Volume 3, Issue , 2024
PP 277-288

International Journal of Futuristic Innovation in Arts, Humanities and Management (IJFIAHM)

POWER QUALITY MANAGEMENT STRATEGY USING DQ THEORY FOR SINGE PHASE INVERTER OF POWER GENERATION SYSTEM USING MATLAB

Mayur S. Pote
mayurpote6@gmail.com
Electrical Engineering Department
Shri Sai College of Engineering & Technology, Bhadrawati

Umesh G. Bonde
bondeumesh88@gmail.com
Electrical Engineering Department
Shri Sai College of Engineering & Technology, Bhadrawati

Sameer S. Raut
raut.sameer65@gmail.com
Electrical Engineering Department
Shri Sai College of Engineering & Technology, Bhadrawati

Divya A. Bawane
divyabawane079@gmail.com
Electrical Engineering Department
Shri Sai College of Engineering & Technology, Bhadrawati

ABSTRACT

Single-phase surge protectors are mainly used to eliminate harmonics in single-phase AC power systems. In this paper, we design and simulate a single-phase power filter and indirect control process. This control method can be used with input phase (voltage/current) phase π/2. This article explains the full functionality of an active power filter, which removes not only active power but also harmonics generated by the line load at the source. Filter release is ensured using MATLAB/Simulink software.

Keyword: Harmonics, Single Phase Shunt Active Power Filter, Distributed power generation, power quality

INTRODUCTION:

Due to the high cost of energy/equipment, it plays an important role in modern energy consumption. As a result, these devices/machines attract non-sinusoidal energy towards the resource due to their incompatibility. Energy quality concerns have power engineers thinking about devices that reduce harmonics in the supply chain. These devices are known as efficient surge protectors/regulators with harmonic current/energy compensation. Active power filters are divided into active shunt power filters, series power filters, and integrated power filters.

Connectors that can solve a wide range of power quality issues. One of the major advantages of APFs is that they are able to adapt to changes in network flexibility and loading and consume only a small amount of space compared to standard performance filters. Nowadays energy quality issues in a single-phase system are more than three categories due to the high use of indirect loads and due to the proliferation of newly developed production systems such as voltaic solar image, small wind power systems etc. in a single-phase network. Current energy andharmonious current are important when considering a single-phase network, which is a major concern for the energy distribution system, as these problems lead to other energy quality problems. In this paper a single-phase power filter is used based on the indirect control process to make the reference signal used.

LITERATURE REVIEW

1. Milan Prodanovid and Timothy C. Green, “Control of Power Quality in Inverter-Based DistributedGeneration” , 0-7803-7474-6/021%17.00 02002 IEEE. Power quality is an important additional service ofinverter-based interfaces for distributed generators. In grid connected applications the power qualitydepends on the harmonic content of the current injected at the point of common coupling. By careful designof the powerconverter and its output filter the switching frequency components in the output current spectrum can bereduced to low levels. The effect of the harmonic distortion of the grid Voltage on the output current can beminimized by using an appropriate inverter control strategy. Conventional control methods (manipulationof inverter voltage magnitude and phase) offer active and reactive power control, hut not the control of theoutput current quality. This paper describes a new choice of control structure and explains the interactionbetween the applied control loops. The inverter is used to control the current in the first element of an LCLfilter. A further controller is wrapped around this loop to control power export to the grid. The usefulnessof this arrangement in providing high power quality is emphasized. Experimental results from a lOkVAprototype are used to evaluate the distortion rejection properties and the regulation of active and reactivepower control. The results show high quality of generated power and excellent transient and steady state responseto both active and reactive power demands.

2. A.M. Fahmy*, K.H. Ahmed+, M.S. Hamad*, and G.P. Adam^, “Single-Phase Grid Connected DistributedGeneration Interfacing Converter with Power Quality Improvement Capability”, 978-1-4799-0224-8/13/$31.00 ©2013 IEEE. With the growing of distributed

generation penetration which feeds single-phaselinear and/or nonlinear loads, the utility power quality is affected in terms of low power factor and currentharmonics. In this paper, a single-phase DG unit is connected to the grid via a multifunctional converter.The converter exchanges the power with the loads and/or the grid in addition to improving the powerquality by acting as a shunt active power filter. A predictive current control technique is used without usinga phase locked loop. The proposed system performance is investigated at different operating conditionsusing a MATLAB/SIMULINK simulation model.

