# Renewable Energy Source Inter-Connected with Grid System using Frequency Synchronization

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***Abstract***

*Renewable energy resources are now commonly used in distribution systems with the help of power electronic inverters. This paper presents a control strategy that improves power quality by grid interfaced inverter. Grid connected Current source inverter is capable of providing leading reactive current for static grid. Shunt active power filters compensate current unbalance and load current harmonics and also load reactive power demand. The current source inverter with shunt active power filter provides optimal energy conversion with high efficiency by controlling the reactive power and harmonics. Simulation of the proposed system is verified using MATLAB/Simulink software.*

**Keywords:** *Renewable energy, Current Source Inverter, Shunt Active Power Filter, Simulation.*

## I. INTRODUCTION

The demand for electrical energy is being increasing day by day to increase in population and industry. In India most of the power is generated from burning of fossil fuels. But fossil fuel has so many disadvantages like air pollution, concern of global warming, high cost and availability. Due to the above mentioned problems, the renewable energy sources are necessary for power generation to meet the increasing demand. The photovoltaic (PV) panels are used today in many applications such as charging, water pumping, home power supply, water heating systems etc. They have the advantage of being less maintenance, no pollution. The Photovoltaic (PV) uses some of the properties of semiconductors to directly convert light into electricity. The fundamental unit of a PV panel is the cell.

The main material of the cell is some kind of semiconducting material. Generally the semiconductor is different types of cells. The cells made from gallium arsenide, crystalline silicon, amorphous silicon and others. These all signify different types or forms of semiconducting material The grid interfacing current source inverter can be utilized to perform the following functions are transfer of active power harvested from the renewable resources and load reactive power demand support. The load current harmonics and load unbalance at distribution level are compensated using Active Power Filters (APF).

## II. PROPOSED GRID INTERFACING CURRENT SOURCE INVERTER

The block diagram of Grid Interfacing Current Source inverter is shown in Fig.1. It consists of PV panel, four leg inverter circuit, Driver circuit, Active Power Filter (APF), Generator, transformer and loads.

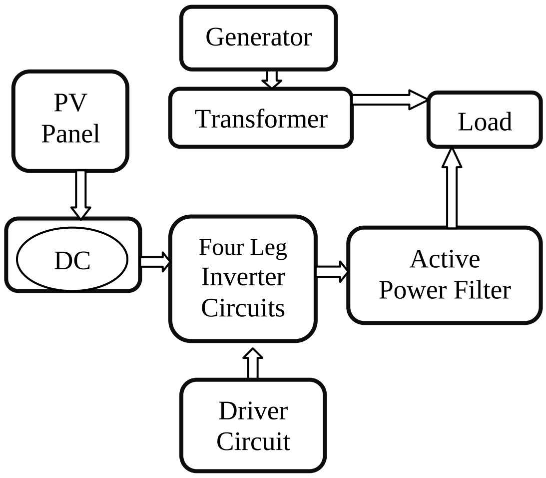


**Fig.1. Block Diagram of Grid Interfacing Current Source Inverter**

Fig.1. shows proposed circuit based on grid interfacing current source inverter. Thus the inverter tries to generate a pure sinusoidal output voltage and where the inverter output current should have low Total Harmonic Distortion (THD). A CSI converts the input DC current to an AC current at the output terminals. The output frequency of AC current depends upon the rate of triggering the switches. In the Current Source Inverter (CSIs) input current is constant but adjustable. The amplitude of output current from CSI is independent of the load. The magnitude of output voltage and its waveform output from CSI dependent upon the nature of the load

impedance. The grid connected into load side has consists of nonlinear load. The nonlinear load consists of RL and RLE load. In general Generator is connected to the load via the transformer. Due to nonlinear load, the output voltage from the transformer is distorted and it produces unbalance current and harmonics. Grid interfacing inverter is used to inject the voltage between the grid and load in order to minimize or nullify the effect due to nonlinear loads. It is also used to transfer the harvested active power from the PV Panel to the grid and it provides support for reactive power demand.

