

Matlab Simulation of Grid Connected PV System Using Hysteresis Current Control Inverter

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Abstract: *This paper describes the Grid Connected Solar Photovoltaic (PV) system Using Hysteresis Current Control Inverter to supplies electric power to the utility grid and is one of the major renewable energy sources. In this paper we are going to develop a complete computer simulation program of a grid-connected solar PV system in distribution power network using MATLAB/Simulink and SIM Power System tool. This paper aims to grid-connected solar PV system at steady state and also to study their transient responses to changing inputs. These control method provides robust current regulation, achieve unity power factor, low THD and optimize the PV energy extraction suitable for grid connected PV systems.*

Keywords: *Solar PV system, Power conditioning Unit, Hysteresis current control inverter.*

1. INTRODUCTION

Renewable energy resources will be an increasingly important part of power generation in the new millennium. Besides assisting in the reduction of the emission of green house gases, they add the much- needed flexibility to the energy resource mix by decreasing the dependence on fossil fuels [1]. In other hand, deregulation of the electric utility industry is providing an opportunity for higher penetration and use of distributed resources (DR). Distributed resources are generation sources that can be located at or near loads. Distributed resources can provide benefits that bulk power generation can not. PV systems are ideally suited for distributed resource applications. Photovoltaic (PV) systems produce DC electricity when sunlight shines on the PV array, without any emissions. This article refers about a model for modeling and simulation of PV module based on Shockley diode equation.

Grid interconnection of PV power generation system has the advantage of more effective utilization of generated power. However, the technical requirements from both the utility power system grid side and the PV system side need to be satisfied to ensure the safety of the PV installer and the reliability of the utility grid. Clarifying the technical requirements for grid interconnection and solving the problems such as islanding detection, harmonic distortion requirements and electromagnetic interference are therefore very important issues for widespread application of PV systems. Grid interconnection of PV systems is accomplished through the inverter, which convert dc power generated from PV modules to ac power used for ordinary power supply to electric equipments. Inverter system is therefore very important for grid connected PV systems.

The regulated DC bus voltage is then applied to the main inverter which implements a single band hysteresis current control technique to produces power to be fed into the grid. A reference current is used in order to produce switching pulses for the power switches. The current produced by the inverter must be synchronized and in phase with grid voltage in order to achieve high efficiency and unity power factor. Simulations and experimental result have operates at verified the feasibility of the proposed PV inverter system.

2. PV GENERATOR

A photovoltaic PV generator is the whole assembly of solar cells, connections, protective parts, supports etc. In the present modeling, the focus is only on cell/module/array [3]. Solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor (usually silicon). In the dark, the I-V output characteristic of a solar cell has an exponential characteristic similar to that of a diode [4]. When solar energy (photons) hits the solar cell, with energy greater than band

gap energy of the semiconductor, electrons are knocked loose from the atoms in the material, creating electron-hole pairs [5]. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation. When the cell is short circuited, this current flows in the external circuit; when open circuited, this current is shunted internally by the intrinsic p-n junction diode.

3. MODELING THE SOLAR CELL

Equivalent circuit of a solar cell is a current source in parallel with a diode as shown in Fig 1. The output of the current source is directly proportional to the light falling on the cell. When light hits the solar cell, the energy of the photons generates free charge carriers. The current source produces the photoelectric current (photocurrent) I_{ph} . Since the current is dependent upon the radiance.