3. Ganji Jhansi Rani1, Pavan Kumar, “Single Phase Inverter with Improved Power Quality Control Schemefor Distributed Generation System”, Vol. 2, Issue 9, September 2013, IJAREEIE. Distributed generation(DG) systems are interfaced with the electrical power network most commonly by means of powerelectronic converters. This paper deals with a single-phase inverter for DG systems which requireimprovement in power qualities, such as harmonic elimination and reactive power compensation for gridconnectedoperation. The main theme of the projects is to integrate the DG system with shunt active powerfilter capabilities. By using this technique, the inverter controls the active power flow from the renewableenergy source to the grid and also performs the nonlinear load current harmonic compensation by keepingthe grid current nearly sinusoidal. The power quality control strategy employs a current reference generatorbased on sinusoidal signal integrator and instantaneous reactive power (IRP) theory together with adedicated repetitive current controller. Simulation of the power quality control scheme based inverter iscarried out for 4-kVA inverter.

METHODOLOGY:

- **SINGLE-PHASE SHUNT ACTIVE POWER FILTER**

In this topology, the active power filter is connected in parallel to the grid and non-linear loads. Pulse width modulated voltage source inverters are used as current-controlled voltage sources in parallel active power filters. The integrated power supply compensates for the current relationship by injection balance and balance offset (180-degree phase shift), thus eliminating the relationship from fitting properly. A reference signal is generated with the help of the control input and then compared with the current to form the gate signal of the switch. There are different control strategies for the sign of signal use, such as instantaneous active and reactive power theory (pq theory), Parks d-q or synchronous reference frame theory.

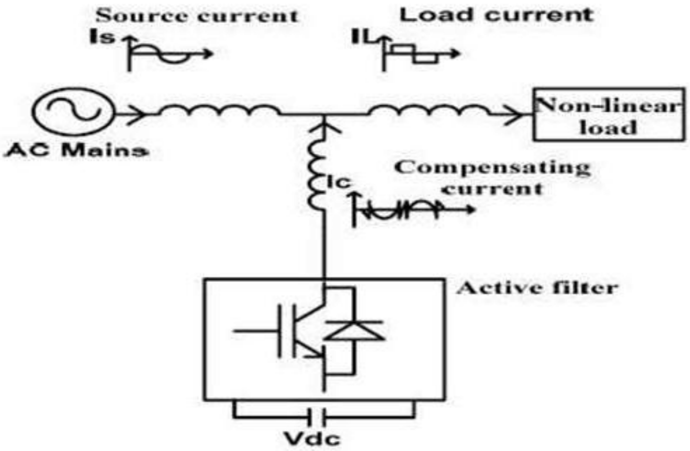

Fig -1: Principle of shunt active power filter

These control strategies focus mainly on three-phase systems. The three phase pq theory is converted into a single phase machine by phase shifting the theory changes such as voltage or current signal by 90 degrees. This idea is then extended to d-q phase synchronization.

INDIRECT CONTROL TECHNIQUE

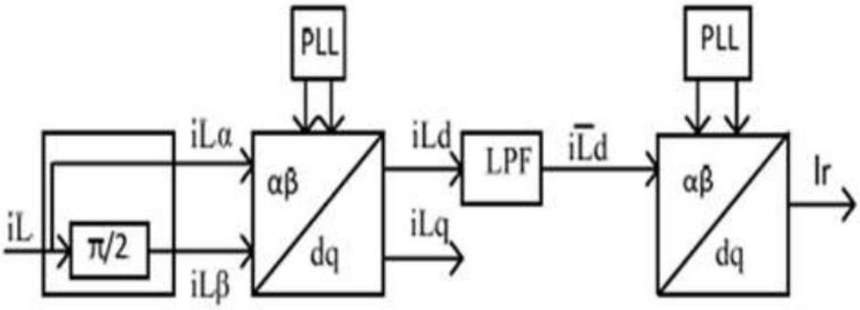

Fig -2: Reference signal generation using single-phase d-q transformation.

- **Single-phase d-q transformation**

A single-phase system can directly convert into αβ frame without any matrix transformation. An imaginaryvariable obtained by shifting the original signal (voltage/current) by 90 degrees and thus the original signal andimaginary signal represent the load current in αβ co-ordinates.

$$\begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} = \begin{bmatrix} i_{L(\omega t+\emptyset)} \\ i_{L(\omega t+\emptyset+\pi/2)} \end{bmatrix} \quad \ldots\ldots (1)$$

From second equation we can write as

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \end{bmatrix} = \begin{bmatrix} sin(\omega t) & -cos\,(\omega t) \\ cos\,(\omega t) & sin\,(\omega t) \end{bmatrix} \begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} \quad \text{.........(2)}$$

From $iLdandiLq$ we can derive fundamental active ,fundamental reactive, harmonic active, and harmonic reactive byusing appropriate filters .The DC components iLd and iLq are obtained by using LPF and AC components iLd , iLq areobtained by using HPF.

