{3}{2} \cdot V_m^2 \cdot \left(\frac{1}{\omega L} - \omega C \right). \qquad (2)$$

In (1) and (2), Vmandωrepresent the amplitude and frequency of the load voltage, respectively. When the nonlinear local load is fed, it can still be equivalent to the parallel RLC circuit by just taking account of the fundamental component. During the time interval from the instant of islanding happening to the moment of switching the control system to voltage mode control, the load voltage is neither fixed by the utility no regulated by the inverter, so the load voltage may drift from the normal range [6]. And this phenomenon can be explained as below by the power relationship. During this time interval, the inverter is still controlled as a current source, and its output power is kept almost unchanged. However, the power injected to utility decreases to zero rapidly, and then the power consumed by the load will be imposed to the output power of DG. If both active power Pg and reactive power Qg injected into the grid are positive in the grid-tied mode, then Pload and Qload will increase after the islanding happens, and the amplitude and frequency of the load voltage will rise and drop, respectively, according to (1) and (2). With the previous analysis, if the output power of inverter PDG+jQDG could be regulated to match the load demand by changing the current reference before the islanding is confirmed, the load voltage excursion will be mitigated. And this basic idea is utilized in this paper. In the proposed control strategy, the output power of the inverter is always controlled by regulating the three-phase inductor currentiLabc, while the magnitude and frequency of the load voltage vCabcare monitored. When the islanding happens, the magnitude and frequency of the load voltage may drift from the normal range, and then they are controlled to recover to the normal range automatically by regulating the output power of the inverter.

C. Control Scheme

Fig. 2 describes the overall block diagram for the proposed unified control strategy, where the inductor currentiLabc,the utility voltagevgabc, the load voltagevCabc, and the load current iLLabcare sensed. And the three-phase inverter is controlled in the SRF, in which, three phase variable will be represented by dc quantity. The control diagram is mainly composed by the inductor current loop, the PLL, and the current reference generation module. In the inductor current loop, the PI compensator is employed in bothD- andQ-axes, and a decoupling of the cross coupling denoted by ω0Lf/k PWM is implemented in order to mitigate the couplings due to the inductor. The output of the inner current loopddq , together with the decoupling of the capacitor voltage denoted by 1/kPWM, sets the reference for the standard space vector modulation that controls the switches of the three-phase inverter. It should be noted thatkPWMdenotes the voltage gain of the inverter, which equals to half of the dc voltage in this paper.

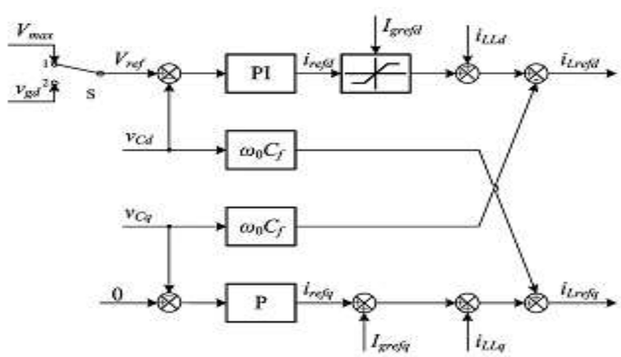

Fig.7. Block Diagram of the current reference generation module.

