POWER QUALITY CONTROL STRATEGY USING D-Q THEORY FOR SINGLE PHASE INVERTER IN GENERATION SYSTEM USING MATLAB

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ABSTRACT

A single-phase power filter is mainly used to eliminate harmonics in single-phase AC networks. In this paper a single-phase power filter, the indirect control process is designed and simulated. This control method is available in the input phase (voltage / current) phase π/ 2. The full function of the active power filter to eliminate harmonics created by the linear load on the side of the source is discussed in this paper and the active power filter release is guaranteed using software MATLAB / Simulink.

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

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1. INTRODUCTION

Due to the high cost of energy-based power / equipment they play an important role in today's energy consumption. As a result these devices / machines attract non-sinusoidal energy to the resources side due to their incompatibility. This energy quality concern makes power engineers think of devices that reduce harmonics in the supply line. Such devices are known as effective power filters / conditioners that are capable of receiving current / harmonic energy compensation. Active power filters are divided into active shunt power filters, series and integrated power connectors that can address a wide range of energy quality problems. 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 and harmonious 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. In this section (2) which deals with the specific energy filter, section (3) provides an overview of the indirect control strategy followed by a simulation study and conclusions..

2. LITERATURE REVIEW

1) Milan Prodanovid and Timothy C. Green, “Control of Power Quality in Inverter-Based Distributed Generation” , 0-7803-7474-6/021%17.00 02002 IEEE. Power quality is an important additional service of inverter-based interfaces for distributed generators. In grid connected applications the power quality

depends on the harmonic content of the current injected at the point of common coupling. By careful design of the power

2) converter and its output filter the switching frequency components in the output current spectrum can be reduced to low levels. The effect of the harmonic distortion of the grid Voltage on the output current can be minimised by using an appropriate inverter control strategy. Conventional control methods (manipulation of inverter voltage magnitude and phase) offer active and reactive power control, hut not the control of the output current quality. This paper describes a new choice of control structure and explains the interaction between the applied control loops. The inverter is used to control the current in the first element of an LCL filter. A further controller is wrapped around this loop to control power export to the grid. The usefulness of this arrangement in providing high power quality is emphasized. Experimental results from a lOkVA prototype are used to evaluate the distortion rejection properties and the regulation of active and reactive power control. The results show high quality of generated power and excellent transient and steady state-response to both active and reactive power demands.

3) Annai Theresa, M. Arun Noyal Doss, “Direct Current Control based Bidirectional AC/DC Single Phase Converter in a Grid-Tied Micro Grid Systems”, This paper presents a novel simplified direct current control strategy for the bidirectional ac/dc single phase converter in a micro grid system. Based on the simplified Pulse Width Modulation (PWM) strategy, a feasible feed forward control scheme is developed to achieve better rectifier mode and inverter mode performance compared with the conventional dual loop control scheme. The proposed simplified PWM strategy with the proposed feed forward control scheme has lower total harmonic distortion. The features of the proposed converter will be verified by the simulation using MATLAB.

4) A.M. Fahmy*, K.H. Ahmed+, M.S. Hamad*, and G.P. Adam^, “Single-Phase Grid Connected Distributed Generation 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-phase linear and/or nonlinear loads, the utility power quality is affected in terms of low power factor and current harmonics. 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 power quality by acting as a shunt active power filter. A predictive current control technique is used without using a phase locked loop. The proposed system performance is investigated at different operating conditions using a MATLAB/SIMULINK simulation model.

5) Ganji Jhansi Rani1, Pavan Kumar, “Single Phase Inverter with Improved Power Quality Control Scheme for 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 power electronic converters. This paper deals with a single-phase inverter for DG systems which require improvement in power qualities, such as harmonic elimination and reactive power compensation for grid-connected operation. The main theme of the projects is to integrate the DG system with shunt active power filter capabilities. By using this technique, the inverter controls the active power flow from the renewable energy source to the grid and also performs the nonlinear load current harmonic compensation by keeping the grid current nearly sinusoidal. The power quality control strategy employs a current reference generator based on sinusoidal signal integrator and instantaneous reactive power (IRP) theory together with a dedicated repetitive current controller. Simulation of the power quality control scheme based inverter is carried out for 4-kVA inverter.

