Mitigation of Lower Order Harmonics in PV Fed Three Phase Inverter

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Abstract - In this project a simple photo voltaic fed three phase inverter was implemented and in this topology will not inject any lower order harmonics into the load due to high-frequency pulse width modulation operation. The implemented design of inverter that reduces the lower order harmonics present in this project. A Hysteresis controller is used to reduce to overcome the lower order harmonic distortions. Total harmonics distortion achieved by this topology is less than 2%. The complete model has been validated with MATLAB software and the all over system operation is observed.

***Key Words*:** **PV, Boost Converter, Inverter, PWM, & Hysteresis controller.**

1. INTRODUCTION

With the Time passing, the world is being more machinist and automation dependent. This has been made easy, convenient and cheaper with the use of photovoltaic concept. Conversion of solar and electrical energy is now easy and cheap to install and handle. The Use of Photovoltaic concept is increasing day by day as it has shown great ways to increase the generation capacity of electrical energy in terms of its largely spread areas. We have an increased load demand and a lesser supply of power in recent time with the use of photovoltaic inverter.
The Photovoltaic inverter or solar inverter converts the variable Direct Current (DC), output of a photovoltaic solar panel in to a utility frequency Alternating Current (AC) that can be used by a local, off-grid electrical network. [1]

1.1 photovoltaic

Photovoltaic (PV) is used to covers the conversion of light into electricity using semiconducting materials. To consider the power quality behaviors resulted from operation of a PV plant in distributed generation system, the main components of PV generation plants are PV module and PV inverters. The PV module is convert light energy to electrical energy form of the dc voltage and current. The PV inverter is then used to convert the dc to ac power to be used by consumer or to connect to the grid.[2]

1.2 Boost Converter

A boost converter (step-up converter) is a DC to DC power converter, the input voltages is always less than their output voltages when the power device is on. The main application of boost converter is re-generative breaking of DC motor and regulated DC power supply. [5]

2. HARMONICS

The power electronic equipment such as rectifier, chopper and inverter having switching device when they are working then their operation produce voltage and current harmonic into the system and harmonics is a non-sinusoidal component involve in a complex wave having a frequency of integral multiples of the fundamental frequency.[3]

The Effect of harmonics is: -

(a) Increased heating effect on electrical distribution equipment and cables,
(b) Excessive voltage drops,
(c) Large neutral current etc.

2.1 Harmonics Performance Parameters of inverter

he output of inverter should be a sinusoidal voltage. The non-sinusoidal voltage output given by practical inverter and this may be solved into harmonics component and fundamental component. Performance of an inverter is evaluated of the following performance parameter:

2.1 (a) Harmonic factor of nth Harmonics (HFn)

The harmonics factor is calculate to the single harmonic in the output voltage of an inverter. It is known as the ratio of the rms voltage of a particular harmonics component to the rms of fundamental component.

$$HFn = \frac{E_{n\ rms}}{E_{1\ rms}}$$

2.1 (b) Lowest-Order Harmonics (LOH)

The lowest frequency harmonics, with a magnitude equal to and greater than three-per-cent of the magnitude of the fundamental component of the output voltage, is known as lowest order harmonics. Higher the frequency of the LOH, lower will be the distortion in the current waveform.

2.1 (c) Total Harmonics Distortion (THD)

The total harmonic distortion is calculated as the ratio of the rms value of its total harmonic component of the output voltage and the rms value of the fundamental component. A total harmonics distortion is an evaluate of closeness in a shape between the output voltage waveform and its fundamental components.

$$THD = \frac{\sqrt{E_{rms}^2 - E_1^2}}{E_{rms}^1}$$

2.1 (d) Distortion Factor (DF)

A distortion factor shows the amount of harmonics that remain in the output voltage waveform, after the waveform has been subjected to second order attenuation. It is found as