Here we are using the DC component for the generation of reference current hence it is called indirect method.The load requires only fundamental active part of the source current.

$$\begin{bmatrix} i^*_{Ld} \\ i^*_{Lq} \end{bmatrix} = \begin{bmatrix} i_{\bar{L}d} + 0 \\ 0 + 0 \end{bmatrix} \quad \text{.........(3)}$$

$$\begin{bmatrix} i^*_{s\alpha} \\ i^*_{s\beta} \end{bmatrix} = \begin{bmatrix} sin\,(\omega t) & -cos\,(\omega t) \\ cos\,(\omega t) & sin\,(\omega t) \end{bmatrix}^{-1} \begin{bmatrix} i^*_{Ld} \\ i^*_{Lq} \end{bmatrix} \quad \text{.........(4)}$$

In order to obtain a constant DC voltage across the active filter the term i_{DC} is added to the above equation.

$$\begin{bmatrix} i^*_{s\alpha} \\ i^*_{s\beta} \end{bmatrix} = \begin{bmatrix} sin\,(\omega t) & cos\,(\omega t) \\ -cos\,(\omega t) & sin\,(\omega t) \end{bmatrix} \begin{bmatrix} i_{\bar{L}d} + i_{DC} \\ 0 \end{bmatrix} \quad \text{.........(5)}$$

Therefore the reference signal is

$$i^*_{s\alpha}(\omega t) = \sin(\omega t)(i_{\bar{L}d} + i_{DC}) \quad \text{.........(6)}$$

The generated reference current is used for making gating pulses to the inverter switches which further inject thecompensating current into the line.

➢ SYSTEM SIMULATION

The different scenarios that have been studied in order to support a simulation based design of an invertersystem capable to operate in stand-alone and in grid-connected modes using MATLAB/Simulink platform. It iscomposed of four sections: the first and second ones contain case studies that support the control design and the LCLfilter simulation performance evaluations for the standalone mode and grid connected mode operation. The third partcontains simulation for ride-through operation, and the system response when the inverter transits to standalone fromgrid connected mode.

The block diagram of the simulated system is shown on Figure 3. The system was built using PowerSystems Toolbox in Simulink. The total harmonic distortion (THD) analysis was done with Power Systems Toolbox.A voltage closed loop controller block diagram that was implemented for the inverter.

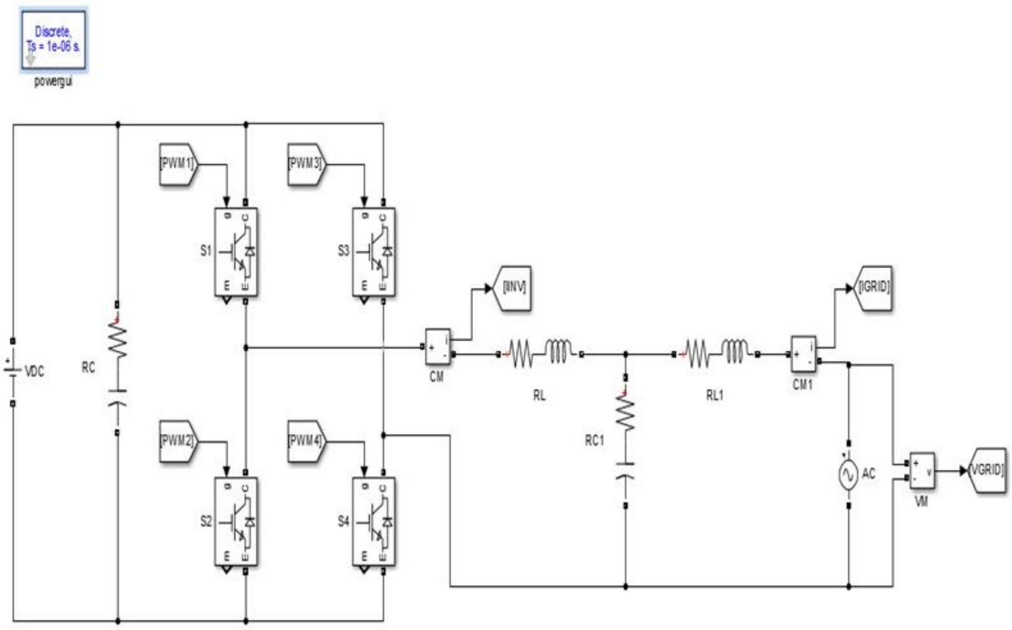

Fig-3: Simulink model of stand-alone inverter with load.

- **Stand Alone Mode Operation**

The block diagram of the simulated system is shown on Figure 4.1. The system was built using Power Systems Toolbox in Simulink. The total harmonic distortion (THD) analysis was done with Power Systems Toolbox. A voltage closed loop controller block diagram that was implemented for the inverter.