3. SINGLE-PHASE SHUNT ACTIVE POWER FILTER

In this topology the active power filter is connected in parallel to the utility and the non-linear load. Pulse width modulated voltage source inverters are used in shunt active power filter and they are acting as a current controlled voltage source. The compensation for current harmonics in shunt active power filter is by injecting equal and opposite harmonic compensating current (180 degree phase shifted).As a result the harmonics in line get cancelled out and source current becomes sinusoidal and makes it in phase with source voltage .With the help of control strategies reference signals are generated and which then compared with the source current to produce the gating signals for the switches.. For the reference signal generation there are different control strategies like instantaneous active reactive power theory (pq theory) developed by Parks d-q or synchronous reference frame theory.

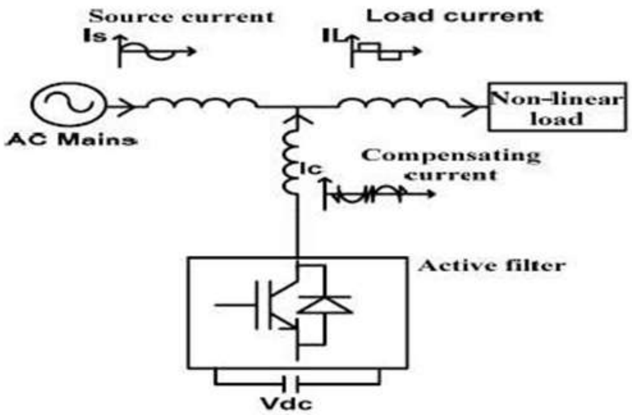

Fig -1: Principle of shunt active power filter

These control strategies are mainly focused on three phase systems. The three phase pq theory is made applicable to the single phase systems by phase shifting an imaginary variable which is similar to voltage or current signals by 90 degree. Later this concept extended to single phase synchronous d-q.

4. INDIRECT CONTROL TECHNIQUE

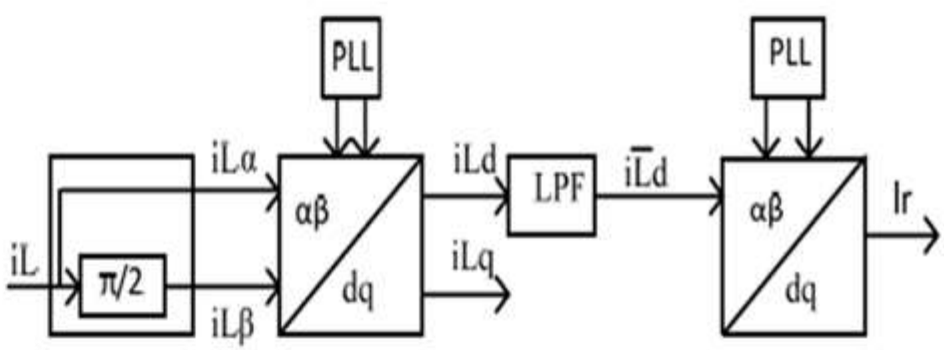

Fig -2: Reference signal generation using single-phase d-q transformation.

4.1 Single-phase d-q transformation

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

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

From second equation we can write as

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

From i_{Ld} *and* i_{Lq} we can derive fundamental active ,fundamental reactive, harmonic active, and harmonic reactive by using appropriate filters .The DC components i_{Ld} and i_{Lq} are obtained by using LPF and AC components i_{Ld} , i_{Lq} are obtained 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.

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

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

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

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

Therefore the reference signal is

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

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

5. SYSTEM SIMULATION

The different scenarios that have been studied in order to support a simulation based design of an inverter system capable to operate in stand-alone and in grid-connected modes using MATLAB/Simulink platform. It is composed of four sections: the first and second ones contain case studies that support the control design and the LCL filter simulation performance evaluations for the standalone mode and grid connected mode operation. The third part contains simulation for ride-through operation, and the system response when the inverter transits to standalone from grid connected mode. The last section contains further results evaluation and discussions.

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.