3 HARMONICS REDUCTION

The power electronics equipments, such as inverter & rectifier e.t.c have switching devices and their output produces voltage & current harmonics to the system from which they are working and these harmonics affect the operation of other equipments connected to the same system through conduction or by radio interference. This harmonics gives the following disadvantage: (a) harmonics current will lead to excessive heating in the induction motor connected with the thyristor system and this will reduce the load carrying capacity of the motor. (b) Harmonics current cause losses in the a.c. system. (c) If the control & regulating circuits are not properly shielded, harmonics from power side can affect their operation & malfunctioning. [3]

These effects can be reduced by reducing the harmonic content. There are various methods:

3.1 Single-pulse Width Modulation.
3.2 Transformer Connections.
3.3 Stepped Wave Inverter.
3.4 Multiple Commutations in Each Half-cycle.

4 HARMONICS ANALYSIS

Harmonic analysis is a branch of mathematics concerned with the version of functions or signals as the superposition of basic waves, and the study of and generalization of the concept of Fourier series and Fourier transforms.

A harmonic is a signal, wave or whose frequency is an integral (or whole-number) multiple of the frequency of some reference wave or signal. The term can also transfer to the ratio of the frequency of such a wave or signal to the frequency of the reference wave or signal. Let f represent the fundamental or main, frequency of an alternating current signal, sound wave or electromagnetic field. This frequency, usually expressed in hertz and the frequency at which most of the energy is contained, or at which the signal is defined to occur. If the wave or signal is displayed on an oscilloscope, the waveform will appear to repeat at a rate corresponding to f Hz. As is observed the harmonic decreases as n increases. It decreases with a factor of (1/n). Even harmonics are absent–Nearest harmonics is the 3rd. If fundamental is 50Hz, then nearest harmonic is 150Hz.

Due to the small separation between the harmonics and fundamental, output low-pass filter design can be relatively difficult. The effects of harmonics are unpleasant due to the fact that these cause unbalance and excessive neutral currents. Harmonics give rise to interference in nearby communication networks and disturbance to other consumers. In electric motor drives, they cause torque pulsations and cogging.[4]

5 FFT ANALYSES

It is a linear algorithm that can take a time domain signal into the frequency domain and back. Fourier analysis allows a more intuitive look at an unknown signal in frequency domain. As is presented in Figure 1. the fundamental component & the harmonic components can be understood without cumbersome.[4]

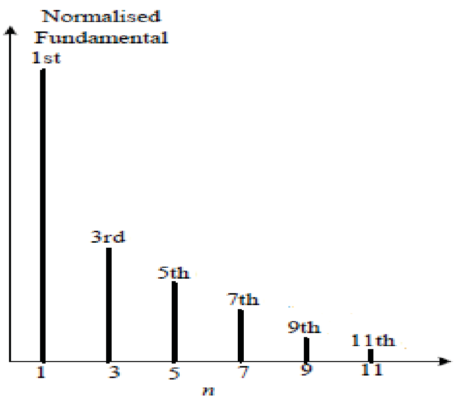


Figure 1 Harmonic Spectra of an Inverter

6 PROPOSED SYSTEMS

In this work a PV (Photovoltaic) fed three phase inverter system are considered, the main point of the system is to reduce the lower order harmonics that are induced on the inverter due to dead time of inverter and these lower order harmonics will make switching losses and reduce the efficiency of system & life. The higher order harmonics cannot affect the system largely and it can be eliminated by using passive or active filters. The proposed system consists of Hysteresis controller is used to reduce the lower order harmonics.

BLOCK DIAGRAM

The topology of the solar inverter system is simple. It consists of the following stages as shown in Figure.2.

1. A PV module with Maximum Power Point Tracking (MPPT).
2. A boost converter stage to perform (DC-DC Converter).
3. A low-voltage three-phase H-bridge inverter.