- **Case 1: Active Load**

A resistive load has been connected in order to provide 5000 W active load. The phase voltage $v_{Æ}$ and line current $i_{Æ}$ (both in p.u.). The inverter output voltage $v_{iÆ}$(V) (just before the LCL filter) is depicted in figure. The filtered phase voltage and line current can be seen on Figure 3.3 and figure. The harmonic analysis of line current is shown with THD of 0.88%.

This simulation study allows the sizing of inverter relay protection, as well as inverter built-in protection. The systems implemented in the experimental work is operating with the Semikron provided board protection. However, for future deployment and retrofit, it might be necessary additional over current and under voltage protection devices.

- **CASE 2: Grid Connected Mode**

When the inverter is connected to the grid, capable of providing active and reactive power the system must behave in current-controlled mode.Many case studies have been considered for active power injection to the grid, mixed power injection and also when the inverter takes power from the grid (for example in charging a battery in the dc-link). All those cases have been thoroughly simulated in order to observe system behavior and performance.

- **Power Injection to the Grid**

The DC Voltage Source block implements an ideal DC voltage source. The positive terminal is represented by a plus sign on one port. You can modify the voltage at any time during the simulation.

The DC Voltage Source block represents an ideal voltage source that is powerful enough to maintain specified voltage at its output regardless of the current flowing through the source. You specify the output voltage by using the Constant voltage parameter, which can be positive or negative.

- **RESULT**

This scope are show that each IGBT gate signal are provide from PWM control system to generate the each PWM signal for given to IGBT with zero to one amplitude.

