Harmonic Mitigation in Single-Phase Grid Connected Photovoltaic System Using SPWM Inverter

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***Abstract*— The PWM technique has been used to mitigate the harmonic distortion in a wide range of grid-connected distributed generation applications, including Photo Voltaic (PV) inverters, wind and water turbines. Several advance control solutions have been recently introduced to cope with this problem and introduce a control scheme that improves the harmonic distortion in such adverse conditions. A simple control scheme is proposed here as a good alternative of previous control solutions for voltage source single-phase PV inverters connected to the utility grid. In this paper Phase, the Shift modulation technique is carried out, in order to obtained low current distortion even during polluted grid conditions. To achieve the reliability of the system, good quality of power must be transmitted to the grid with less harmonic and unbalance. Hence proper filter action is to be carried out to attenuate ripple. Thus the main contribution of this work is the Phase Shift PWM control scheme intended for single-phase applications which features high harmonic rejection capability and obtained improved THD.**

Keywords- Photo voltaic (PV), Maximum power point tracking (MPPT), multilevel inverter (MI), Sinusoidal Pulse Width Modulation (SPWM), Total harmonic distortion (THD).

I. INTRODUCTION

Renewable energy resources are playing a vital role in today's power scenario due to the exponential growth of future energy demand and depletion of fossil fuels. It includes wind power, PV system, biomass, wave energy and small hydro, etc.[1]. A photovoltaic converter based on two cascaded full bridges with different dc-link voltages can synthesize up to nine voltage levels with a single dc bus since one of the full bridges is supplied by a flying capacitor. The multilevel used to mitigate harmonic distortion and electromagnetic interference.[2]. The carrier pulse width modulation techniques are implemented, which can minimize the total harmonic distortion and enhances the output voltages from the five-level inverter. Three methods are constant switching frequency (CSF), variable switching frequency (VSF), and phase-shifted pulse width modulation (PSPWM) concepts are divided into two techniques like subharmonic pulse width modulation which minimizes total harmonic distortion and switching frequency optimal pulse width modulation of the output voltages.[3].

MPPT is necessary to control the action of the boost converter. P&O MPPT is carried out for its less time complexity and simple algorithm method. The effective controller design for harmonic elimination and to synchronized grid frequency with inverter frequency.[4,6].

LC filter used to limit the switching current ripple by providing high attenuation of harmonic and high dynamic performance. This paper also presents the most relevant control and modulation methods by a new reference/carrier-based PWM scheme.[8]. To achieve the reliability of the system a good quality of power must be transmitted to the grid with fewer harmonics. Hence proper control action is to be carried out to control the output of the inverter and to transfer the power at unity power factor.[9]. The feasibility and profitability of using PI controller, in order to synchronize grid frequency with the inverter frequency has been investigated. To fed good quality of power, grid voltage and grid current should be in the same phase. The controller has to be designed to delivered power to the grid at unity power factor (UPF) to improve the power quality of energy delivered to the grid.[10]. The shunt active filter for power conditioning which provides reactive power compensation. This paper deals with different power quality issues and from that harmonics is one of the important issues that affect equipment connected in our system. The harmonics are introduced because of the nonlinear load in a system that causes severe damage to the power system. The reduction of harmonics is done using shunt active power filter.[11]

II. VARIOUS ELEMENTS OF CONSIDERED PV BASED SYSTEM

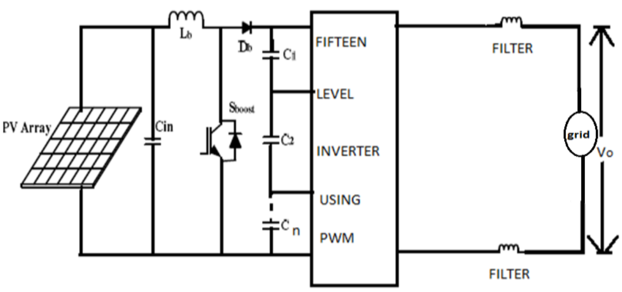

Fig-1PWM based multilevel inverter connected to a pv cell

The main circuit of the system is shown in Fig-1, which is made up of PV arrays, Boost converter, cascaded H-bridge multi-level inverters (CHB-MI) connected with filter .Multilevel inverter has been investigated to delivered good quality of power to the grid. Hence it is necessary to boost the voltage of DG source. For this a conventional boost (DC-DC) converter can be used. The MPPT algorithm will track the maximum power at given environmental condition .Filter action is required which helps in reduction in harmonics and in improving total harmonic distortion (THD).

A. Photovolatic cell.

Photovoltaic cell output voltage is basically functioning of photocurrent which is mainly determined by load current depending on the solar irradiation level during the operation.