The PLL in the proposed control strategy is based on the SRF PLL [50], [51], which is widely used in the three-phase power converter to estimate the utility frequency and phase. Furthermore, a limiter is inserted between the PI compensator GPLL and the integrator, in order to hold the frequency of the load voltage within the normal range in the islanded operation. In Fig. 2. The new part in this paper is the current reference generation module shown in Fig. 2, which regulates the current reference to guarantee the power match between the DG and the local load and enables the DG to operate in the islanded mode. Moreover, the unified load current feedforward, to deal with the nonlinear local load, is also implemented in this module. The block diagram of the proposed current reference generation module is shown in Fig. 3, which provides the current reference for the inner current loop in both grid-tied and islanded modes. In this module, it can be found that an unsymmetrical structure is used in D- and Q-axes. The PI compensator is adopted inD-axes, while the P compensator is employed in Q-axis. Besides, an extra limiter is added in theD-axis. Moreover, the load current feedforward is implemented by adding the load currentiLLdqto the final inductor current reference iLref dq. The benefit brought by the unique structure in Fig. 3 can be represented by two parts: 1) seamless transfer capability without critical islanding detection; and 2) power quality improvement in both grid-tied and islanded operations. The current reference iLredqcomposes of four parts inD-andQ-axes respectively: 1) the output of voltage controllerirefdq; 2) the grid current referenceIgrefdq; 3) the load currentiLLdq; and 4) the current flowing through the filter capacitorCf. In the grid-tied mode, the load voltagevCdqis clamped by the utility. The current reference is irrelevant to the load voltage, due to the saturation of the PI compensator inD-axis, and the output of the P compensator being zero inQ-axis, and thus, the inverter operates as a current source. Upon occurrence of islanding, the voltage controller takes over automatically to control the load voltage by regulating the current reference.

5. OPERATION PRINCIPLE OF DG

The operation principle of DG with the proposed unified control strategy will be illustrated in detail in this section, and there are in total four states for the DG, including the grid-tied mode, transition from the grid-tied mode to the islanded mode, the islanded mode, and transition from the islanded mode to the grid-tied mode

A.Grid-Tied Mode

When the utility is normal, the DG is controlled as a current source to supply given active and reactive power by the inductor current loop, and the active and reactive power can be given by the current reference ofD- andQ-axis independently. First, the phase angle of the utility voltage is obtained by the PLL, which consists of a Park transformation expressed by (3), a PI compensator, a limiter, and an integrator.

$$\begin{pmatrix} x_d \\ x_q \end{pmatrix} = \frac{2}{3}\begin{pmatrix} \cos\theta & \cos\left(\theta - \frac{2}{3}\pi\right) & \cos\left(\theta + \frac{2}{3}\pi\right) \\ -\sin\theta & -\sin\left(\theta - \frac{2}{3}\pi\right) & -\sin\left(\theta + \frac{2}{3}\pi\right) \end{pmatrix} \times \begin{pmatrix} x_a \\ x_b \\ x_c \end{pmatrix}. \quad (3$$

Second, the filter inductor current, which has been transformed into SRF by the Park transformation, is fed back and compared with the inductor current referenceiLrefdq, and the inductor current is regulated to track the reference iLrefdq by the PI compensator GI.

The reference of the inductor current loopiLrefdq seems complex and it is explained as below. It is assumed that the utility is stiff, and the three-phase utility voltage can be expressed as

$$\begin{cases} v_{ga} = V_g \cos\theta^* \\ v_{gb} = V_g \cos\left(\theta^* - \frac{2\pi}{3}\right) \\ v_{gc} = V_g \cos\left(\theta^* + \frac{2\pi}{3}\right) \end{cases} \quad (4)$$

whereVgis the magnitude of the grid voltage, andθ ∗ is the actual phase angle. By the Park transformation, the utility voltage is transformed into the SRF, which is shown as

$$\begin{cases} v_{gd} = V_g \cos(\theta^* - \theta) \\ v_{gq} = V_g \sin(\theta^* - \theta). \end{cases} \quad (5)$$

vgq is regulated to zero by the PLL, so vgdequals the magnitude of the utility voltageVg. As the filter capacitor voltage equals the utility voltage in the gird-tied mode,vCdequals the magnitude of the utility voltageVg, and vCqequals zero, too.

