DC-AC Inverter Using SRF Hysteresis Current Controller For Interfacing Photo-Voltaic Source

Pushpanjali Kumari[1], Parveen Kumar[2],

[1] PG Student, Dept of EE, Mata Raj Kaur Institute of Engineering & Technology, Saharanwas, Rewari, India
[2] Associate Professor & HOD, Dept of EE, Mata Raj Kaur Institute of Engineering & Technology, Saharanwas, Rewari, India

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Abstract Researches related to non-conventional energy sources have significantly growth in the present scenario. The electrical energy from PV panel is considered as one of the very useful natural resources. This project deals with the control and operation of a grid coupled PV system with a nonlinear load. A grid connection is provided in order to fill-up energy levels in case of power shortage from the renewable energy sources. The system consists of a PV sources, boost converter and a inverter connected to a load. The synchronous reference frame (SRF) base hysteresis current controller for the inverter is aimed to regulate the output current and to minimize the THD. The Hysteresis Current Controller (HCC) is adopted to generate the switching pulses of the DC-AC inverter with fixed band hysteresis controller in an instantaneous feedback loop. The proposed inverter control technique interfaces renewable energy sources and the AC bus of micro grid. It offers the opportunity to inject power from the renewable sources and also improves the power quality in the same micro grid. Simulation show the positive results of the proposed inverter control technique in improving the power quality of the system.

Key Words: synchronous reference frame, PV sources, Hysteresis Current Controller,

1. INTRODUCTION

Electrical energy is popular and most efficient form of energy and the modern world heavily depends on the electric supply. At the same time quality of the electric power supplied is also very essential for efficient functioning of the user end equipment or devices. The term power quality developed most noticeable in the power sector and both the electric power supplier and the end user are concerned about it. Nonlinear loads in the commercial and industrial as well as residential sectors drain high harmonics from the grid contributing the power quality degradation. When harmonic currents created by nonlinear loads interrelate with the network line impedance, it results in current and voltage harmonics that affects the power quality of all customers linked to the same Point of Common Coupling (PCC). Additionally, effects can be seen through the too much heating of transformers and electrical equipment, and electromagnetic torque oscillations in motors, increasing noise in the audible frequency. In the present scenario of energy head many studies are being done on feasibility of using grid connected inverters fed from fuel cells, photovoltaic arrays etc with active filter functions. Quality of photovoltaic power depends on output current at the inverters necessitating efficient current control of grid connected inverters. Renewable energy resources have an increasingly significant part in power generation in the present era. Besides support the decrease of the emission of greenhouse gases, they add the much- wanted flexibility to the energy resource mix by reducing the need on fossil fuels. Among renewable sources, the PV generator, which is endless, environmentally friendly and, clean gets a lot of attention.

Grid interconnection of PV power has the advantage of more effective employment of generated power. This paper proposes effective utilization of photovoltaic system as a shunt active filter to reduce harmonics due to nonlinear loads along with real power injection and power factor improvement. Three phase voltage source inverters coupled PV systems with grid. Hysteresis current controller is engaged for the inverter control. Synchronous reference frame method has been employed for reference current extraction.

2. PHOTOVOLTAIC

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be openly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. To find the model of the photovoltaic generator, we must start by identifying the electrical equivalent circuit to that source.

Many mathematical models have been developed to represent their highly nonlinear characteristics resulting from that of semiconductor junctions that are the major elements of PV modules. There are numerous models of

Photovoltaic generators which have a certain amount of parameters involved in the calculation of voltage and current output. In this study, we will present the model of single diodes (Fig.1) taking into account the internal shunt and series resistances of the PV cell.

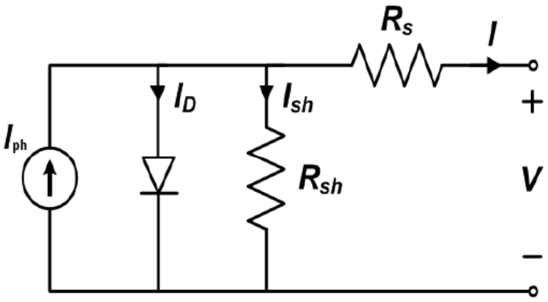

Fig.1 Model of a photovoltaic cell

The current source I_{ph} characterises the cell photo current. R_{sh} and R_s are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of R_s is very small and that of R_{sh} is very large, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays.