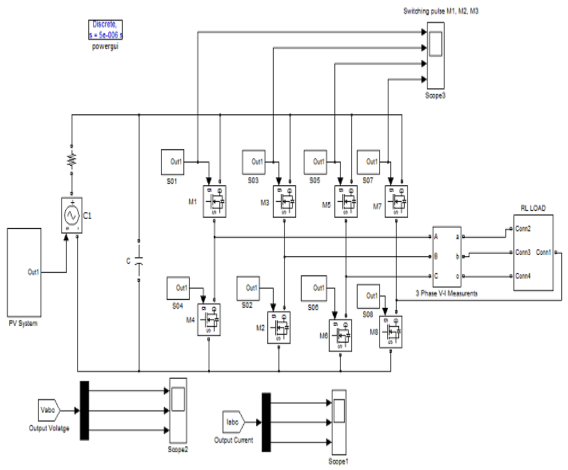

**Fig.2. Proposed Current Source Inverter**

### *A. Modes of Operation*

Mode1. $0^0$-$60^0$ switches 1 and 6 are in conduction. Since c phase is open $Vc_0$=0. The output phase voltages are given by $Va_0$ = Vs/2, $Vb_0$ = -Vs/2 and $Vc_0$ = 0.

Mode2. $60^0$-$120^0$ switches 1 and 2 are in conduction. Since b phase is open $Vb_0$ = 0. The output phase voltages are given by $Va_0$ = Vs/2, $Vb_0$ = 0 and $Vc_0$ = -Vs/2.

Mode3. $120^0$-$180^0$ switches 2 and 3 are in conduction. Since a phase is open $Va_0$ = 0. The output phase voltages are given by $Va_0$ = 0, $Vb_0$ = Vs/2 and $Vc_0$ = - Vs/2.

Mode4. $180^0$-$240^0$ switches 3 and 4 are in conduction. Since c phase is open $Vc_0$ = 0. The output phase voltages are given by $Va_0$ = -Vs/2, $Vb_0$ = Vs/2 and $Vc_0$ = 0.

Mode5. $240^0$-$300^0$ switches 4 and 5 are in conduction. Since b phase is open $Vb_0$ = 0. The output phase voltages are given by $Va_0$ = Vs/2, $Vb_0$ = 0 and $Vc_0$ = -Vs/2.

Mode6. $300^0$-$360^0$switches 5 and 6 are in conduction. Since a phase is open $Va_0$ = 0. The output phase voltages are given by $Va_0$ = 0, $Vb_0$= -Vs/2 and $Vc_0$ = Vs/2.

Switch 7, 8 acts as compensating switch and also used to compensate the unbalanced load.

### *B. PV Panel*

A photovoltaic system is used for converting sunlight into electricity. The basic structure is a cell. These photovoltaic cells are grouped into module. Cells may be grouped to form panels or modules. The photovoltaic panel has a hybrid behavior which may be current or voltage source depends on operating conditions. The photovoltaic cell has a series resistance (R) and its influence is stronger when operated as voltage source and has a parallel resistance R whose influence is stronger when operated as current. The resistance is nothing but the resistance of several devices connected in series and parallel. It consists of negative ones as electrons. The positive ones are a little more conceptually difficult as they are basically holes, or a lack of electrons. A semiconductor with more positive conductors is called a p-type and one with more negative conductors is call n-type.

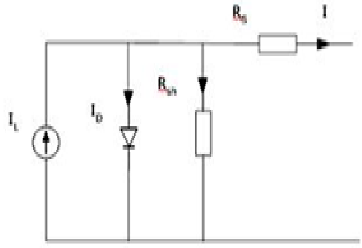

**Fig.3 Circuit Model of PV Solar Cell**

### *C. Active Power Filter*

The load current harmonics and load unbalance at distribution level are compensated using Active Power Filters (APF). The cooperative control makes active filter to reduce the Total Harmonic Distortion (THD). The inverter is controlled to perform as multi-functionality. The active power filters compensating current flows into the power feeder by nonlinear load. The advantages of the active power filter are smaller filter inductor and light weight. It consists of three types 1) shunt 2) series and 3) hybrid. Shunt Active Power Filters (SAPF) compensates the load current harmonics and load unbalance at distribution level.

Design of C values

$$\frac{Vac}{Vdc} = \%r_1 = 0.1\% \qquad (1)$$

$$r_1 = \frac{1}{4\sqrt{3} \times FCR_L} \qquad (2)$$

Design of L values

$$F_5 = 5 \times F \qquad (3)$$

$$F_5 = \frac{1}{2\pi\sqrt{LC}} \qquad (4)$$

### *C. Load*

Current source inverter with active power filter can be connected to nonlinear load under varying renewable generating conditions. In this paper Grid Interfacing Current source inverters are connected to RL load. Nonlinear loads are devices that have different resistance depending on the voltage applied to them.