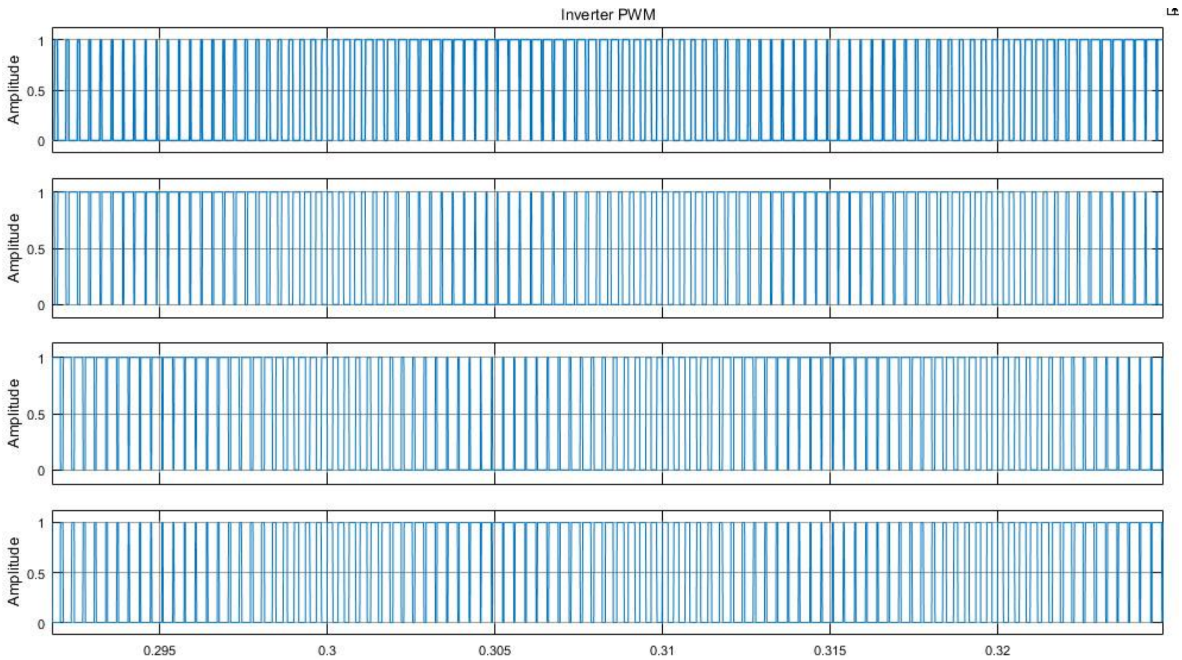

Figure 4. PWM Pulses

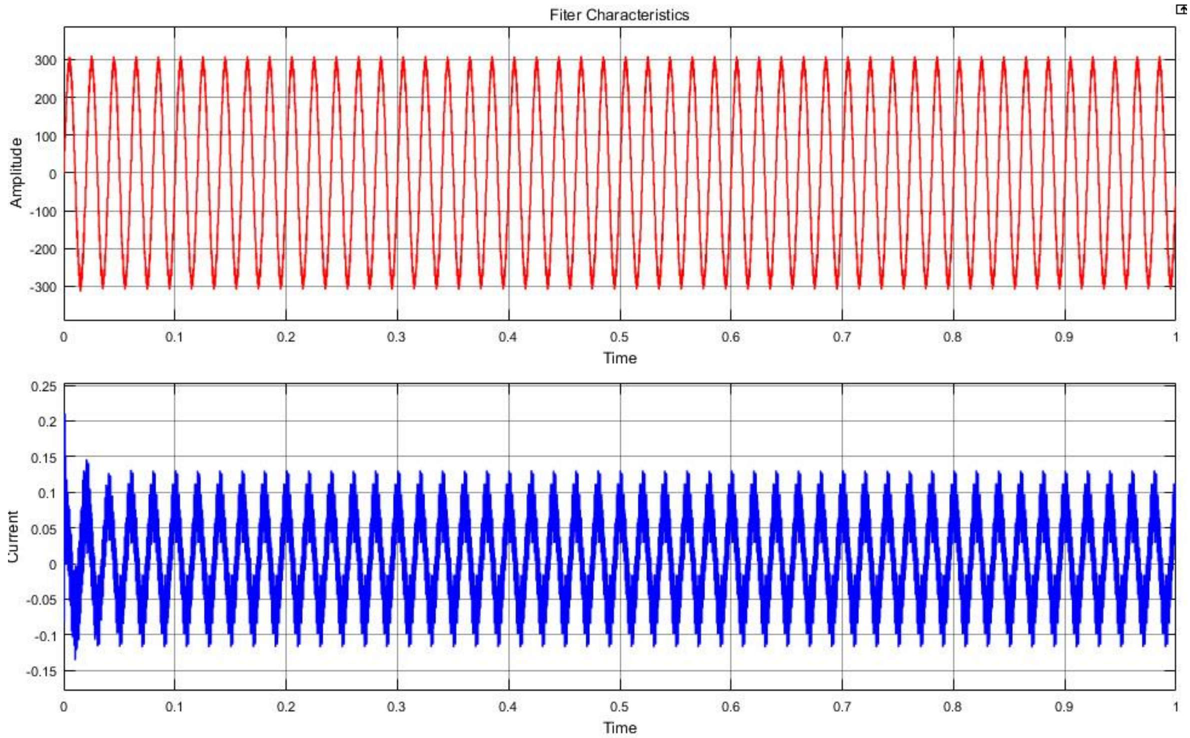

Figure 5. Filter Output

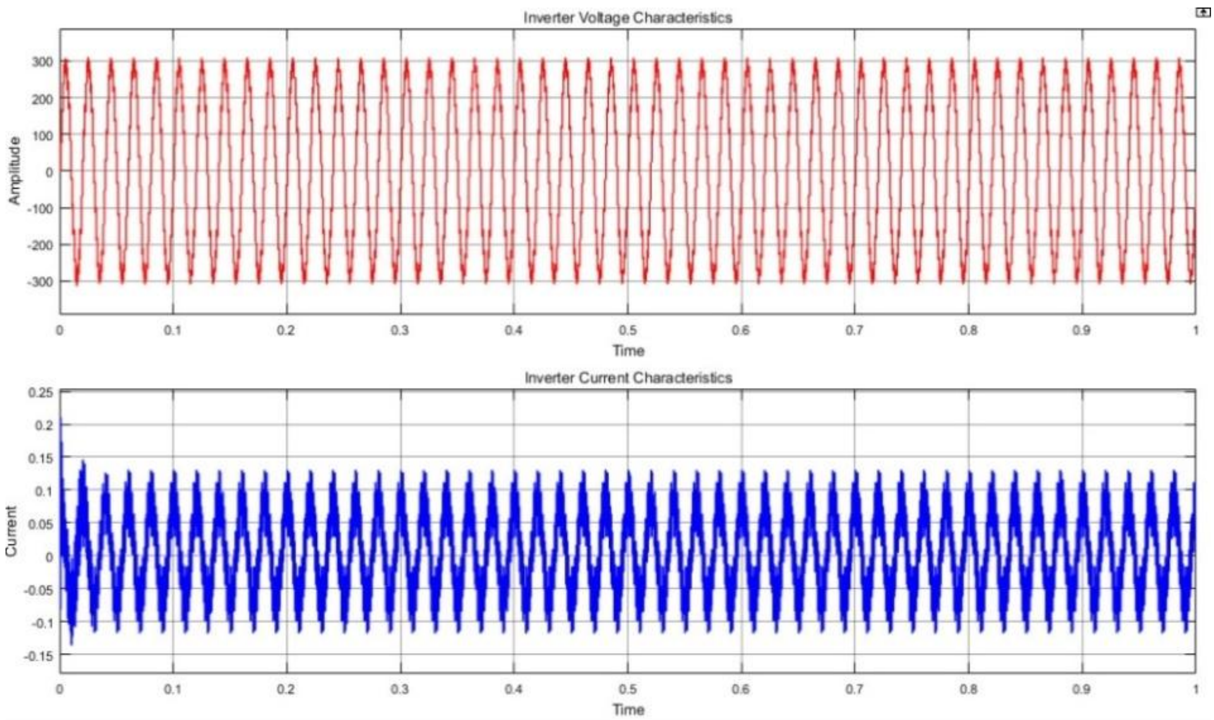

Figure 6. Inverter Output

Volume 3, Issue , 2024
PP 277-288

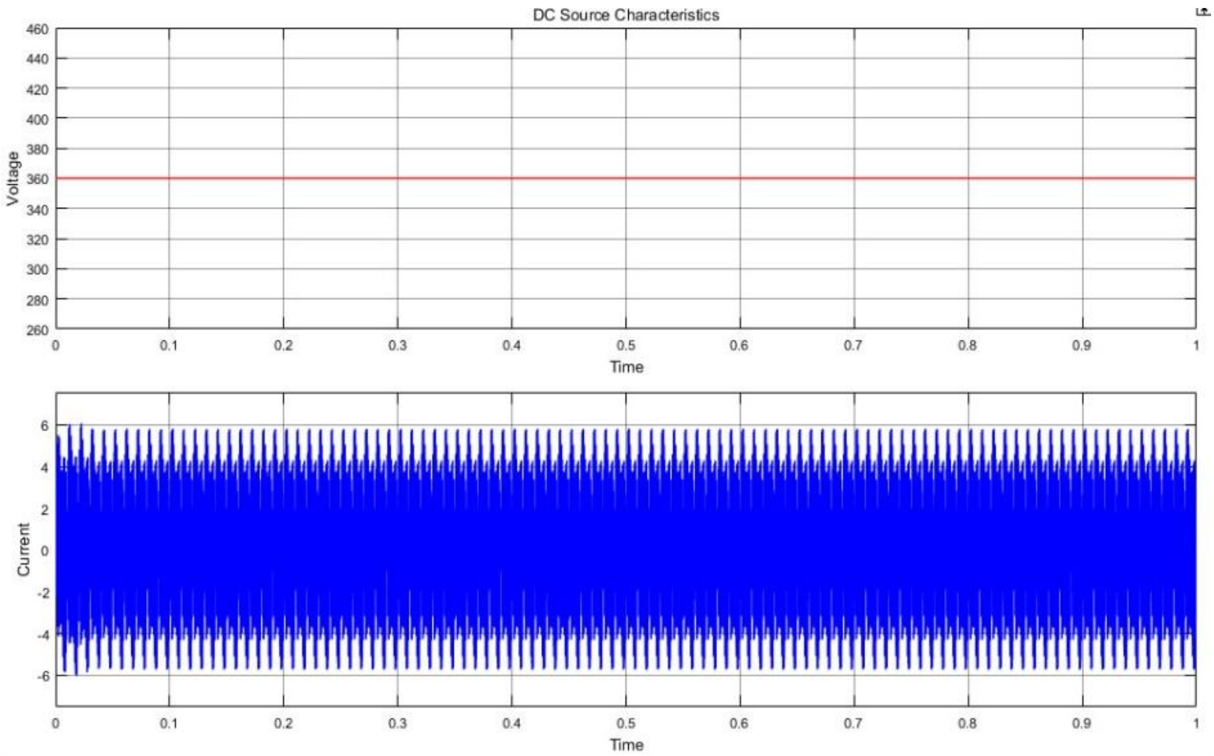

Figure 7. DC Source Output