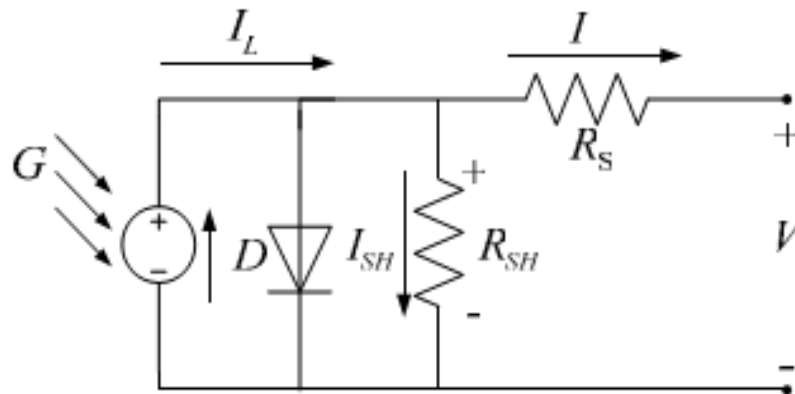


Fig1. Circuit diagram of the PV model

Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode. The output of the current source is directly proportional to the light falling on the cell (photocurrent I_{ph}). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current I_D , called diode (D) current or dark current.

In an ideal cell $R_s = R_{sh} = 0$, which is a relatively common assumption [6]. For this paper, a model of moderate complexity was used. The net current of the cell is the difference of the photo current, I_L and the normal diode current I_0 :

$$I = I_L - I_o \left(e^{\frac{q(V+IR_s)}{nkT}} - 1 \right) \quad (1)$$

The model included temperature dependence of the photocurrent I_L and the saturation current of the diode I_o .

$$I_L = I_L(T_1) + K_o(T - T_1) \quad (2)$$

$$I_L(T_1) = I_{sc}(T_{1,nom}) \frac{G}{G(nom)} \quad (3)$$

$$K_o = \frac{I_{sc}(T_2) - I_{sc}(T_1)}{(T_2 - T_1)} \quad (4)$$

$$I_o = I_o(T_1) * \left(\frac{T}{T_1} \right)^{\left(\frac{3}{n} \right)} e^{\frac{qV_q(T_1)}{nk \left(\frac{1}{T} - \frac{1}{T_1} \right)}} \quad (5)$$

$$I_o(T_1) = \frac{I_{sc}(T_1)}{e^{\frac{qV_{oc}(T_1)}{nkT_1} - 1}} \quad (6)$$

A series resistance R_s was included; which represents the resistance inside each cell in the connection between cells.

$$R_s = - \frac{dV}{dI_{Voc}} - \frac{1}{X_V} \quad (7)$$

$$X_V = I_o(T_1) \frac{q}{nkT_1} e^{\frac{qV_{oc}(T_1)}{nkT_1}} - \frac{1}{X_V} \tag{8}$$

4. SIMULATION RESULTS FOR PV CELL

The BP SX150 PV module was chosen for modeling, due is well-suited to traditional applications of photovoltaic. The BPSX 150 module provides 150 watt of nominal maximum power, and has 72 series connected polycrystalline silicon cells. A typical I-V characteristic of the solar cell for a certain ambient irradiation G and a certain fixed cell temperature T is shown in Fig 2.

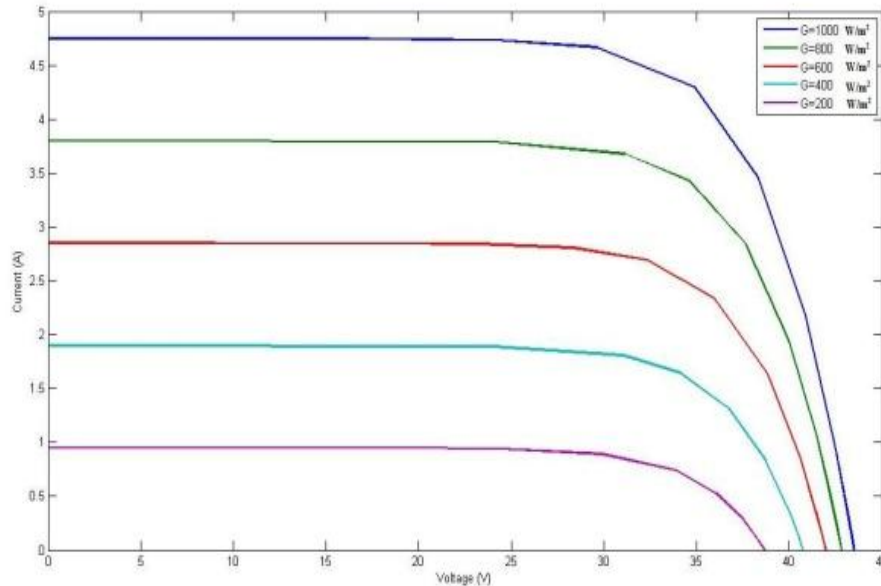


Fig2. A typical current-voltage -V curve for a solar cell.