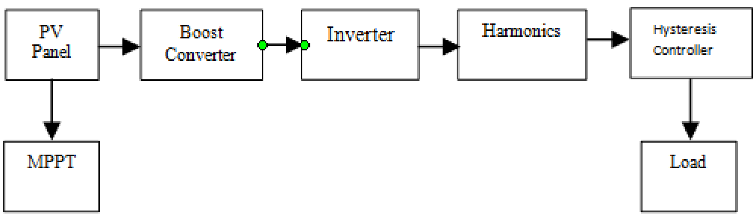


Figure 2. Proposed System Block Diagram

ADVANTAGES

1. The switches are all rated for low voltage which reduces the cost
2. Lesser component count in the system improves the overall reliability.
3. It will be a good choice for low-rated PV inverters of rating less than a kilowatt.
4. The cost of the system is very low.
The THD of the system will be less than 2%.

MPPT

The voltage at which PV module can introduce maximum power is known as 'maximum power point' (or peak power voltage). A PV's Maximum Power point (MPP) changes with the temperature and solar insulation. The total efficiency of a plant is depend mainly by three factors which are: (1) The efficiency of the PV panel [In commercial PV panels it is between 8-15%], (2) The efficiency of the Inverter which is near to 95-98%, and (3) The efficiency of the maximum power tracking point which is over 98%.[5]

Improving the efficiency of the PV panel and the inverter is not easy but it's depend on the available technology, may be required better components which can be effect the cost of the installation MPPT

MPPT algorithms is important and must in PV array because PV array have a non linear current – voltage characteristic with a unique point where the power produced is maximum. The some methods are used for improving the efficiency of MPPT algorithm, mostly for this P&O (Perturb and Observe) used.

The Perturbation and Observation algorithm is mostly used because it's easy and simple to construct. The flowchart of P&O is given below, and the method basically perturbation increase or decrease by the controller reference voltage by a step size noted as C, hence the subsequently estimate the power difference between the present PV power and that before the perturbation (Observation stage) and the PV source terminal voltage. If the PV power difference is obtained positive that means the PV power is increased and the tracking is in the right direction, the perturbation direction will be carried on (increase or decrease). On the other size the power difference is negative then the power reduction is caused due to the perturbation, so the direction of perturbation should be reversed.
For continues perturbation result, P&O algorithm may not stop at desired MPP voltage but oscillates around it, causing PV power loss. If we reduced the perturbation voltages step, this is the one way to minimize the tracking oscillation.

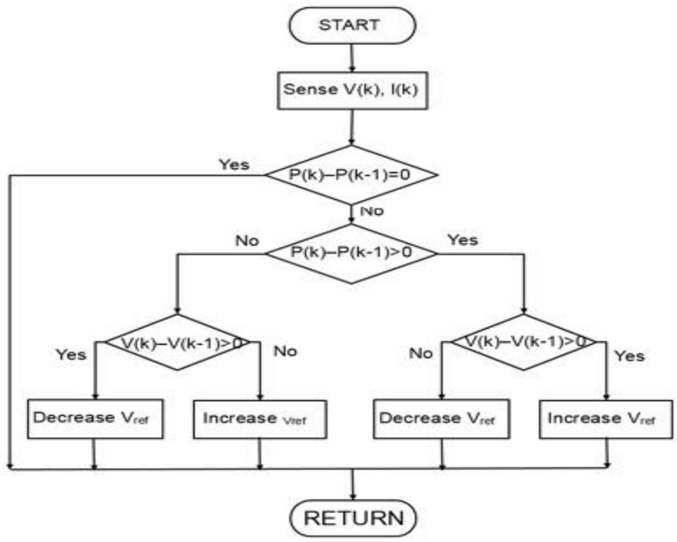


Figure 3. MPPT Algorithm.

As the end of that, in the constant irradiance state the PV power curve will be very simple ripples with smoothness. However, the tracking speed will minimize causing losing the ability and more power loss to track certainly at the rapid atmospheric changes. If we choosing a large perturbation step will result in achieving fast tracking response at the instantly atmospheric changes, in the steady state the mentioned oscillation will be quite considerable.