In the D-axis, the inductor current reference iLrefdcan be expressed by (6) according to Fig. 3

$$i_{Lrefd} = I_{grefd} + i_{LLd} - \omega_0 C_f \cdot v_{Cq}. \quad (6)$$

In theQ-axis, the inductor current referenceiLrefqconsists of four parts as

$$i_{Lrefq} = v_{Cq} \cdot k_{Gvq} + I_{grefq} + i_{LLq} + \omega_0 C_f \cdot v_{Cd} \quad (7)$$

Where kGvq is the parameter of the P compensator, denoted by GVQ in the following part. The first part is the output of GVQ

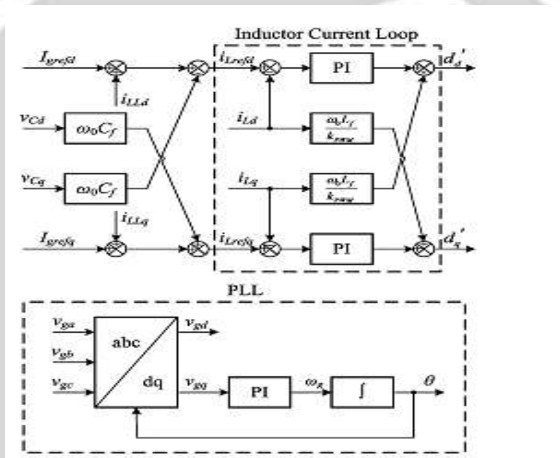

Fig.8. Simplified block diagram of the control strategy when DG operates in gried tied mode.

which is zero as thevCqhas been regulated to zero by the PLL. The second part is the given current referenceIgrefq, and the third part represents the load current in Q-axis. The final part is the proportional part−ω0Cf ·vCd, which is fixed since vCd depends on the utility voltage. Therefore, the current reference iLrefq cannot be influenced by the external voltage loop and is determined by the given referenceIgrefq and the load current iLLq. With the previous analysis, the control diagram of the inverter can be simplified as Fig. 4 in the grid-tied mode, and the inverter is controlled as a current source by the inductor current loop with the inductor current reference being determined by the current reference Igref dq and the load current iLLdq. In other words, the inductor current tracks the current reference and the load current. If the steady state error is zero,Igrefdq represents the grid current actually, and this will be analyzed in the next section.

4 SIMULATION RESULTS

The simulated results are presented in this section for validating steady-state and dynamic performances of this proposed DG.