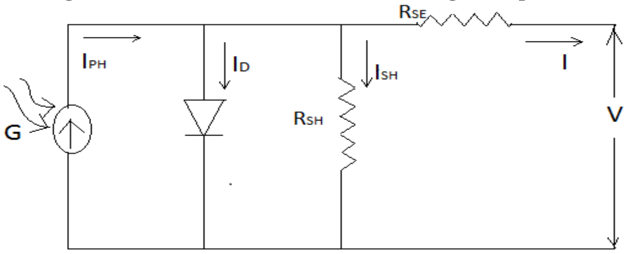

Fig.2. (Equivalent ckt diagram of solar cell)

I_{PH} = represents photo cell current

ID = represents diode current

ISH = represents shunt current

R_{sh} and R_s = are the shunt and series resistances of the cell (Usually the value of R_{sh} is very large and that of R_s is very small, hence they may be neglected to simplify the analysis)

B. Maximum Power Point Tracking using Perturb & Observe (P&O) algorithm.

The I-V and P-V characteristics of the PV module have a complex relationship with temperature, solar irradiance and total resistances that produce non-linear output efficiency. Hence maximum power point tracking is necessary to sample the output of the cells and apply the proper load resistance to obtain maximum power at any given environmental condition. Many algorithms are implemented for tracking maximum power at any environmental conditions. One of the algorithms for MPPT is perturbed and observe (P&O) algorithm.

Perturb & Observe (P&O) is the simplest method. The time complexity of this algorithm is very minimum. In this method we use only one sensor, which is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. It keeps on perturbing in both directions. When the algorithm has reached very close to the MPP we can set an appropriate error limit. In this method controller first, check the change in power, if it is positive then it will check the change in voltage whether change in voltage is increasing or decreasing.

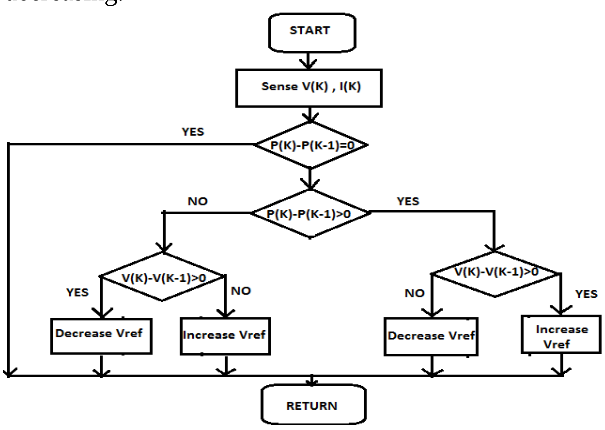

Fig.3. [flow chart of P&O algorithm]

C. CHB-Multilevel inverter (MI)

The H-bridge inverter units are connected in series with cascaded multilevel inverter. The general function of this multilevel inverter is to synthesize the desired voltage from several separate DC sources (SDCSs). Each SDCS is connected to an H-bridge inverter. The different level inverters are connected in series with the AC terminal. The phase output voltage is synthesized by the sum of inverter outputs, Van = Va1 + V a2 + --- + VaN. The required number NS of isolated dc sources, hence the number of H-bridges, to get them output phase voltage levels is: N = (m-1) / 2

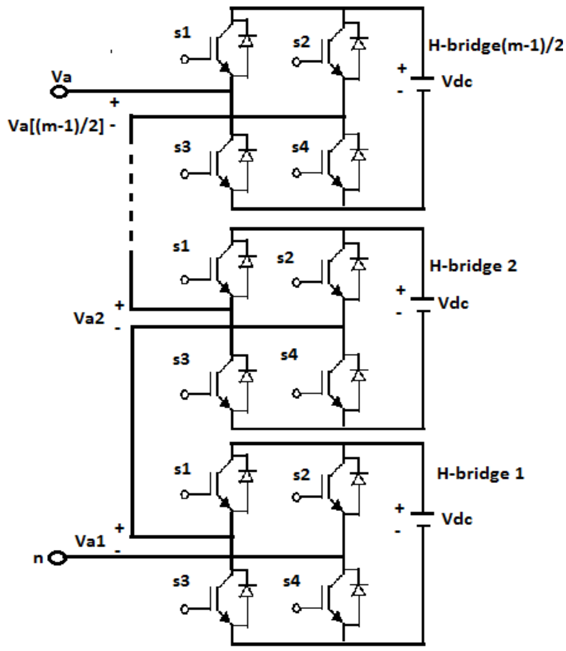

fig. 5. [Circuit diagram of CHB]

D. SPWM of a Single Phase H-Bridge Inverter.

The basic SPWM techniques are unipolar pulse width modulation and bipolar pulse width modulation which are used in a single phase H –bridge inverter to vary its output voltage .

D.1 Bipolar Pulse Width Modulation

In this modulation, the gate pulses are obtained by comparing a sinusoidal modulating signal or reference signal with a high frequency carrier signal.