7 Simulations and Result

7.1 The PV system with PWM controller with linear load

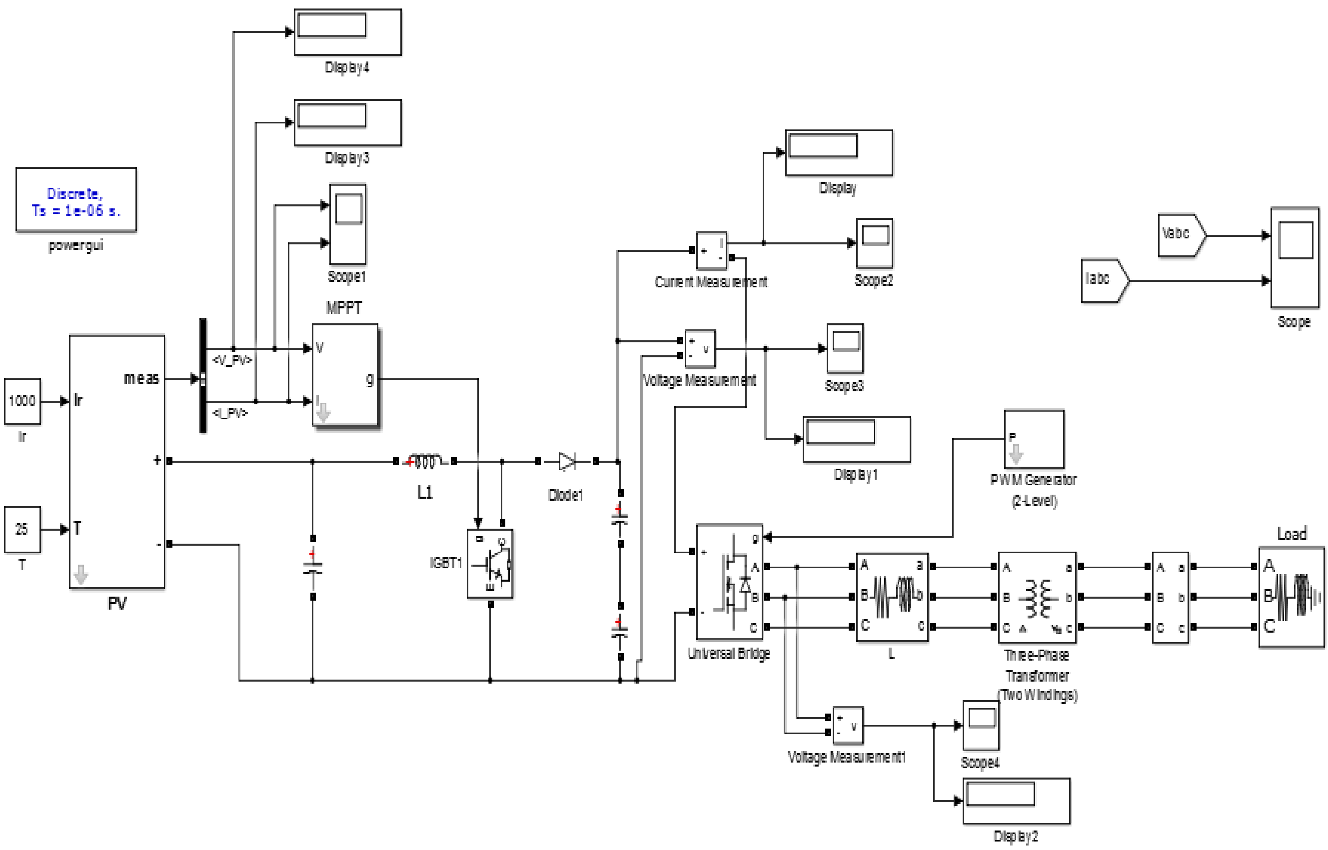
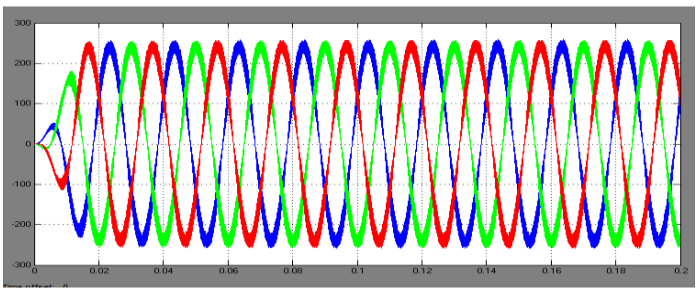