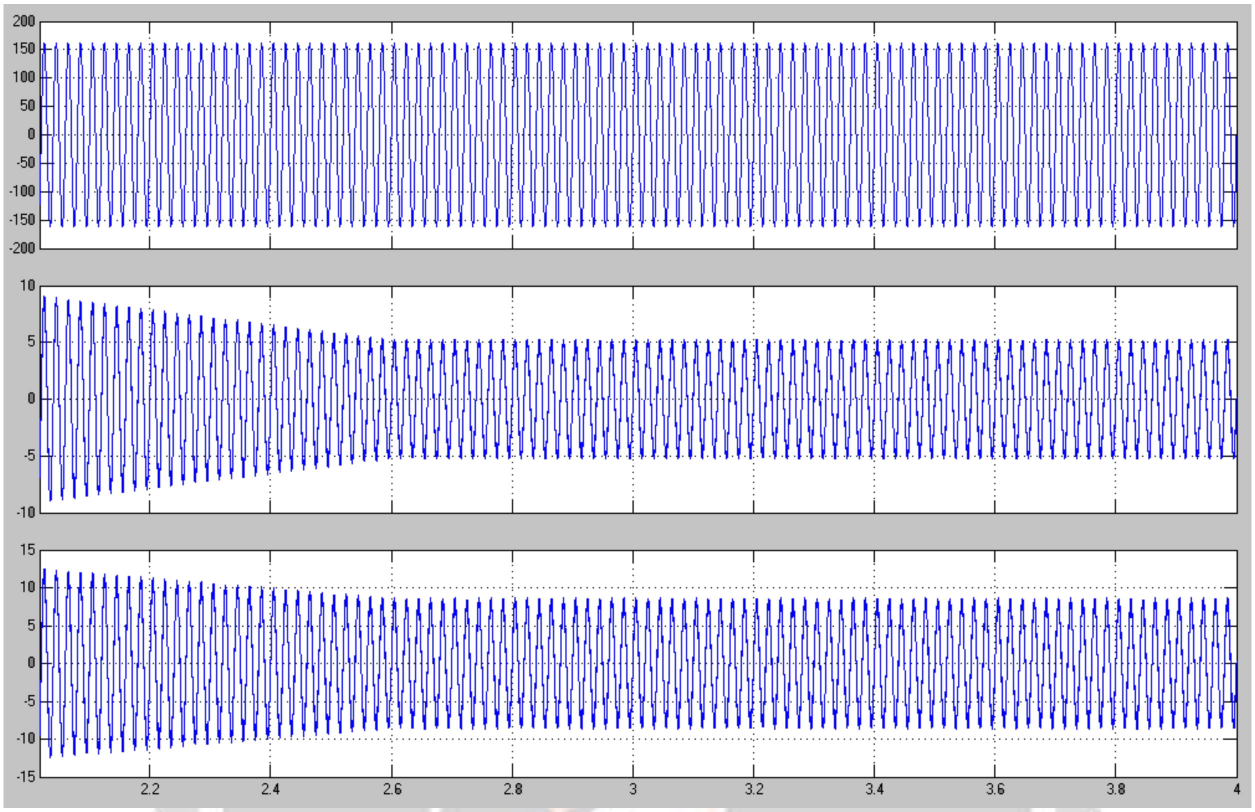

Fig. 9. Simulation waveforms of load voltage v_{Ca} , grid current i_{ga}, and inductor current i_{La} when DG is in the grid-tied mode under condition of the step down of the grid current reference from 9 A to 5 A with: (a) conventional voltage mode control,