Fig.3 and 4 shows the I - V characteristics for different values of temperature and fixed irradiance of 1000W=m2 respectively. From the figures, we can conclude that when the irradiation is 1000W=m2, which corresponds approximately to a cloud-free, sunny day, the upper curve shows that the open-circuit voltage of the cell is about 43.2 Volt. As the load (current) of the cell increases, the voltage decreases and at short-circuit (voltage = 0) the current is approximately 4.75 A.

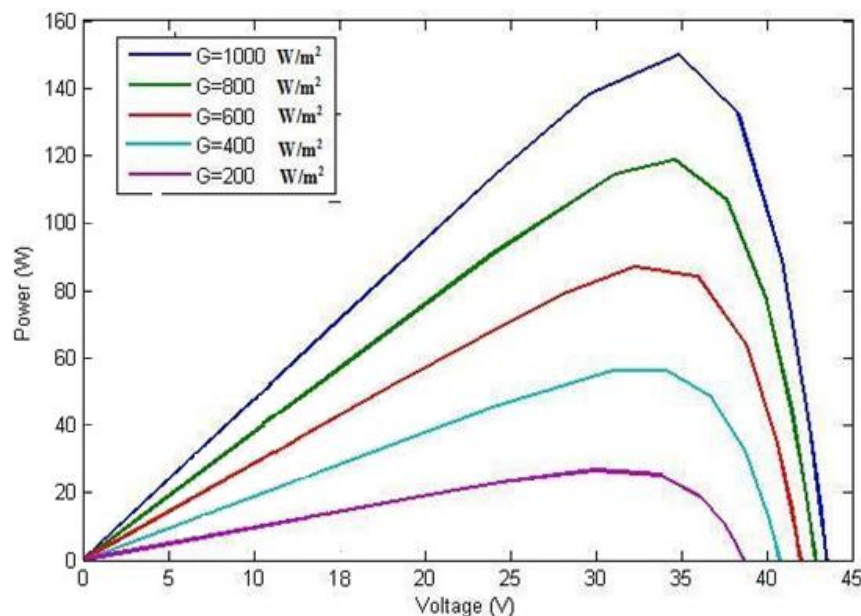


Fig3. P-V characteristic for a PV cell at a constant temperature of 25°C

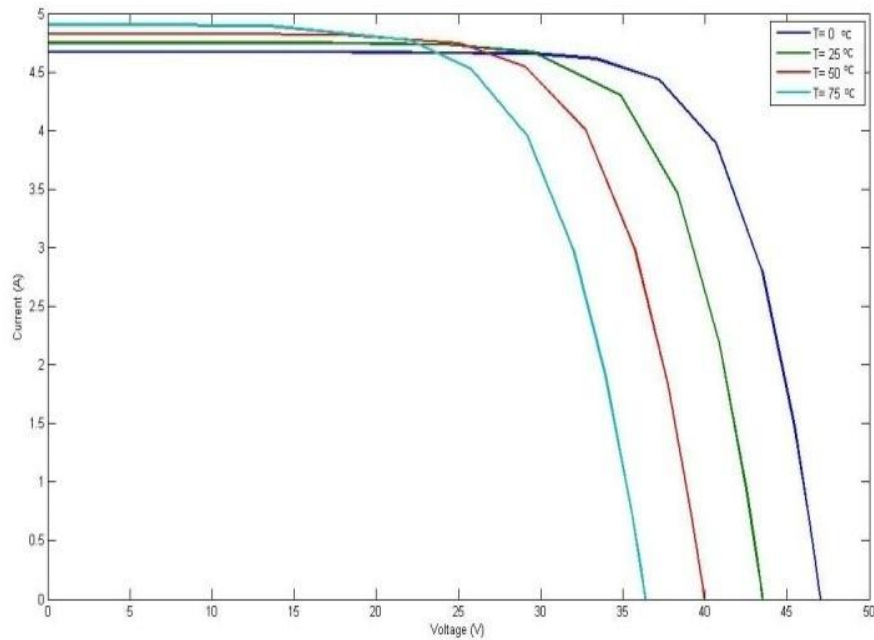


Fig4. I-V characteristic for a PV cell at constant $G= 1000W/m^2$

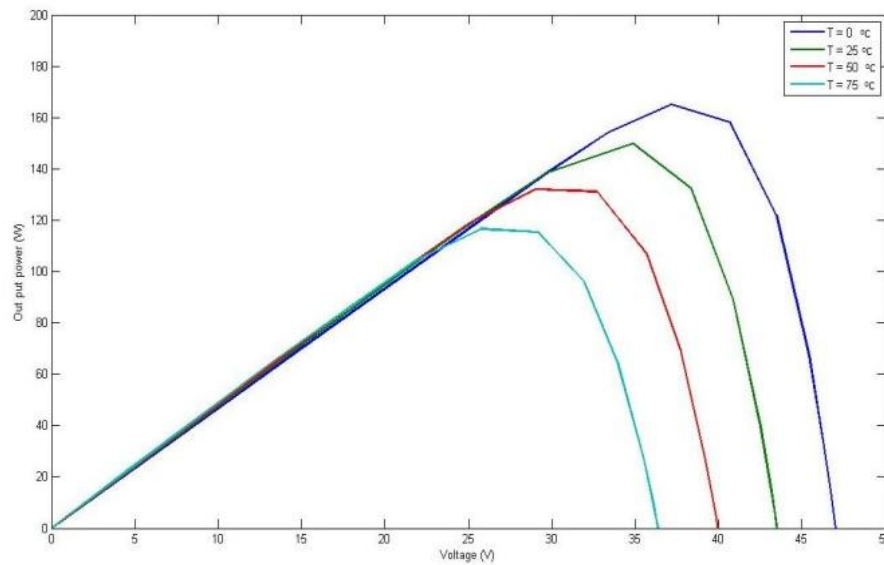


Fig5. P-V characteristic for a PV cell at constant $G= 1000W/m^2$

At open circuit and at short-circuit, no power is produced. At a point called the maximum power point (MPP), maximum power is gained from the PV-cell. To visualize this, a rectangle can be drawn from a point on the curve to the x and y-axis. For the point where this rectangle has the largest area, the maximum power is generated. At a lower irradiation, the short-circuit current decreases approximately linearly with irradiation. The open circuit voltage does not decrease as much until a very low irradiation. However, the open circuit voltage is much more affected by the temperature of the PV-cell. At a higher temperature, the open circuit voltage decreases. The phenomenon has quite a large impact and it decreases the output power by approximately 15% at a temperature increase from $25^{\circ}C$ to $75^{\circ}C$.

The effect of irradiance and cell temperature on I-V characteristic curve is shown in Fig.2 and 4. Fig.2 shows that the maximum power output varies almost linearly with the irradiance. Fig.4 shows that the maximum output power from the PV decreases as the temperature increases

5. HYSTERESIS CURRENT CONTROLLER

The Hysteresis current controller contributes to the generation of the switching signals for the inverter. Hysteresis-band PWM is basically an instantaneous feedback current control method of PWM where the actual current continually tracks the command current within hysteresis-band.

This method controls the switches in an inverter asynchronously to ramp the current through an inductor up and down so that it tracks a reference current signal. The proposed hysteresis current controller is shown in Fig.3.