The photovoltaic panel can be modelled mathematically as given in equations (1) - (4)

Module photo-current:

$$I_{ph} = [I_{SCR} + K_i(T - 298)] * \frac{\lambda}{100} \qquad (1)$$

Module reverse saturation current:

$$I_{rs}=I_{scr}/[\exp(qv_{oc}/N_s kAT)-1] \qquad (2)$$

The module saturation current I_s varies with the cell temperature, which is given by

$$I_s=I_{rs}[T/T_r]^3\exp[q*E_g/Ak(1/T_r-1/T)] \qquad (3)$$

The current output of PV module i

$$I_{PV}=N_p*I_{Ph}\ N_p*I_0[\exp\{q*(V_{pv}+I_{pv}R_s)/N_sAkT\}-1 \qquad (4)$$

Where V_{pv} and I_{pv} represent the output voltage and current of the PV, I_{ph} is the photocurrent; I_o are diode saturation current; q is coulomb constant (1.602 e-19C); Tris the reference temperature is 298 K;K is Boltzmann's constant (1.381e-23 J/K); ;N_p is the number of cells connected in parallel is 1 .T is cell temperature (K); N_S are P-N junction duality factor;Ns is the number of cells connected in series is 36

3. SRF-Based Controller

In this method the measured load currents are converted into the rotating reference frame (d-q frame) that is synchronously rotating at the line voltage frequency using Clark's Transformation and Park's Transformation. The line frequency components of the load currents become DC quantities and the harmonic components are frequency removed by ωt in the d-q reference frame.

1. Clark's Transformation

It converts sensed source current signal from a-b-c stationary to α-β stationary coordinate system by following equation

$$\begin{bmatrix} I_\alpha \\ I_\beta \\ I_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I_{ca} \\ I_{cb} \\ I_{cc} \end{bmatrix}$$

2. Park's Transformation

Now this signal α-β is transformed in d-q frame by using equation

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t \\ -\sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix}$$

A LFP pass filter in the d-q frame, with a cut-off at the line frequency can be used to extract the DC components.

3. Reverse Park's Transformation (α-β to d-q)

$$\begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} = \begin{bmatrix} \cos\omega t & -\sin\omega t \\ \sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} I_d \\ I_q \end{bmatrix}$$

Currents to convert them back to original frame, the inverse conversion from d-q to α-β frame, and then to a-b-c frame is carried out utilizing (3) and (4).

4. Reverse Clark's Transformation (d-q to a-b-c)

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \sqrt{\frac{2}{3}} \cdot \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \cdot \begin{bmatrix} I_\alpha \\ I_\beta \\ I_o \end{bmatrix}$$

Reference current (i_{ca*},i_{cb*},i_{cc*}) generated using current SRF controller which shown in figure 4.1

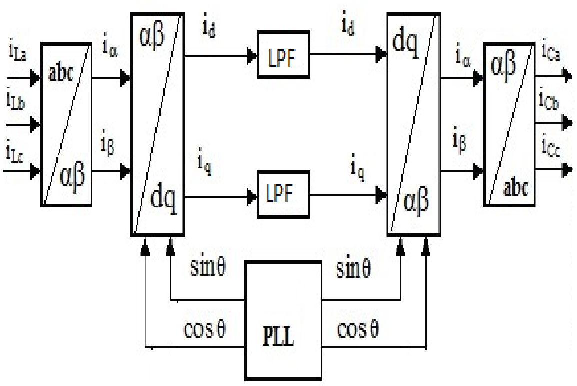

Fig.2 Reference compensating currents generated using SRF theory

Reference current take out by Synchronous reference method is compared with the filter current in the Hysteresis loop and corresponding pulses are given for inverter switching. Inductor provides smoothing and isolation of high frequency components. Desired current waveform is obtained by controlling the switching of IGBT switches in the inverter.

4. HYSTERESIS CURRENT CONTROL METHOD

Hysteresis current control (HCC) is an instantaneous closed loop control method in which the output current *i* of the inverter is made to track the command current and maintain the error within the hysteresis band.

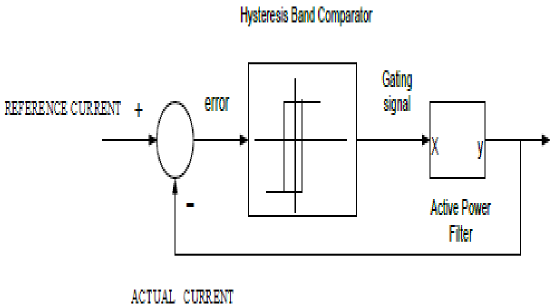

Fig.3 Block diagram of hysteresis current controller

It is principally a fed back current control method, where the actual current uninterruptedly tracks the reference current in the hysteresis band .The reference and actual current is equated with respect to hysteresis band which chooses switching pulse of voltage source inverter. As the current crosses a set hysteresis band, the upper switch in the lower switch is turned on and.the half-bridge is turned off. As the current beats the lower band limit, the upper switch is turned on and the lower switch is turned off.