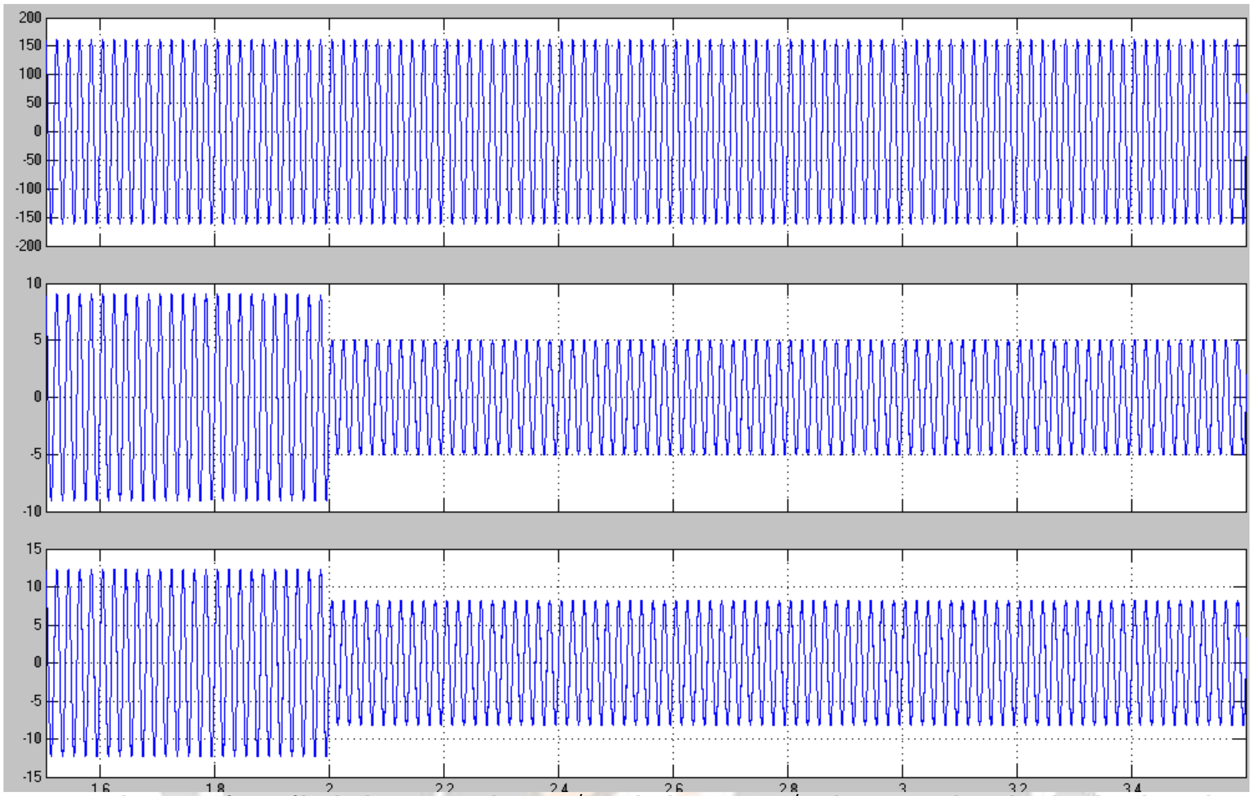

Fig. 10. Simulation waveforms of load voltage v_{Ca}, grid current i_{ga}, and inductor current i_{La} when DG is in the grid-tied mode under condition of the step down of the grid current reference from 9 A to 5 A with: (b) proposed unified control strategy.

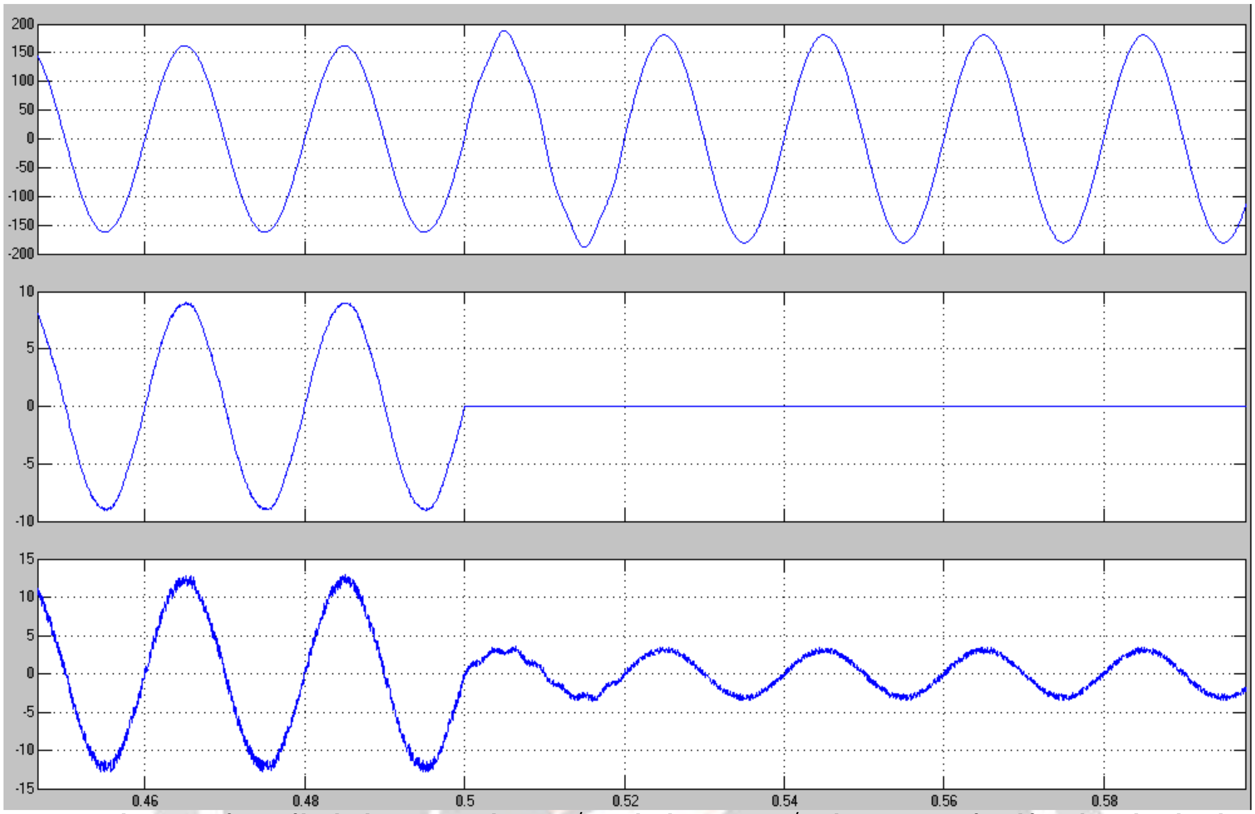

Fig. 11. Simulation waveforms of load voltage v_{Ca}, grid current i_{ga}, and inductor current i_{La} when DG is transferred from the grid-tied mode to the islanded mode with: (a) conventional hybrid voltage and current mode control,