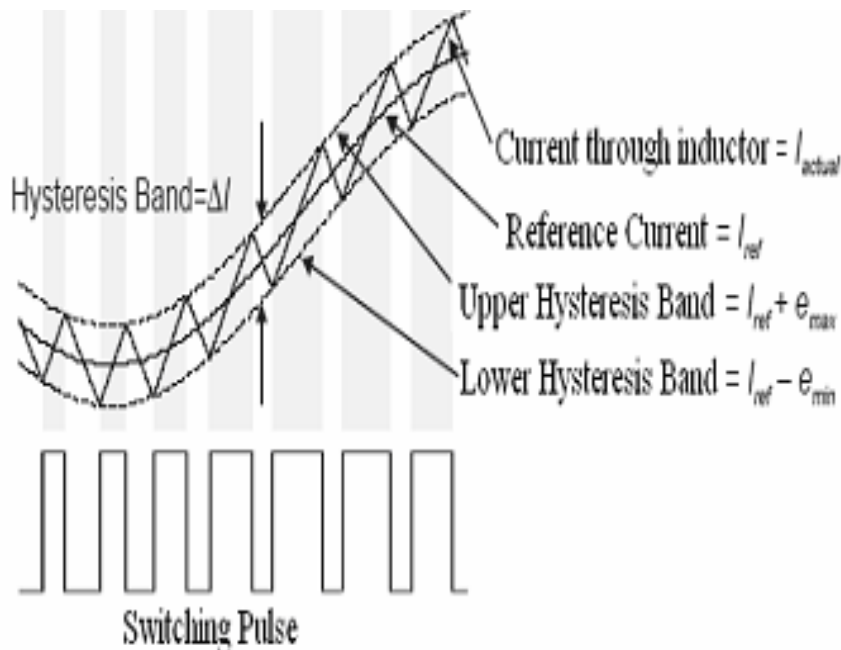


Fig6. Hysteresis Current Control

6. THE ESTABLISHMENT OF SIMULATION MODEL AND SIMULATION RESULTS

In this paper the inverter output current (i.e. load current) will be compared every time with the reference current. The current error is then compared directly against a predefined band called hysteresis band to produce switching pulses for the voltage source inverter. This method controls the switches in an inverter asynchronously to ramp the current through an inductor up and down so that it tracks a reference current signal and the output of the Hysteresis controller generates 6 pulses.

In the below The performance and practicality of the presented transformer less PV Inverter and Hysteresis Current Control have been confirmed by simulation and experiment result.