## III. SIMULATION RESULTS

### *A. Circuit Diagram of Grid Connected Load without Interfacing Inverter*

Fig.4. shows the circuit diagram of grid connected load without interfacing inverter. It consists of generator; step down transformer and point of common coupling and non linear load. The nonlinear load consists of RL load.

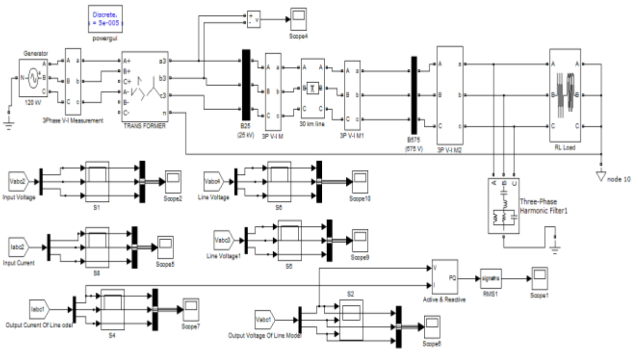

**Fig.4. Simulation Diagram of Grid Connected Load without Interfacing Inverter**

### *B. Circuit Diagram of Grid Connected Load with Interfacing Inverter.*

Fig.5. shows the circuit diagram of grid connected load with interfacing inverter. It consists of generator; step down transformer, current source inverter, point of common coupling and non linear load.

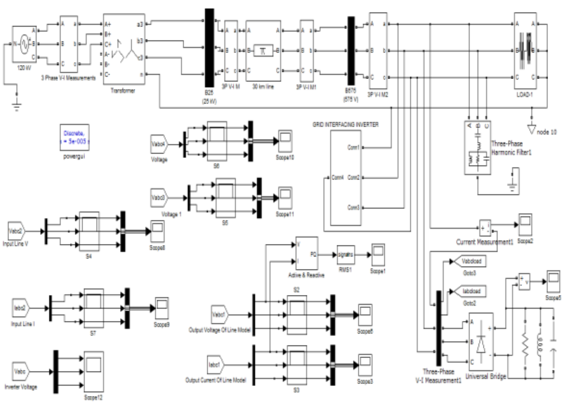

**Fig.5. Simulation Diagram of Grid Connected Load with Interfacing Inverter**

### *C. Circuit Diagram of Current Source Inverter with Shunt Active Power Filter*

Fig.6.shows the circuit diagram of grid interfacing inverter with shunt active power filter for PV System where the output of PV Panel is connected to the inverter circuit which converts DC to AC voltage. It consists of eight MOSFET switch, solar Photovoltaic (PV) system, capacitors and load. Four inductors are connected in series with the inverter.

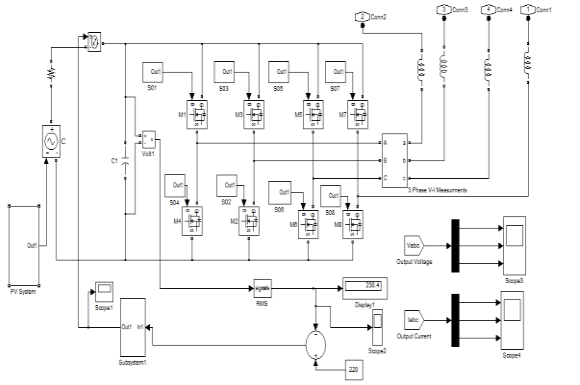

**Fig.6. Simulation Diagram of Current Source Inverter with shunt Active Power Filter for PV System**

The external triggering pulse is given to each MOSFET. The shunt active power filter is used to compensate the current unbalance, load current harmonics and load neutral current.

### *D. Simulation Diagram of PV Panel*

Fig.7. shows the simulation circuit of PV Panel which is connected to the Inverter circuit to convert DC to AC.

