

Power Quality Enhancement Using Cascaded Current-Voltage Controller

P Sowjanya¹ A Neela Manikanta² M Bhavya Sri³

K Grishma⁴ G V Madhav⁵

Asst.Professor, Department of EEE, Srinivasa Inst.of Engg &Technology, Amalapuram,AP,India.¹

B.Tech Students, Department of EEE, Srinivasa Inst.of Engg &Technology, Amalapuram,AP,India.^{2,3,4,5.}

ABSTRACT

In this paper, a cascaded current-voltage control strategy is proposed for inverters to simultaneously improve the power quality of the inverter local load voltage and the current exchanged with the grid. It also enables seamless transfer of the operation mode from stand-alone to grid-connected or vice versa. The control scheme includes an inner voltage loop and an outer current loop, with both controllers designed using the H_∞ repetitive control strategy. This leads to a very low total harmonic distortion in both the inverter local load voltage and the current exchanged with the grid at the same time. The proposed control strategy can be used to single-phase inverters and three-phase four-wire inverters. It enables grid-connected inverters to inject balanced clean currents to the grid even when the local loads (if any) are unbalanced and/or nonlinear. Results will verify through MATLAB/SIMULINK software

Index Terms— Power Quality, Micro Grid, Cascaded Current Voltage Controller, H_∞ Repetitive Control, Total Harmonic Distortion (THD).

I. INTRODUCTION

I. INTRODUCTION

MICROGRIDS are emerging as a consequence of rapidly growing distributed power generation systems. Improving the control capabilities and operational features of micro grids brings environmental and economic benefits. The introduction of micro grids leads to improved power quality, reduces transmission congestion, decreases emission and energy losses, and effectively facilitates the utilization of renewable energy. Micro grids are normally operated in the grid-connected mode; however, it is also expected to provide sufficient generation capacity, controls, and operational strategies to supply at least a part of the load after being disconnected from the

distribution system and to remain operational as a stand-alone (islanded) system [1] [6]. Traditionally, the inverters used in micro grids behave as current sources when they are connected to the grid and as voltage sources when they work autonomously [7]. This involves the change of the controller when the operational mode is changed from stand-alone to grid-connected or *vice versa* [8].

It is advantageous to operate inverters as voltage sources because there is no need to change the controller when the operation mode is changed. A parallel control structure consisting of an output voltage controller and a grid current controller was proposed in [8] to achieve seamless transfer via changing the references to the controller without changing the controller. Another important aspect for grid connected inverters or micro grids is the active and reactive power control; see, e.g., [9] and [10] for more details. As nonlinear and/or unbalanced loads can represent a high proportion of the total load in small-scale systems, the problem with power quality is a particular concern in micro grids [11]. Moreover, unbalanced utility grid voltages and utility voltage sags, which are two most common utility voltage quality problems, can affect micro grid power quality [12], [13].

Cascaded Control Structure: Research proposes using cascaded current-voltage control strategies to improve power quality in grid-connected systems, addressing issues like harmonics, voltage fluctuations, and grid synchronization.

- **Control Techniques:** Studies explore various control methods, including Proportional Resonant (PR) controllers, Predictive Control, and Sliding Mode Control, to regulate grid current and voltage, ensuring low Total Harmonic Distortion (THD) and grid compliance.

- **Grid Support Functions:** Cascaded control enables grid support functions like reactive power compensation, voltage regulation, and power factor correction in grid-

connected systems with renewable energy sources (e.g., solar PV, wind).

II. PROPOSED CONTROL SCHEME

The structure of a single-phase inverter connected to the grid. It consists of an inverter bridge, an LC filter, and a grid interface inductor connected with a circuit breaker. It is worth noting that the local loads are connected in parallel with the filter capacitor. The current i_1 flowing through the filter inductor is called the filter inductor current in this paper, and the current i_2 flowing through the grid interface inductor is called the grid current in this paper. The control objective is to maintain low THD for the inverter local load voltage u_o and, simultaneously, for the grid current i_2 . As a matter of fact, the system can be regarded as two parts, as shown in Fig 2.1 cascaded together. Hence, a cascaded controller can be adopted and designed.

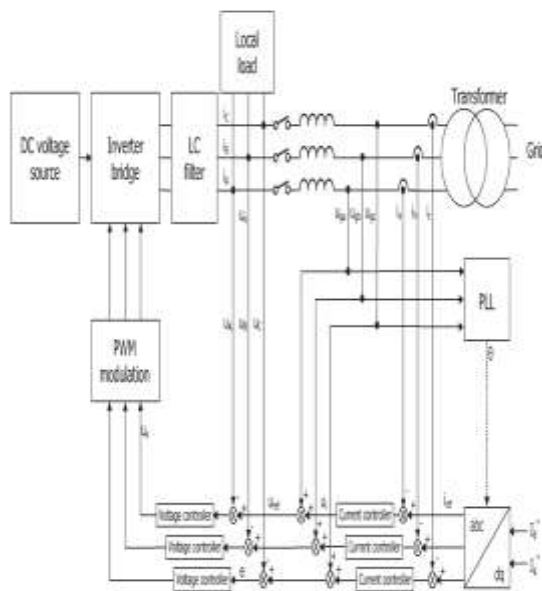


Fig. 2.1 Sketch of a grid-connected three-phase inverter using the proposed strategy.