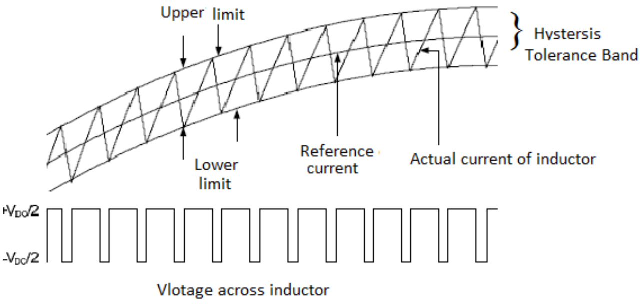

Fig.4 Hysteresis tolerance band

The switching frequency be subject to how fast the current alterations from upper limit to lower limit and vice versa. This in turn be influenced by voltage v_d and load inductance.

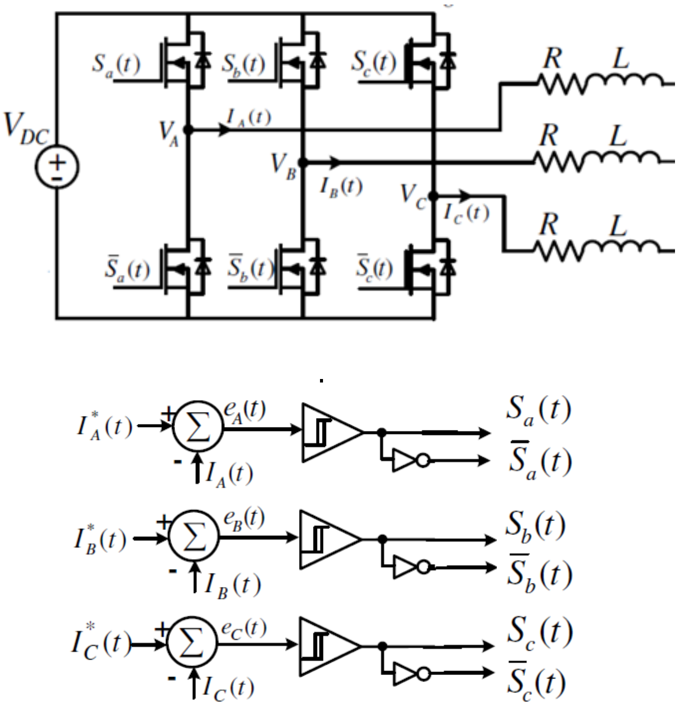

Fig.5 Hysteresis current control method in three phase circuit

The three-phase HCC for this voltage source inverter is shown in fig.5. In this configuration, each phase leg is controlled by a separate HCC, which compares its phase leg current against a commanded reference current to generate a per phase current error. The current errors are then compared against three separate sets of (fixed) hysteresis bands to individually switch each inverter phase leg to the upper or lower DC supply voltage in order to control its output current.