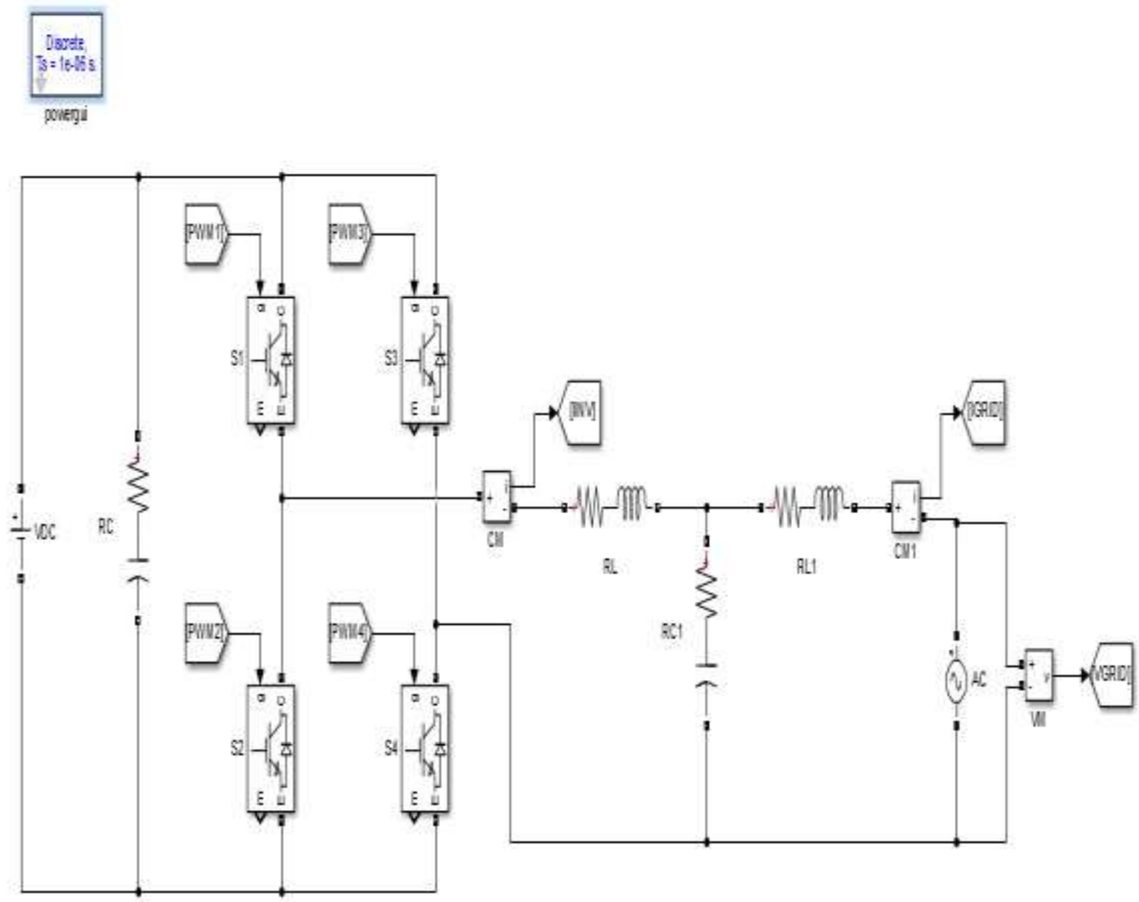

Fig-3: Simulink model of stand-alone inverter with load.

4.2 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.

4.2.1 Case 1: Active Load

A resistive load has been connected in order to provide 5000 W active load. The phase voltage vÆ and line current iÆ (both in p.u.). The inverter output voltage viÆ(V) (just before the LCL filter) is depicted in figure; it has THD of 43.85% as indicated in Figure 3.5. The filtered phase voltage and line current can be seen on Figure 3.3 and figure. The harmonic analysis of line current is shown on Figure with THD of 0.88%. This simulation study allows the sizing of inverter relay protection, as well as inverter built-in protection (described in Chapter 4). 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 undervoltage protection devices.

4.2.2 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.

4.3 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. Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the voltage source, respectively. The current is positive if it flows from positive to negative, and the voltage across the source is equal to the difference between the voltage at the positive and the negative terminal, V(+) – V(–).Output voltage. You can specify positive or negative values. The default value is 1 V.

5. 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.