Fig. 4. The MATLAB (Simulink) PV system with PWM controller with three phase load

7.2 The output waveform of Voltage with PWM controller:-



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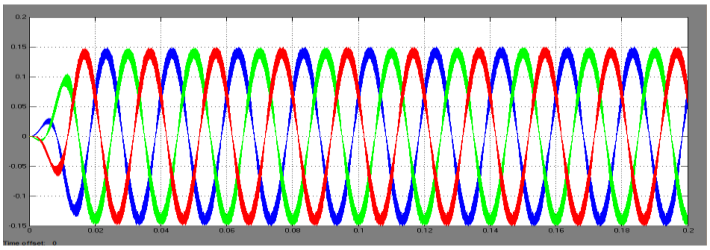
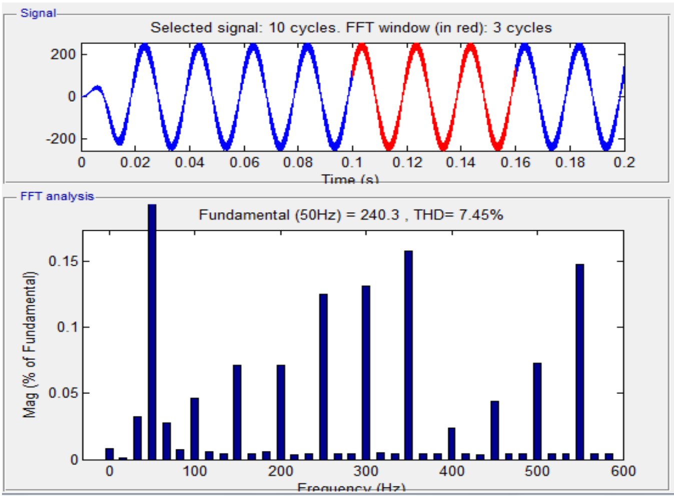
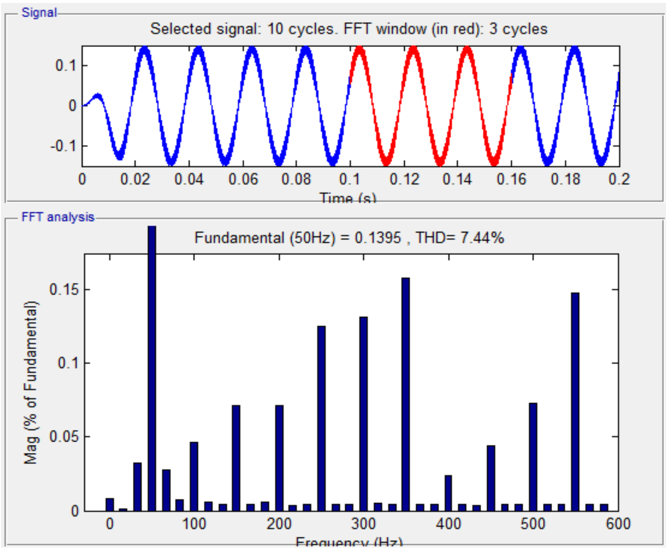
7.3 The output waveform of current with PWM controller:-