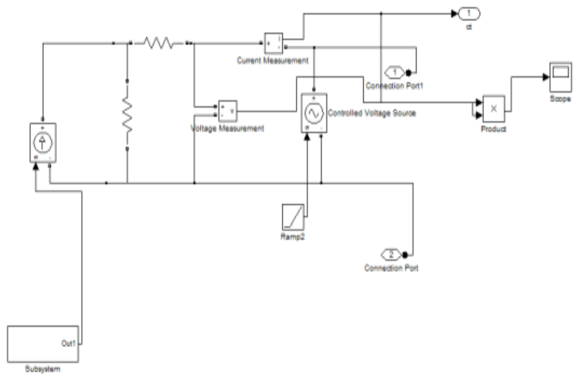

**Fig.7. Simulation Diagram of PV Panel**

### *E. Simulation Output of PV Panel*

Fig.8. shows that the DC source produces the DC voltage of 200v which is given as the input for Current Source Inverter.


**Fig.8. Simulation Output of PV Panel**

### *F. Simulation Output of Grid Connected Load without Interfacing Inverter*

Fig.9. Shows the Simulation output of Voltage, Current, Real and Reactive Power for without grid interfacing inverter.

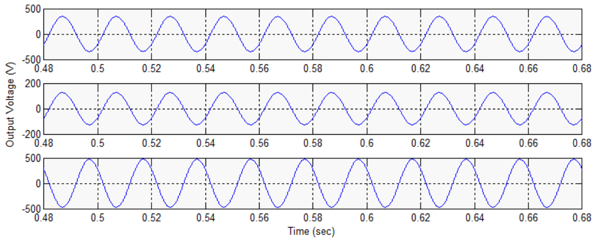


**Fig.9. Output Voltage of Grid Connected Load without interfacing inverter**

Fig.10. Shows the Simulation output of Current for without grid interfacing inverter.

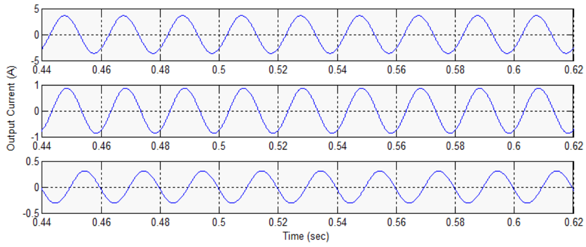


**Fig.10. Output Current of Grid Connected Load without Interfacing Inverter.**

Fig.11. Shows the Simulation output of Real and Reactive Power for without grid interfacing inverter.

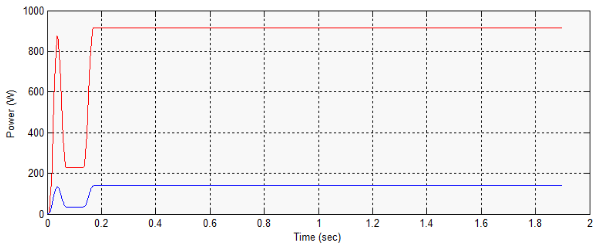


**Fig.11. Output of Real and Reactive Power of Grid Connected Load without Interfacing Inverter.**

### *G. Simulation Output of Grid Connected Load with Interfacing Inverter*

Fig.12. Shows the Simulation output of Voltage for with grid connected inverter.

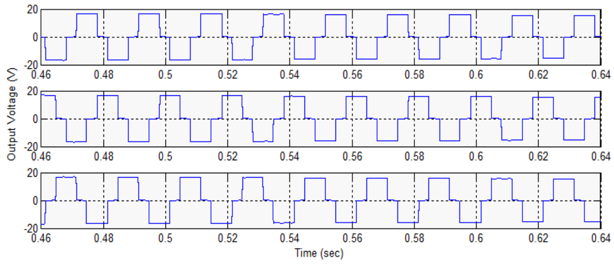


**Fig.12. Output Voltage of Grid Connected Load with Interfacing Inverter**

Fig.13. Shows the Simulation output of Current for with Grid interfacing inverter

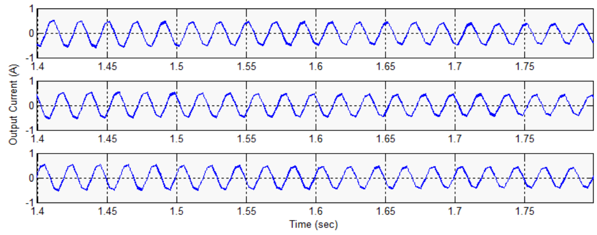


**Fig.13. Output current of Grid Connected Load with interfacing inverter**

Fig.14. Shows the Simulation output of Voltage, Current, Real and Reactive Power for with grid interfacing inverter