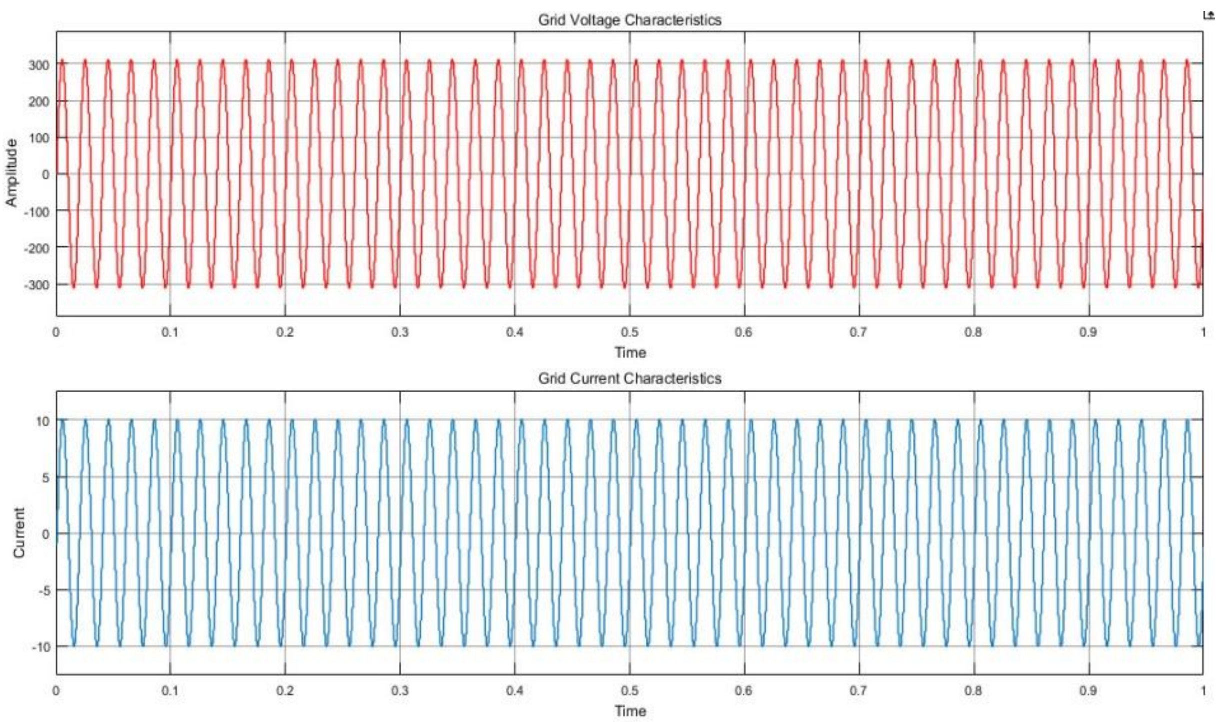

Figure 8. Grid Output

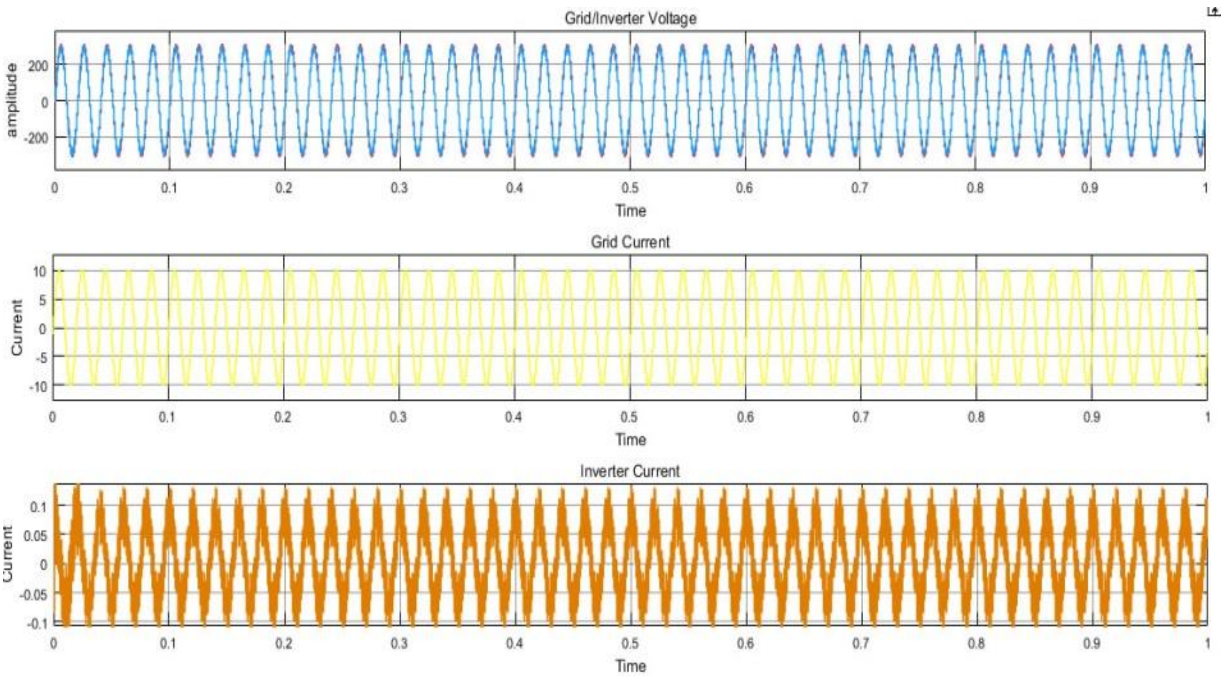

Figure 9. Grid Inverter Output

- **CONCLUSION**

This paper deals with a single-phase H-bridge inverter for DG systems, requiring power quality features as harmonic and reactive power compensation for grid-connected operation. The proposed control scheme employs a current reference generator based on SSI and IRP theory, together with a dedicated repetitive current controller. The grid-connected single-phase H-bridge inverter injects active power into the grid and is able to compensate the local load reactive power and also the local load current harmonics.