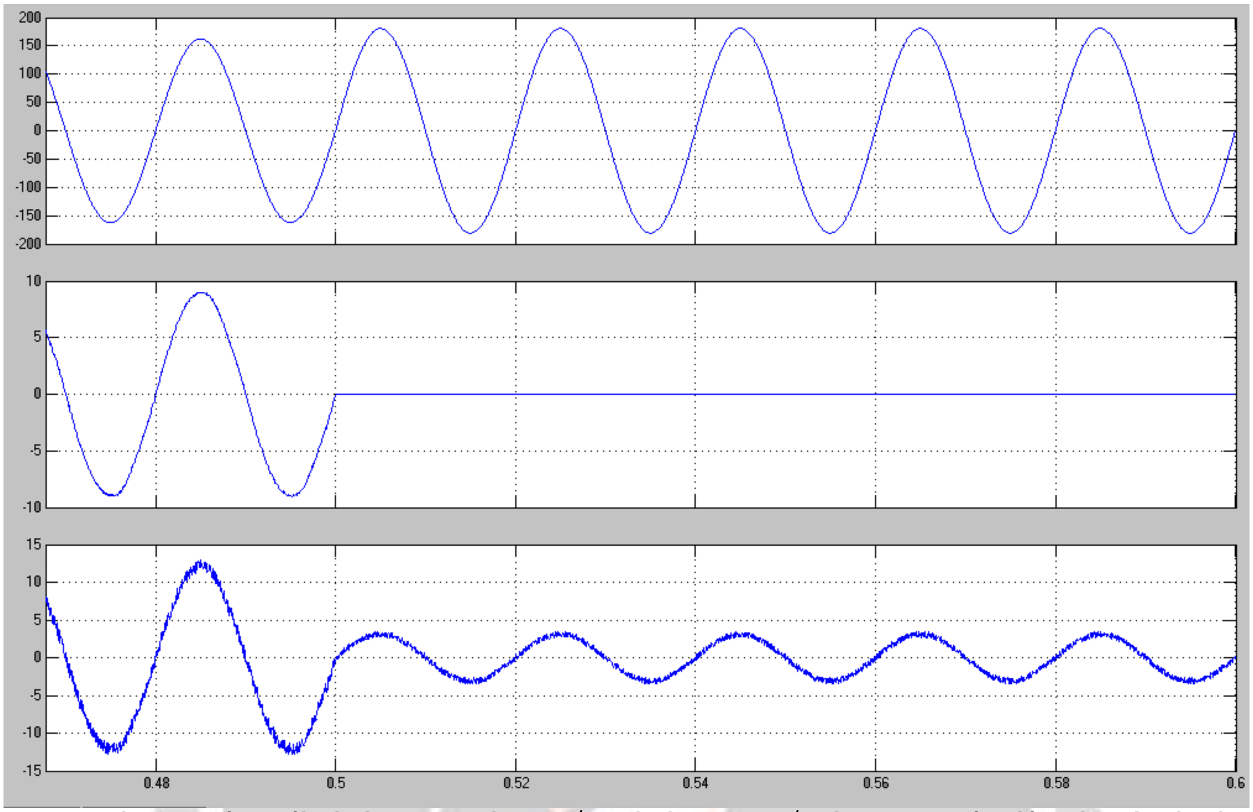

Fig. 12. Simulation waveforms of load voltage v_{Ca}, grid current i_{ga}, and inductor current i_{La} when DG is transferred from the grid-tied mode to the islanded mode with: (a) conventional hybrid voltage and current mode control, and (b) proposed unified control strategy.