The proposed controller, as shown in Fig.6.1, consists of two loops: an inner voltage loop to regulate the inverter local load voltage u_o and an outer current loop to board, a three-phase LC filter, a three-phase grid interface inductor, a board consisting of voltage and current sensors, a step-up wye-wye transformer (12 V/230 V/50 Hz), a d SPACE DS1104 R&D controller board with Control MATLAB Simulink/SimPower software package. The inverter board consists of two independent three-phase inverters and has the capability to generate PWM voltages from a constant 42-V dc voltage source.

One inverter was used to generate a stable neutral line for the three-phase inverter.

The generated three-phase voltage was connected to the grid via a controlled circuit breaker and a step-up transformer. The PWM switching frequency was 12 kHz. A Yokogawa power analyzer WT1600 was used to measure the THD. The parameters of the inverter are given in Table I. Three sets of identical controllers were used for the three phases because there was a stable neutral line available. The control structure for the three-phase system is shown in Fig. 6. A traditional dq PLL was used to provide the phase information needed to generate the three-phase grid current references via a dq/abc transformation from the current references I_d and I_q . The internal model was implemented according to [12] with the capability to adapt to the frequency change in the grid. It is worth noting that it is quite a challenge to work with low-voltage inverters to improve the voltage THD, because, in general, the higher the voltage, the bigger the value of the fundamental component. Moreover, the impact of noises and disturbances is more severe for low-voltage systems than for high-voltage ones. Hence, it should be easy to apply the strategy proposed in this paper to inverters at higher voltage and higher power ratings.

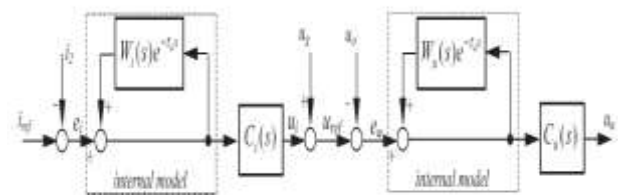


Fig. 2.2. Proposed cascaded current-voltage controller for inverters, where both controllers adopt the H_∞ repetitive strategy.

Regulate the grid current i_2 . According to the basic principles of control theory about cascaded control, if the dynamics of the outer loop is designed to be slower than that of the inner loop, then the two loops can be designed separately. As a result, the outer-loop controller can be designed under the assumption that the inner loop is already in the steady state, i.e., $u_o = u_{ref}$. It is also worth stressing that the current controller is in the outer loop and the voltage controller is in the inner loop. This is contrary to what is normally done. In this paper, both controllers are designed using the H_∞ repetitive control

strategy because of its excellent performance in reducing THD. The main functions of the voltage controller are the following: to deal with power quality issues of the inverter local load voltage even under unbalanced and/or nonlinear local loads, to generate and dispatch power to the local load, and to synchronize the inverter with the grid. When the inverter is synchronized and connected with the grid, the voltage and the frequency are determined by the grid.

The main function of the outer-loop current controller is to exchange a clean current with the grid even in the presence of grid voltage distortion and/or nonlinear (and/or unbalanced for three-phase applications) local loads connected to the inverter. The current controller can be used for over current protection, but normally, it is included in the drive circuits of the inverter bridge. A phase-locked loop (PLL) can be used to provide the phase information of the grid voltage, which is needed to generate the current reference I_{ref} . As the control structure described here uses just one inverter connected to the system and the inverter is assumed to be powered by a constant dc voltage source, no controller is needed to regulate the dc-link voltage (otherwise, a controller can be introduced to regulate the dc-link voltage). Another important feature is that the grid voltage u_g is fed forward and added to the output of the current controller. This is used as a synchronization mechanism, and it does not affect the design of the controller. Design of voltage and current controller are explained in paper [1].