Experimental results have been obtained on a 4-kVA inverter prototype tested for different operating conditions, including active power generation, load reactive power compensation, and load current harmonic compensation. The experimental results have shown good transient and steady state performance in terms of grid current THD and transient response.

The integration of power quality features has the drawback that the inverter will also deliver the harmonic compensation current with the direct consequence of increase the inverter overall current and cost. A current limitation strategy should be implemented and if the inverter output current exceeds the switch rating, then the supplied harmonic current must be reduced. In this way, the inverter available current is mainly used for active power injection and if there is some current margin, this can be used for the compensation of reactive power and nonlinear load current harmonics. An analysis of the inverter design that takes into account the current required for reactive power and current harmonics compensation is beyond the paper scope and it will be subject of future study.

REFERENCES

1. R. Teodorescu, M. Liserre, and P. Rodriguez, Grid Converters for Photovoltaic and Wind Power Systems. John Wiley and Sons, 2011, p. 416.
2. Voltage-Sourced Converters in Power Systems. John Wiley and Sons, 2010, p. 451.
3. R. Carnieletto, D. Brandao, S. Syryanarayanan, F. Farret, and M. G. Simoes, “A multifunctional single-phase voltage-source inverter,” IEEE Industry Applications Magaize, no. Sep/Oct, pp. 27– 35, 2011.
4. “1547.1 IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems,” IEEE Std 1547.1-2005, 2005.
5. “519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems,” IEEE Std 519-1992, 1993.
6. O. Vodyakho and C. C. Mi, “Three-Level Inverter-Based Shunt Active Power Filter in Three- Phase Three-Wire and Four-Wire Systems,” IEEE Transactions on Power Electronics, vol. 24, no. 5, pp. 1350–1363, May 2009.
7. M. Liserre, V. E. Orabana, R. Teodorescu, and F. Blaabjerg, “Stability of Grid-Connected PV Inverters with Large Grid Impedance Variation,” in IEEE Electronics Specialists Conference, 2004, pp. 0–6.
8. J. Gabe, F. Montagner, and H. Pinheiro, “Design and Implementation of a Robust Current Controller for VSI Connected to the Grid Through an LCL Filter,” IEEE Transactions on Power Electronics, vol. 24, no. 6, pp. 1444–1452, 2009.

9. K. Jalili and S. Bernet, "Design of LCL Filters of Active-Front-End Two-Level Voltage-Source Converter," IEEE Transactions on Industrial Electronics, vol. 56, no. 5, pp. 1674–1689, 2009.
10. W. Sun, Z. Chen, and X. Wu, "Intelligent Optimize Design of LCL Filter for Three-Phase Voltage-Source PWM Rectifier," in Power Electronics and Motion Control Conference, 2009, pp. 970–974.
11. Y. Lang, D. Xu, S. R. Hadianamrei, and H. Ma, "A Novel Design Method of LCL Type Utility Interface for Three-Phase Voltage Source Rectifier," in Power Electronics Specialists Conference, 2005, pp. 313–317.
12. Y. Tong, F. Tang, Y. Chen, F. Zhou, and X. Jin, "Design Algorithm of Grid-side LCL-filter for Three-phase Voltage Source PWM Rectifier," in Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008, pp. 1–6.
13. G. Saccomando and J. Svensson, "Transient operation of grid-connected voltage source converter under unbalanced voltage conditions," in IEEE Industry Applications Conference, 2001, vol. 4, pp. 2419–2424.
14. I. Agirman and V. Blasko, "A novel control method of a VCS without AC line voltage sensors," IEEE Transactions on Industry Applications, vol. 39, no. 2, pp. 519–524, Mar. 2003.
15. R. Teodorescu and F. Blaabjerg, "Flexible Control of Small Wind Turbines With Grid Failure Detection Operating in Stand-Alone and Grid-Connected Mode," IEEE Transactions on Power Electronics, vol. 19, no. 5, pp. 1323–1332, Sep. 2004.
16. F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, "Overview of Control and Grid Synchronization for Distributed Power Generation Systems," IEEE Transactions on Industrial Electronics, vol. 53, no. 5, pp. 1398–1409, Oct. 2006.
17. R. Kadri, J.-P. Gaubert, and G. Champenois, "An Improved Maximum Power Point Tracking for Photovoltaic Grid-Connected Inverter Based on Voltage-Oriented Control," IEEE Transactions on Industrial Electronics, vol. 58, no. 1, pp. 66–75, Jan. 2011.