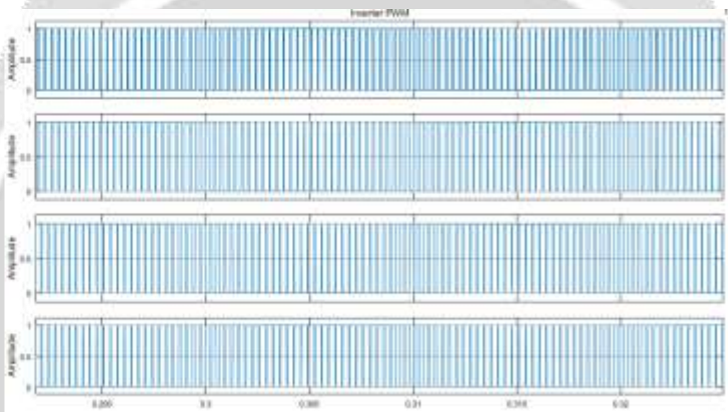

Fig-4 PWM Pulses

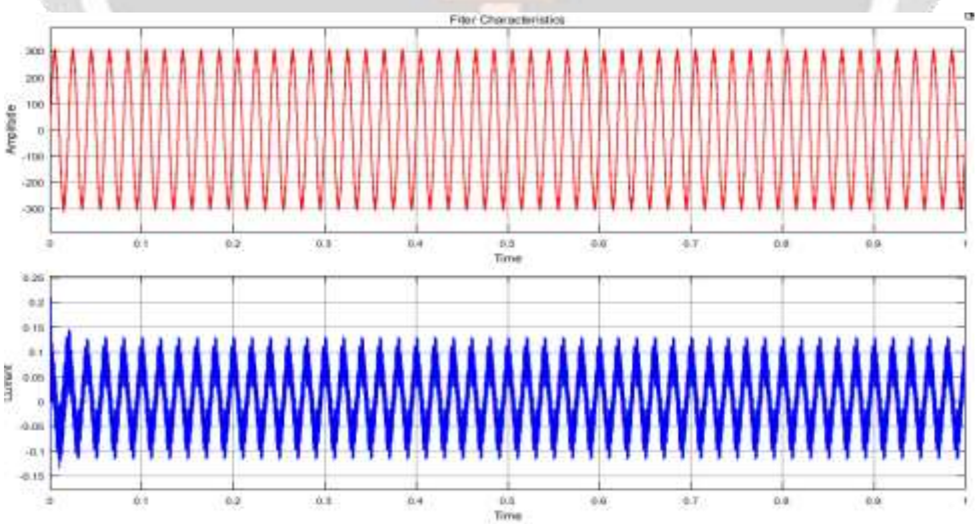

Fig-6 Filter Output

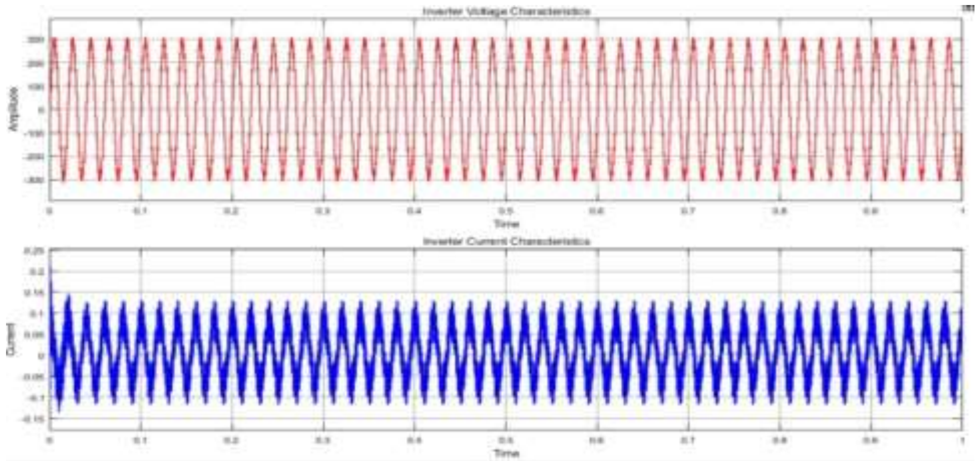

Fig-7 Inverter Output

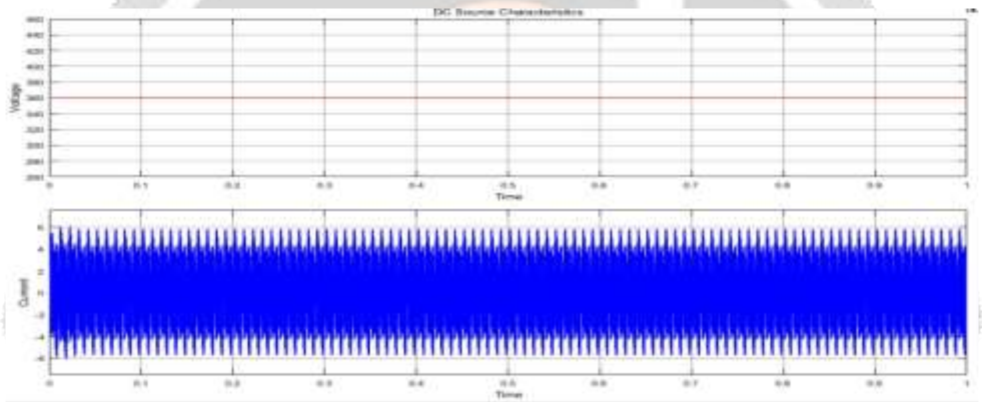

Fig-8 DC Source Output

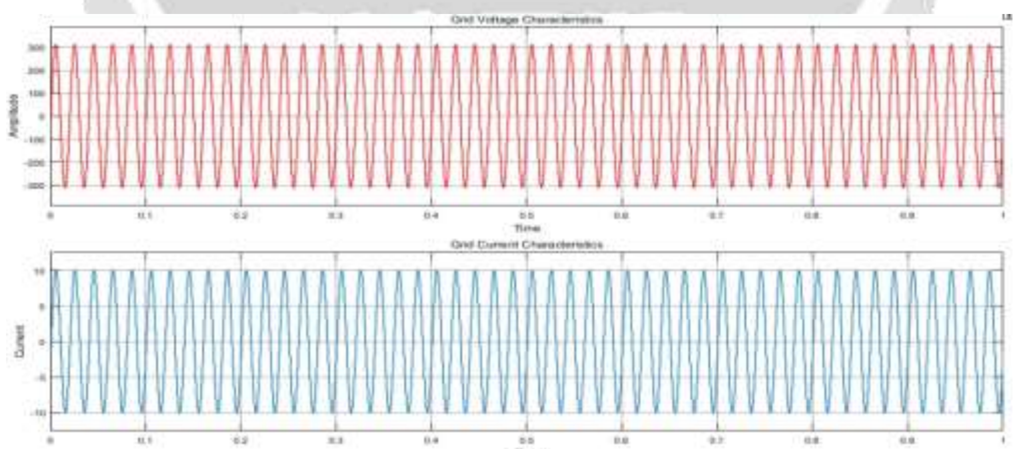

Fig-9 Grid Output

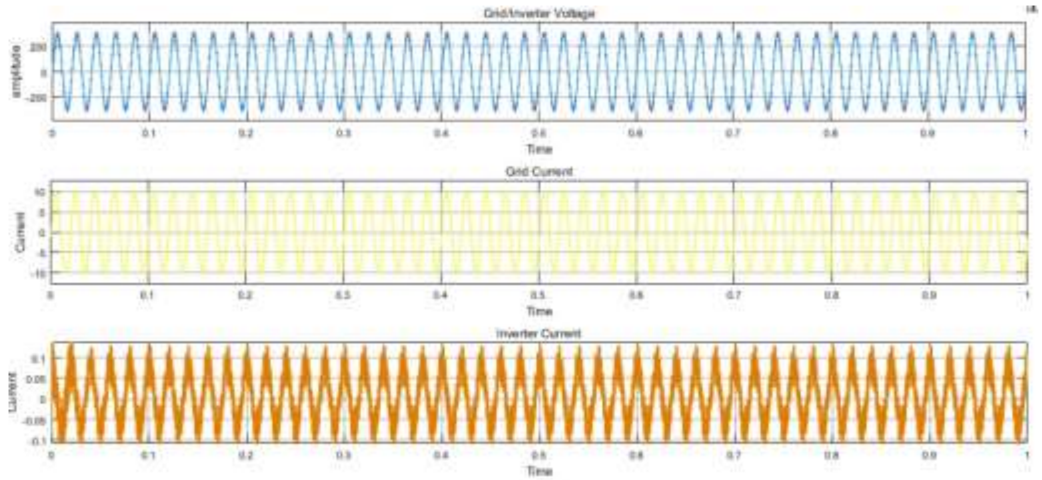

Fig-10 Grid Inverter Output

6. CONCLUSIONS

A single active shunt power filter based on indirect control processes is used in this paper. Using this control signal reference signal was performed successfully. An effective energy filter is found to work by injecting the current compensating harmonic component and thus reducing the current source of THD and improving the strength of the cord. THD was reduced from 38.90% to 9.65% after compensation. It is also evident that the constant voltage comes from the other side of the DC-link capacitor which facilitates the smooth operation of the source voltage.

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