III. SIMULINK MODEL AND RESULTS

3.1 SIMULINK DIAGRAMS:

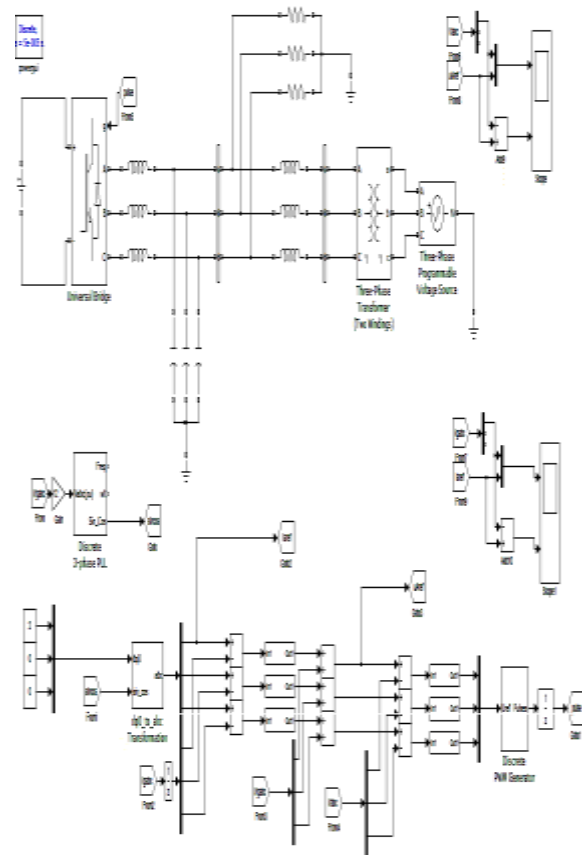


Fig3.1 Simulation Diagram Of Cascaded Grid Resistive Load

3.2 SIMULATION WAVE FORMS:

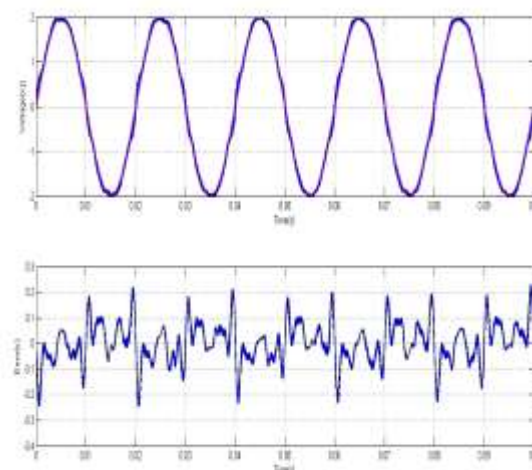


Fig3.2 Cascaded Grid Resistive Load With Voltage Waveforms

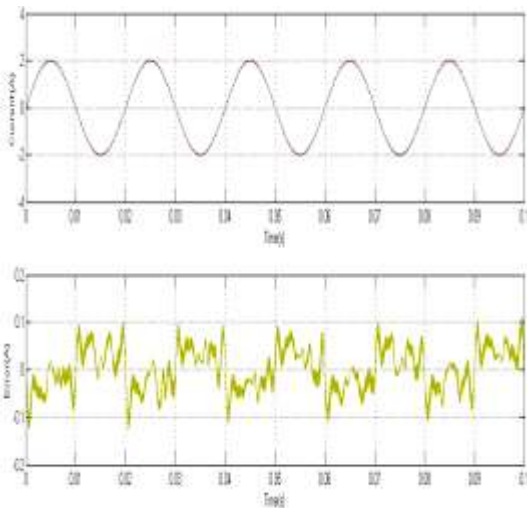
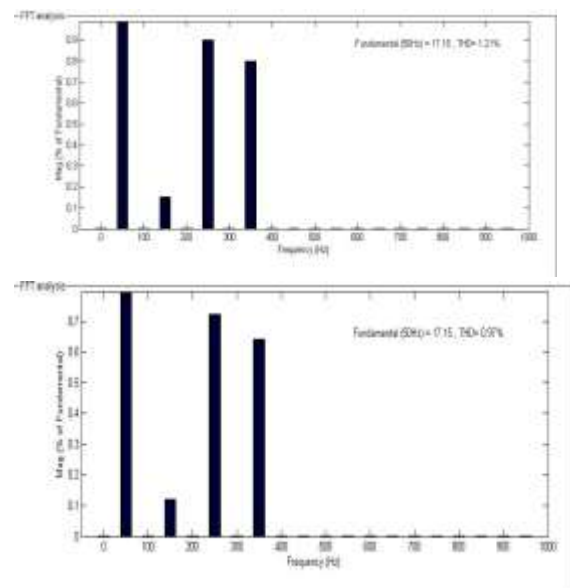


Fig3.3 Cascaded Grid Resistive Load With Current Waveforms

With the Resistive Load: The local load voltage u_A , voltage reference u_{ref} , and filter inductor current i_A are shown in Fig. 3.2&3.3 shows the spectra of the inverter local load voltage and the local load current. The recorded local voltage THD was 1.21%, while the grid voltage THD was 0.97.8%. Since the utility grid voltage was used as the reference, it is worth mentioning that the quality of the inverter local load voltage was better than that of the grid voltage, even without using an active filter.