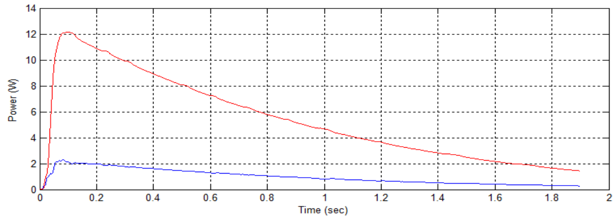


**Fig.14. Output of Real and Reactive power of Grid Connected Load with interfacing inverter.**

### *H. Simulation of Current Source Inverter with Shunt Active Power Filter.*

Fig.15. shows the output voltage waveform of current source inverter with shunt active power filter which converts constant DC source of 230V to AC voltage.

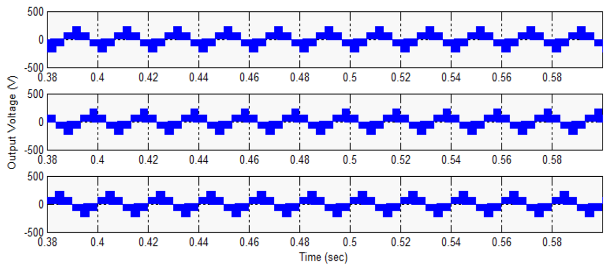


**Fig.15. Grid Interfacing Inverter of Output Voltage Waveform**

Fig.16. shows the output current waveform of current source inverter with shunt active power.

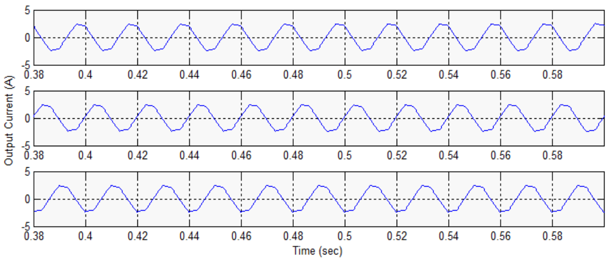


**Fig.16. Grid Interfacing Inverter of Output Current Waveform**

### *I. Total Harmonic Distortion*

Fig.17. Shows the Fast Fourier Analysis for the output current which predicts the Total Harmonic Distortion as 20.25 % for the fundamental frequency.

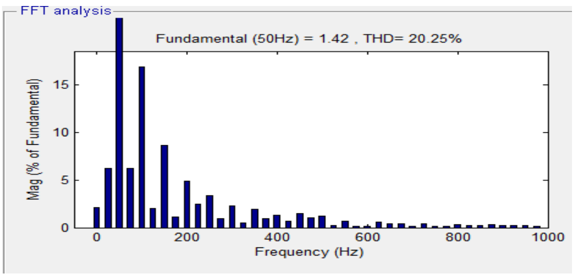


**Fig.17. FFT Analysis of Output Current without Grid Interfacing Inverter**

Fig.18. Shows the Fast Fourier Analysis for the output current which predicts the Total Harmonic Distortion as 12.51 % for the fundamental frequency.

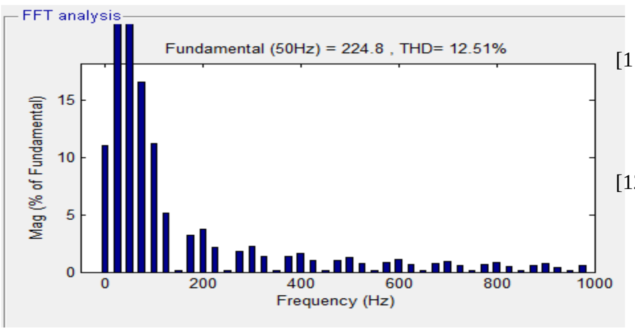


**Fig.18. FFT Analysis of Output Current with grid Interfacing Inverter**

## IV. CONCLUSION

The simulation of the module layout was successfully carried out using MATLAB Simulink software and the obtained waveforms were observed. The output response of the grid connected Current Source Inverter (CSI) with Active Power Filter (APF) for Photovoltaic (PV) system is analyzed. It is observed that the total harmonic distortion without interfacing inverter is 20.25% and with interfacing inverter is 12.51%. This system would show its feasibility in practice.

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