5. CONCLUSIONS

A unified control strategy was proposed for three-phase three-level inverter in DG to operate in both islanded and grid-tied modes, with no need for switching between two different control architectures or critical islanding detection. A novel voltage controller was presented with three-level space vector modulation technique. It is inactivated in the grid-tied mode, and the DG operates as a current source with fast dynamic performance. Upon the utility outage, the voltage controller can automatically be activated to regulate the load voltage. Moreover, a novel load current feed forward was proposed, and it can improve the waveform quality of both the grid current in the grid-tied mode and the load voltage in the islanded mode. The proposed unified control strategy was simulated by using the simulation.

6. 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] R. H. Lasseter, “Microgrids and distributed generation,”J. Energy Eng., vol. 133, no. 3, pp. 144–149, Sep. 2007.

[3] C. Mozina, “Impact of green power distributed generation,” IEEE Ind. Appl. Mag., vol. 16, no. 4, pp. 55–62, Jul./Aug. 2010.

[4] IEEE Recommended Practice for Utility Interface of Photovoltaic(PV) Systems, IEEE Standard 929-2000, 2000.

[5] IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Standard 1547-2003, 2003.

[6] J. Stevens, R. Bonn, J. Ginn, and S. Gonzalez,Development and Testing of an Approach to Anti-Islanding in Utility-Interconnected Photovoltaic Systems. Livermore, CA, USA: Sandia National Laboratories, 2000.

[7] A. M. Massoud, K. H. Ahmed, S. J. Finney, and B. W. Williams, “Harmonic distortion-based island detection technique for inverter-based distributed generation,”IET Renewable Power Gener., vol. 3, no. 4, pp. 493– 507, Dec. 2009.
[8] T. Thacker, R. Burgos, F. Wang, and D. Boroyevich, “Single-phase islanding detection based on phase-locked loop stability,” inProc. 1st IEEE Energy Convers. Congr. Expo., San Jose, CA, USA, 2009, pp. 3371–3377.
[9] S.-K. Kim, J.-H. Jeon, J.-B. Ahn, B. Lee, and S.-H. Kwon, “Frequencyshift acceleration control for anti-islanding of a distributed-generation inverter,” IEEE Trans. Ind. Electron., vol. 57, no. 2, pp. 494–504, Feb 2010.
[10] A. Yafaoui, B. Wu, and S. Kouro, “Improved active frequency drift antiislanding detection method for grid connected photovoltaic systems,” IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2367–2375, May 2012.
[11] J. M. Guerrero, L. Hang, and J. Uceda, “Control of distributed uninterruptible power supply systems,”IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 2845–2859, Aug. 2008.
[12] M. C. Chandorkar, D. M. Divan, and R. Adapa, “Control of parallel connected inverters in standalone AC supply systems,”IEEE Trans. Ind. Appl., vol. 29, no. 1, pp. 136–143, Jan./Feb. 1993.
[13] Y. Li, D. M. Vilathgamuwa, and P. C. Loh, “Design, analysis, and realtime testing of a controller for multibus microgrid system,” IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1195–1204, Sep. 2004.
[14] F. Gao and M. R. Iravani, “A control strategy for a distributed generation unit in grid-connected and autonomous modes of operation,”IEEE Trans. Power Del., vol. 23, no. 2, pp. 850–859, Apr. 2008.
[15] S.-H. Hu, C.-Y. Kuo, T.-L. Lee, and J. M. Guerrero, “Droop-controlled inverters with seamless transition between islanding and grid-connected operations,” inProc. 3rd IEEE Energy Convers. Congr. Expo., Phoenix, AZ, USA, 2011, pp. 2196–2201.
[16] L. Arnedo, S. Dwari, V. Blasko, and S. Park, “80 kW hybrid solar inverter for standalone and grid connected applications,” inProc. 27th IEEE Appl. Power Electron. Conf. Expo., Orlando, FL, USA, 2012, pp. 270– 276.
[17] R. Tirumala, N. Mohan, and C. Henze, “Seamless transfer of gridconnected PWM inverters between utility-interactive and stand-alone modes,” inProc. 17th IEEE Appl. Power Electron. Conf. Expo., Dallas, TX, USA, 2002, pp. 1081–1086