5.SIMULATION RESULTS

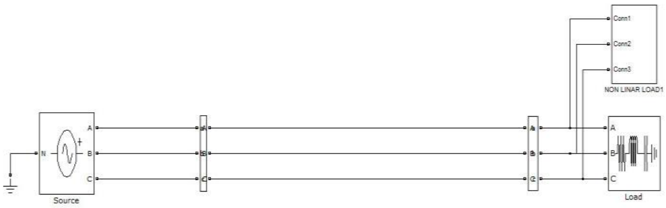

Fig.6 Source with linear load and nonlinar load

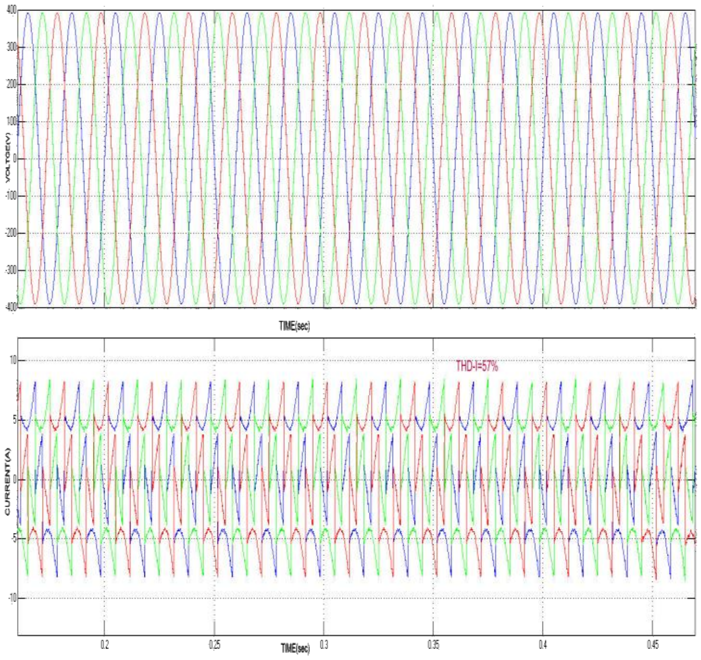

Fig.7 Voltage and current at sources

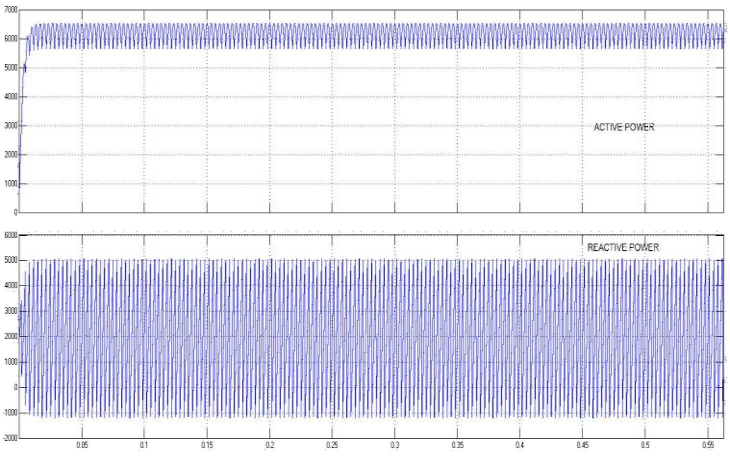

Fig.8 Power delivered to load from source

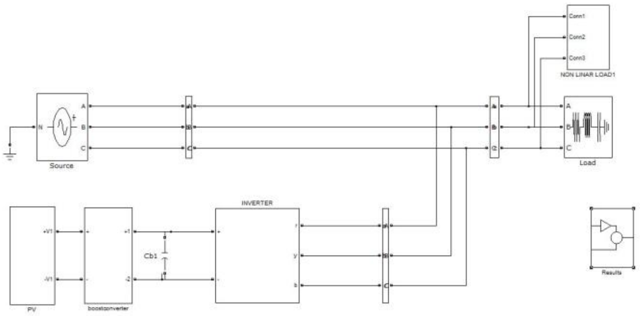

Fig: 9 PV System connected to grid

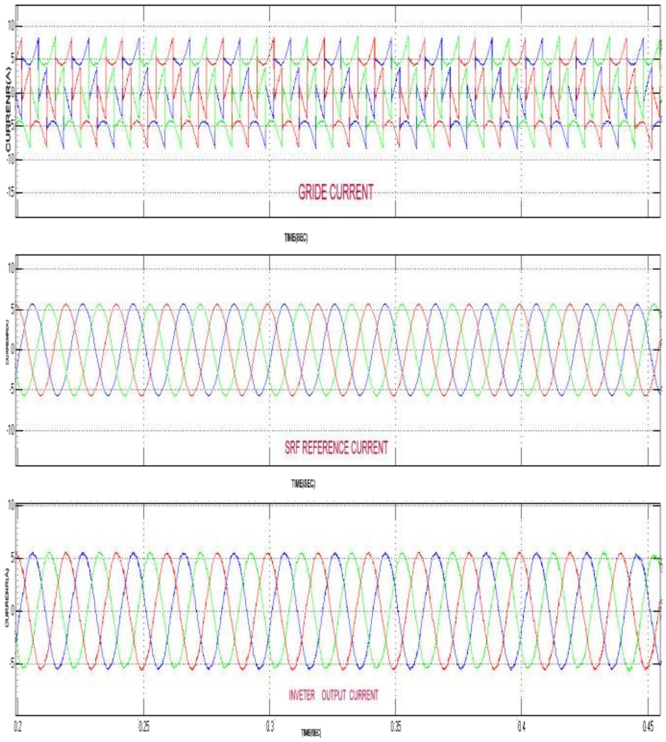

Fig.10 SRF base controller

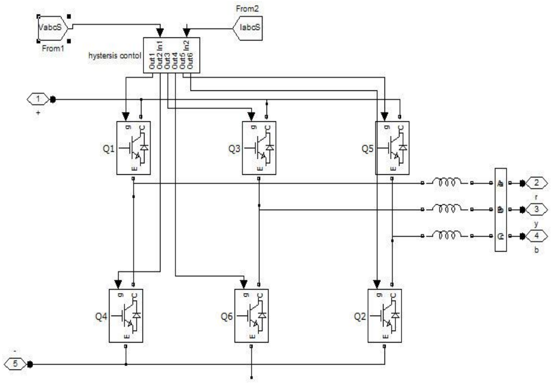

Fig.11 Hysteresis current controlled inverter

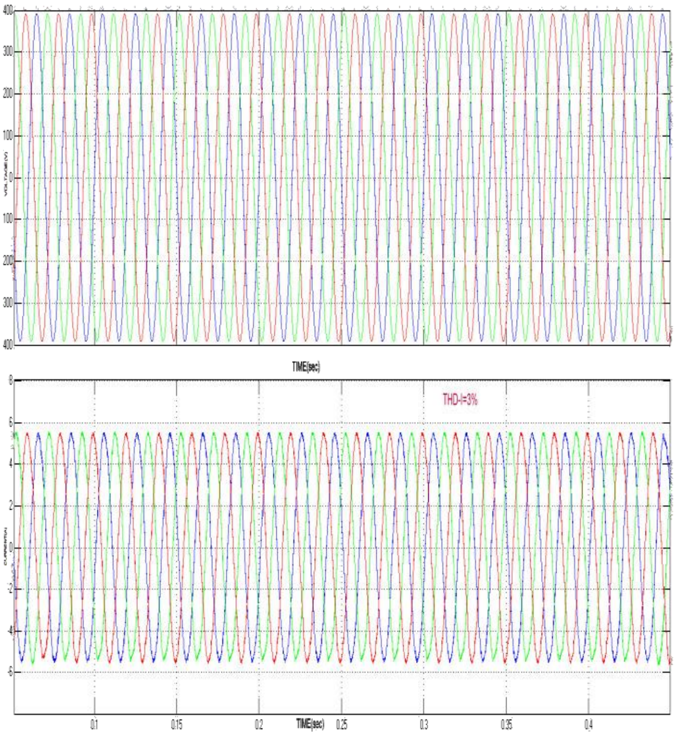

Fig.12 Inverter output voltage and current