7.3 The THD & FFT analysis of load side Voltage with PWM controller



7.4 The THD & FFT analysis of load side current with PWM controller



7.5 The MATLAB Modeling of PV System with three phase load Using Hysteresis controller:-

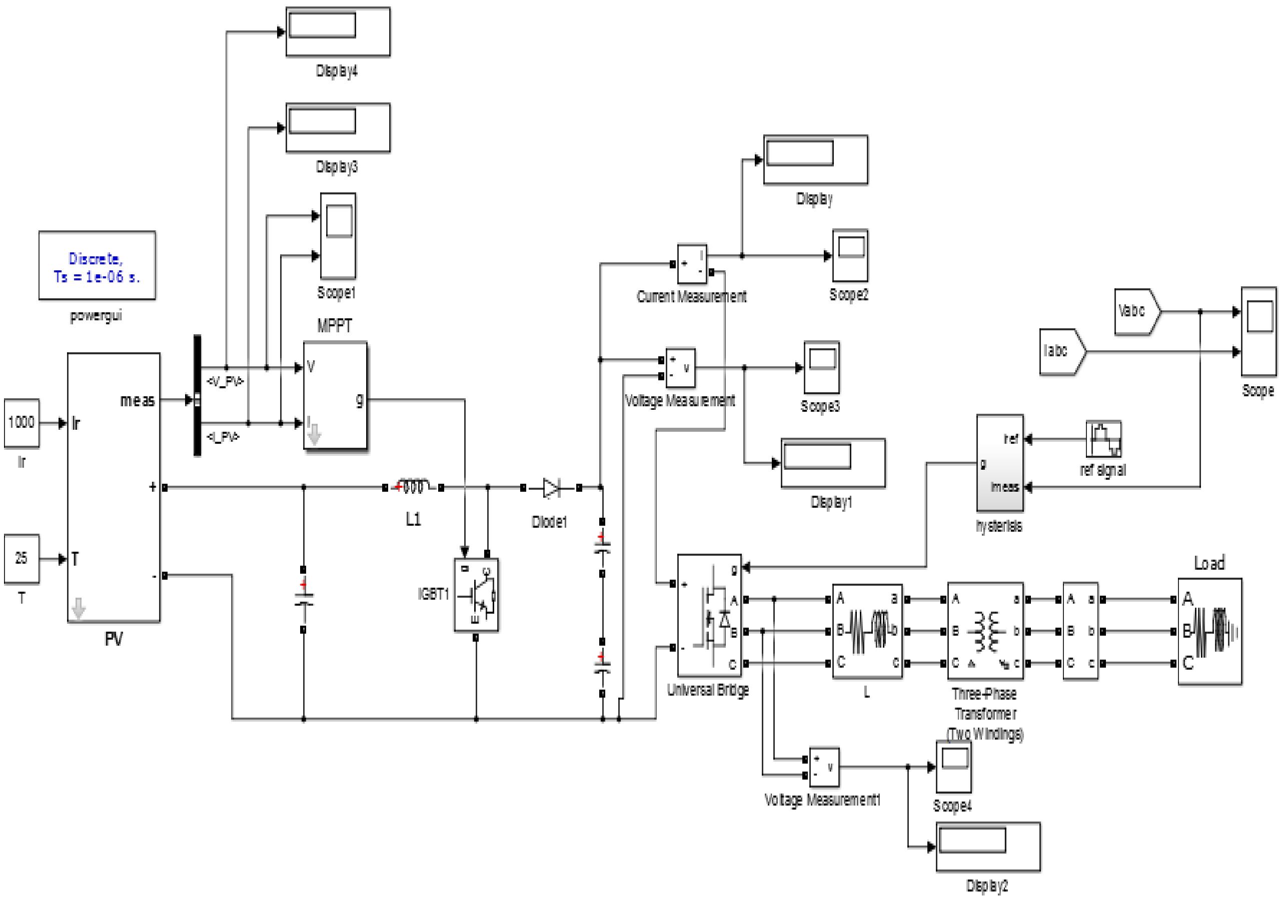
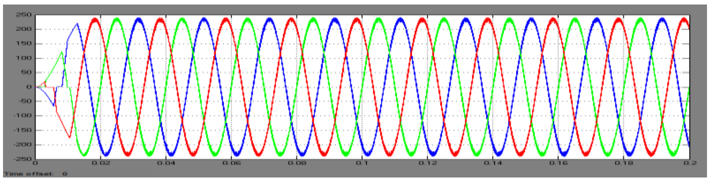
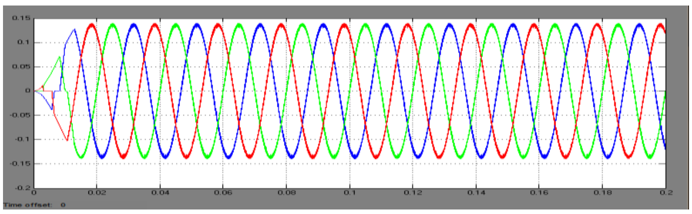