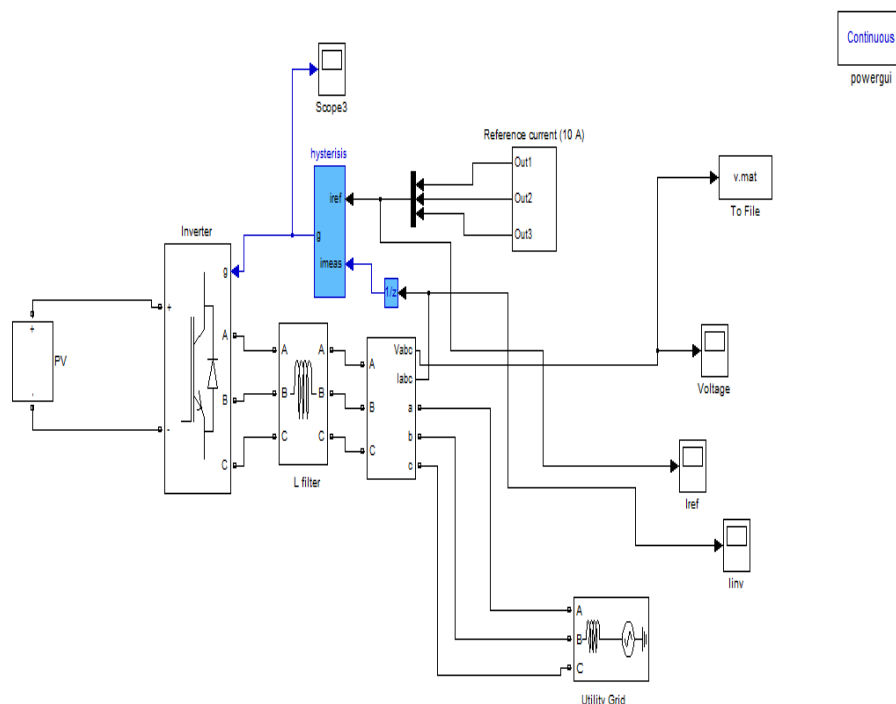


Fig7. Simulink model of Grid Connected inverter

The output voltage wave form of a grid connected inverter having the phase to phase voltage of 440V.

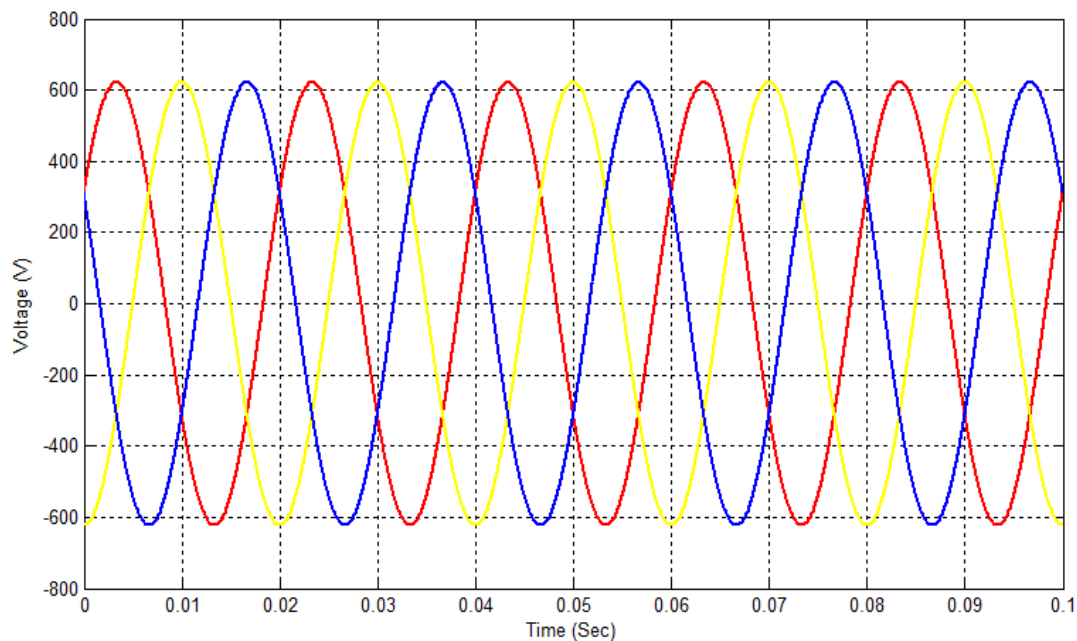


Fig8. Output Voltage of Grid-Connected Inverter

In the figure 6 and 7 shows the reference current of 10A and the Hysteresis current control inverter tracks the 10 A current from the source i.e. Solar PV system and achieve unity power factor, low Total Harmonic Distortion (THD) and it optimizes the PV energy Extraction suitable for grid connected PV systems.