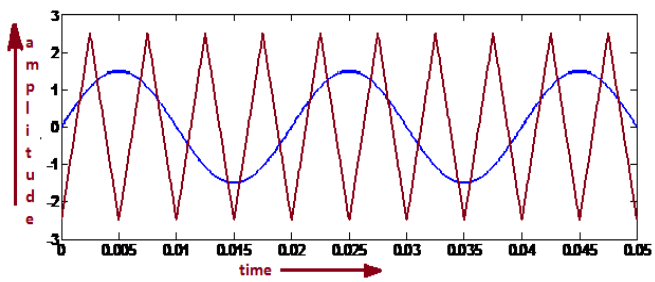

Fig -6.1(Bipolar Pulse Width Modulation)

D.2 Unipolar Pulse Width Modulation

The unipolar modulation normally requires two sinusoidal modulating waves, which are of same magnitude and frequency but 180 degree out of phase.

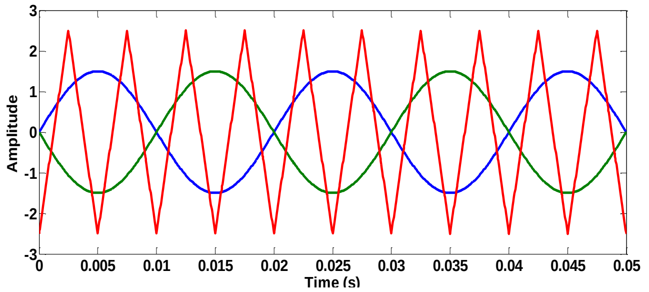

Fig-6.2(Unipolar Pulse Width Modulation)

E. Filter

A filter is an electrical network that alters the amplitude and/or phase characteristics of a signal with respect to frequency. Ideally, a filter will not add new frequencies to the input signal, nor will it change the component frequencies of that signal, but it will change the relative amplitudes of the various frequency components and/or their phase relationships. Filters are often used in electronic systems to emphasize signals in certain frequency ranges and reject signals in other frequency ranges.

- Passive filter
  1. Passive low pass filter
  2. Passive high pass filter
- Active filter
  1. Active low pass filter
  2. Active high pass filter

III. Simulation Results And Discussions

A. Simulation of PV Module at irradiance 1000w/ m^2

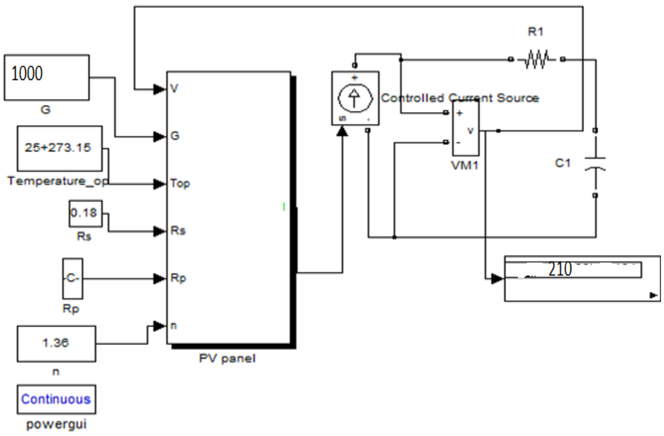

Fig-7.1 (Simulation model of pv cell)

At irradiance 1000w/m^2 we get output voltage 210volt. Waveform of voltage coming from solar cell .The output voltage waveform

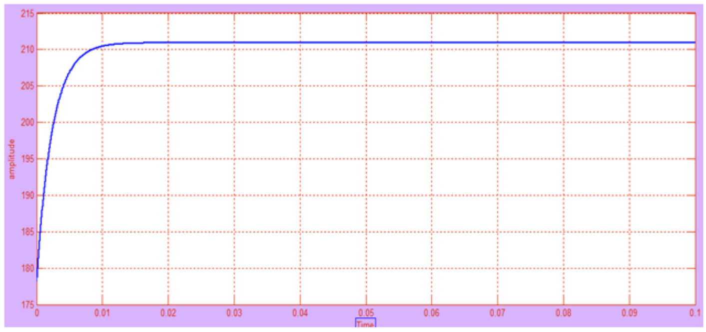

Fig -7.2(Output voltage waveform of a solar cell)