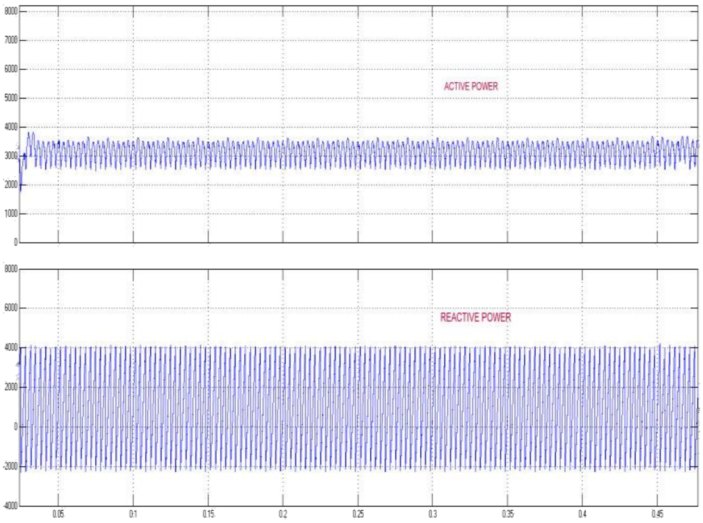

Fig.13 Power delivered to load from source after PV connection to grid

6. CONCLUSION

Grid connected PV system is implemented in MATLAB Simulink and hysteresis current controller is employed for the inverter control. Real power sharing and harmonic elimination are analyzed and found that the given controller is effective in meeting the requirements. The PV system was capable of supporting a 3 kw load .SRF base hysteresis current controller inverter eliminates the harmonics in source current due to nonlinear load

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