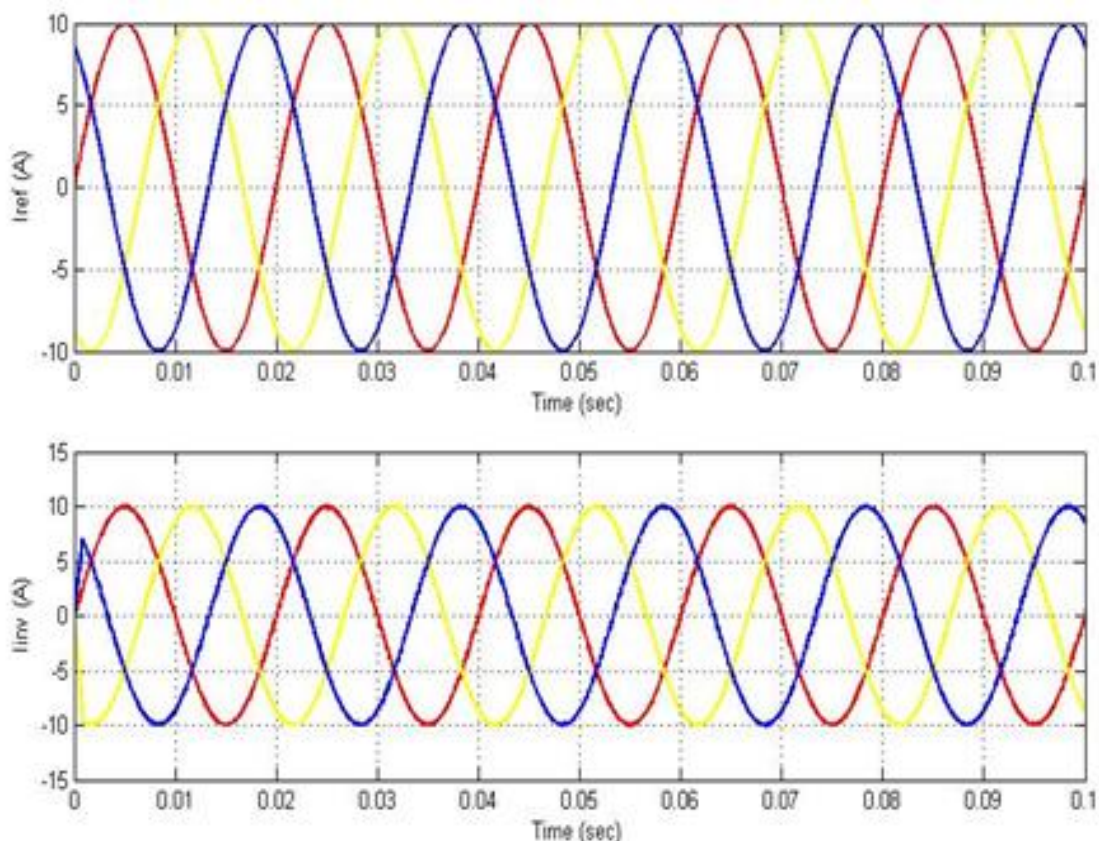


Fig9. Current Response of Grid-Connected Inverter

In the Fig.8 shows that the percentage of Total Harmonic Distortion (THD) for 2 cycles is 0.21% it shows that the Hysteresis Current Control inverter provides the good power quality output.