THD DIAGRAMS:



CONCLUSION

The cascaded current–voltage control strategy has been proposed for inverters in micro grids. It consists of an inner voltage loop and an outer current loop and offers excellent performance in terms of THD for both the

inverter local load voltage and the grid current. In particular, when nonlinear and/or unbalanced loads are connected to the inverter in the grid-connected mode, the proposed strategy significantly improves the THD of the inverter local load voltage and the grid current at the same time. The controllers are designed using the H_∞ repetitive control in this paper but can be designed using other approaches as well. The proposed strategy also achieves seamless transfer between the stand-alone and the grid-connected modes. The strategy can be used for single-phase systems or three-phase systems. As a result, the nonlinear harmonic currents and unbalanced local load currents are all contained locally and do not affect the grid. Simulation results under various scenarios have demonstrated the excellent performance of the proposed strategy.

REFERENCES:

1. Qing-Chang Zhong And Tomas Hornik “Cascaded Current–Voltage Control To Improve The Power Quality For A Grid-Connected Inverter With A Local Load” *IEEE Transactions On Industrial Electronics*, Vol. 60, No. 4, April 2021.
- [2] N. Hatzargyriou, H. Asano, R. Iravani, and C. Marnay, “Microgrids,” *IEEE Power Energy Mag.*, vol. 5, no. 4, pp. 78–94, Jul./Aug. 2017.
- [3] F. Katiraei, R. Iravani, N. Hatzargyriou, and A. Dimeas, “Micro grids management,” *IEEE Power Energy Mag.*, vol. 6, no. 3, pp. 54–65, May/Jun. 2018.
- [4] Y. Mohamed and E. El-Saadany, “Adaptive decentralized droop controller to preserve power sharing stability of paralleled inverters in distributed generation microgrids,” *IEEE Trans. Power Electron.*, vol. 23, no. 6, pp. 2806–2816, Nov. 2008.
- [5] Y. Li and C.-N. Kao, “An accurate power control strategy for powerelectronics- interfaced distributed generation units operating in a lowvoltage multibus microgrid,” *IEEE Trans. Power Electron.*, vol. 24, no. 12, pp. 2977–2988, Dec. 2009.
- [6] C.-L. Chen, Y. Wang, J.-S. Lai, Y.-S. Lee, and D. Martin, “Design of parallel inverters for smooth mode transfer microgrid applications,” *IEEE Trans. Power Electron.*, vol. 25, no. 1, pp. 6–15, Jan. 2010.
- [7] J. Guerrero, J. Vasquez, J. Matas, M. Castilla, and L. de Vicuna, “Control strategy for flexible microgrid based on parallel line-interactive UPS systems,” *IEEE*

Trans. Ind. Electron., vol. 56, no. 3, pp. 726–736, Mar. 2009.

[8] Z. Yao, L. Xiao, and Y. Yan, “Seamless transfer of single-phase gridinteractive inverters between grid-connected and stand-alone modes,” *IEEE Trans. Power Electron.*, vol. 25, no. 6, pp. 1597–1603, Jun. 2010.

[9] Q.-C. Zhong and G. Weiss, “Synchronverters: Inverters that mimic synchronous generators,” *IEEE Trans. Ind. Electron.*, vol. 58, no. 4, pp. 1259–1267, Apr. 2011.

[10] Q.-C. Zhong, “Robust droop controller for accurate proportional load sharing among inverters operated in parallel,” *IEEE Trans. Ind. Electron.*, vol. 60, no. 4, pp. 1281–1290, Apr. 2013.

[11] M. Prodanovic and T. Green, “High-quality power generation through distributed control of a power parkmicrogrid,” *IEEE Trans. Ind. Electron.*, vol. 53, no. 5, pp. 1471–1482, Oct. 2006.

[12] Y. W. Li, D. Vilathgamuwa, and P. C. Loh, “A grid-interfacing power quality compensator for three-phase three-wire microgrid applications,” *IEEE Trans. Power Electron.*, vol. 21, no. 4, pp. 1021–1031, Jul. 2006.

[13] D. Vilathgamuwa, P. C. Loh, and Y. Li, “Protection of microgrids during utility voltage sags,” *IEEE Trans. Ind. Electron.*, vol. 53, no. 5, pp. 1427–1436, Oct. 2006.

[14] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. 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.

[15] G. Weiss, Q.-C. Zhong, T. Green, and J. Liang, “ H_{∞} repetitive control of DC–AC converters in microgrids,” *IEEE Trans. Power Electron.*, vol. 19, no. 1, pp. 219–230, Jan. 2004.