Fig. 4. The MATLAB (Simulink) PV system with Hysteresis controller with three phase load

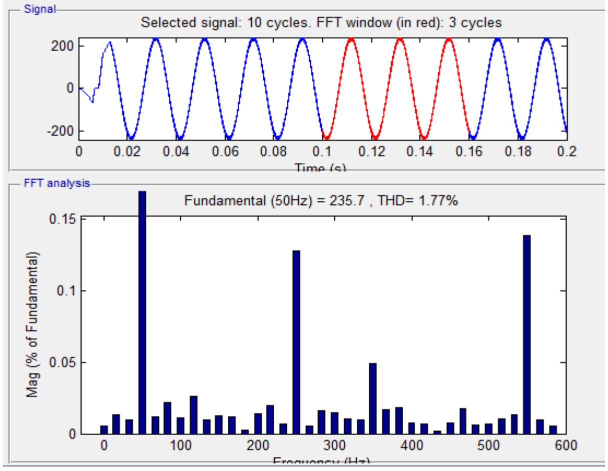
7.6 The output waveform of Voltage with Hysteresis controller:-



7.7 The output waveform of Voltage with Hysteresis controller:-



7.8 The output waveform of Voltage with Hysteresis controller:-



7.9 The THD & FFT analysis of load side current with Hysteresis controller

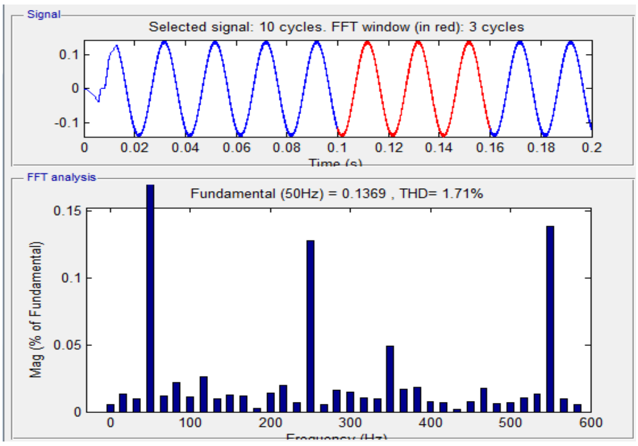


Table 1.THD value

PV Inverter	Voltage THD	Current THD
With PWM Generator	7.45	7.44
With Hysteresis Controller	1.77%	1.71%

8 CONCLUSIONS

In this project work, two controllers are used for reducing the lower order harmonics of the system they are (1) PWM controller and (2) Hysteresis controller. The three phase inverter connected solar photovoltaic system with linear load is employed. In this project the output of the PV system is connected with boost converter (which is design in MATLAB/Simulink software), the output of boost converter is connected with the three phase inverter. The gate signal of inverter is controlled through PWM controller. It is observed that the total THD value of the PV system is reduced less than 8%. When the gate signal is controlled through the proposed Hysteresis controller, the lower order harmonics and the total THD of the system is reduced less than 2%. It has been observed that the proposed Hysteresis controller gives a better result as compared with PWM controller for reducing the lower order harmonic in the system. All the work is done in MATLAB/Simulink Software environment.

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BIOGRAPHIES

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