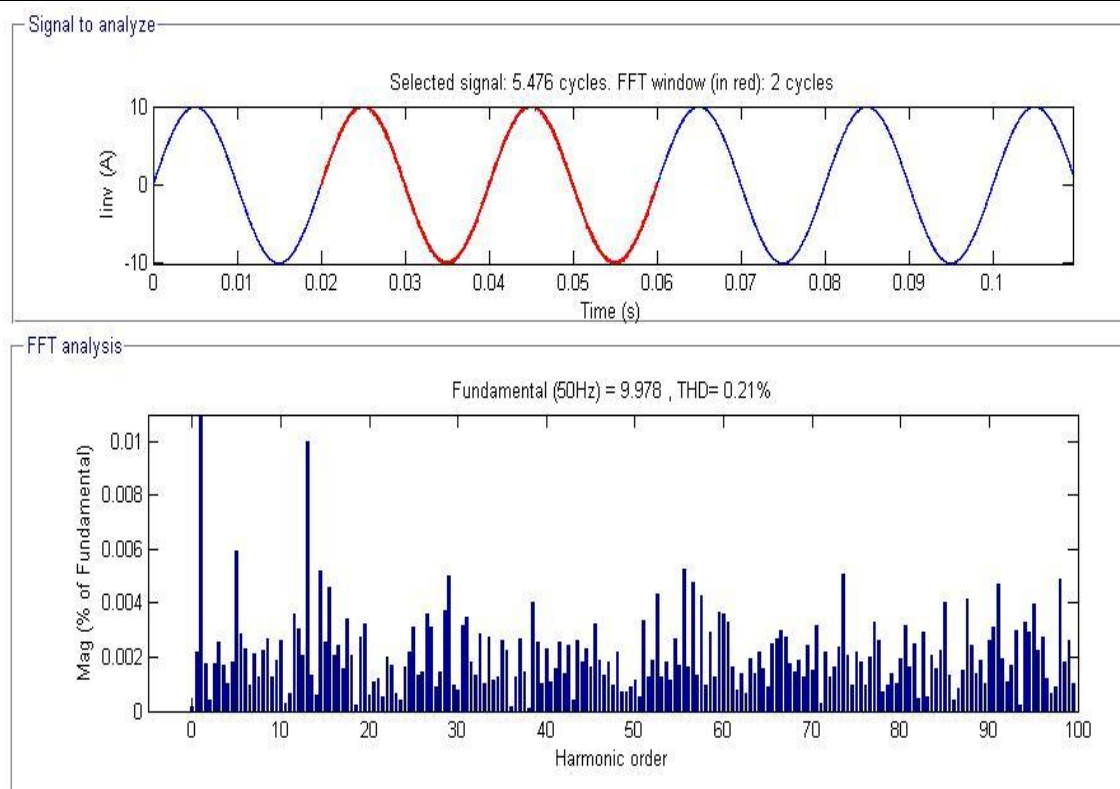


Fig10. % of Total Harmonic Distortion (THD)

7. CONCLUSIONS

This paper concludes that the characteristics of Solar PV cell and Hysteresis Current Control Grid Connected Solar PV system behavior have been developed. The results of the solar PV system provide the current and the inverter tracks the reference current from the solar PV and supplies to the utility grid. And also reduces the total harmonic distortion (THD) by using hysteresis current control technique.

REFERENCES

- [1] L.A.C Lopes and Lienhardt, A.-M. "A simplified nonlinear power source for simulating PV panels". Power Electronics Specialist, 2003. PESC'03. IEEE 34th.
- [2] Annual Conference on, Volume 4, pp. 1729-1734.15-19 June 2003. B. Kroposki, R. DeBlasio, "Technologies for the New Millennium. Photovoltaics as a Distributed Resource". Power Engineering Society Summer Meeting, 2000. IEEE, Vol. 3, p.p. 1798 – 1801, 16-20 July 2000
- [3] Hansen, P. Lars, H. Hansen and H. Bindner. "Models for a StandAlone PV System". Risø National Laboratory, Roskilde, December 2000, ISBN 87-550-2776-8. [Online]. Available: <http://www.risoe.dk/rispubl/VEA/ris-r-1219.html>.
- [4] G. Walker, "Evaluating MPPT converter topologies using a MATLAB PV model," Journal of Electrical & Electronics Engineering, Australia, IEAust, vol.21, No. 1, 2001, pp.49-56.
- [5] Lorenzo, E. (1994). Solar Electricity Engineering of Photovoltaic Systems. Artes Graficas Gala, S.L., Spain.
- [6] Francisco M. González-Longatt publish " Model of Photovoltaic Module in Matlab™ " of 2do congreso iberoamericano de estudiantes de ingeniería eléctrica, electrónica y computación (ii cibelec 2005).
- [7] Nasrudin Abd Rahim, Jeyraj Selvaraj and Krismadinata of Hysteresis Current Control and Sensorless MPPT for Grid-Connected Photovoltaic Systems .

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