B. Simulation Block diagram of a Boost Converter.

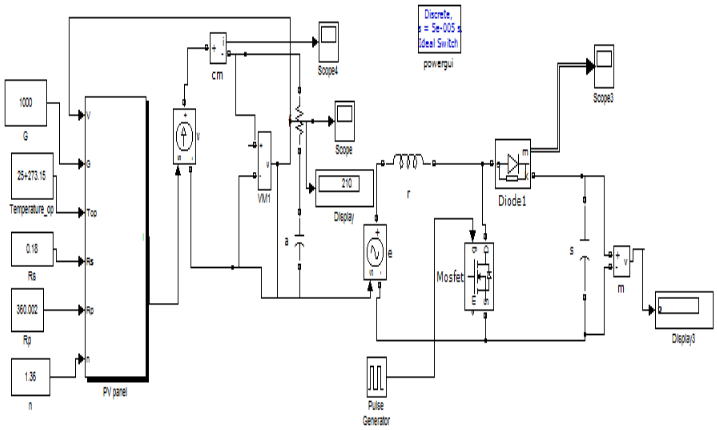

Fig-7.3Simulation model of Boost converter connected to solar cell .

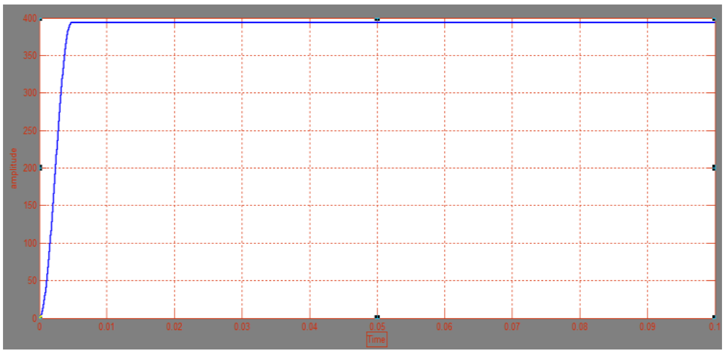

Fig-7.4 Output voltage wave form of a boost converter

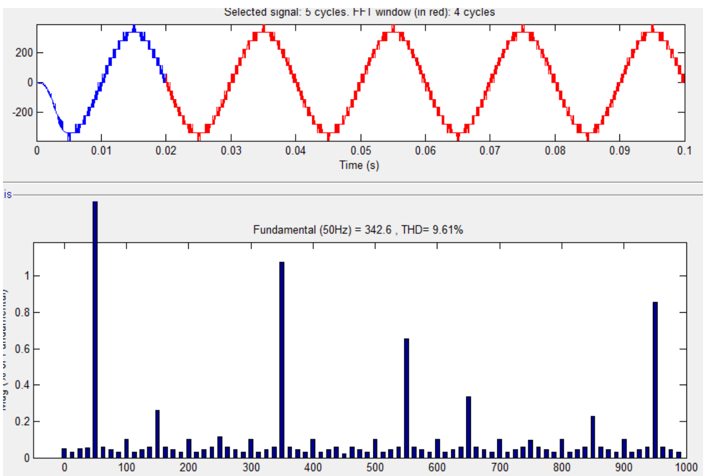

Figure-7.5 above shows the percentage of THD contain in the signal

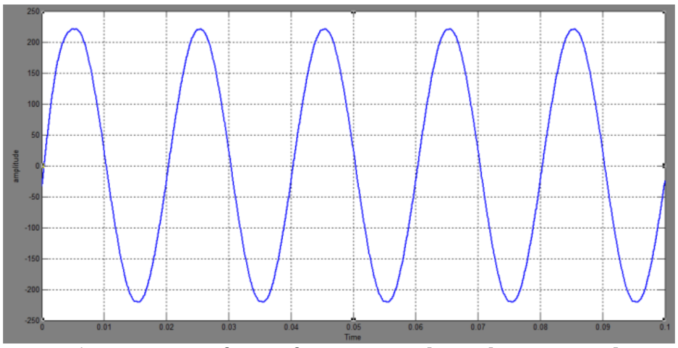

Fig-7.6 Wave form after passing through a passive low pass filter

C. *Comparison of THD using different filter*

C.1. Using RC low pass filter

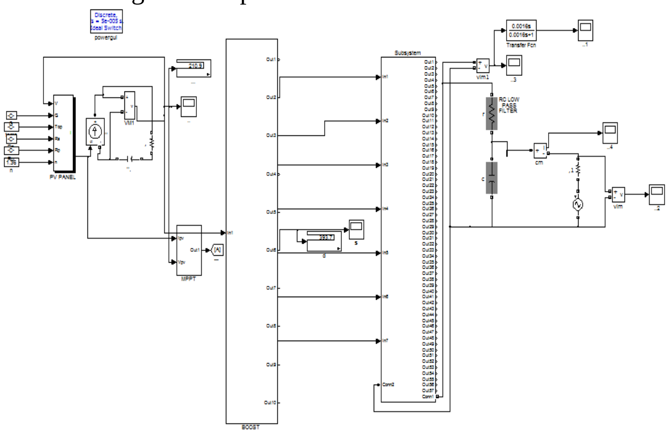

Fig-8.1

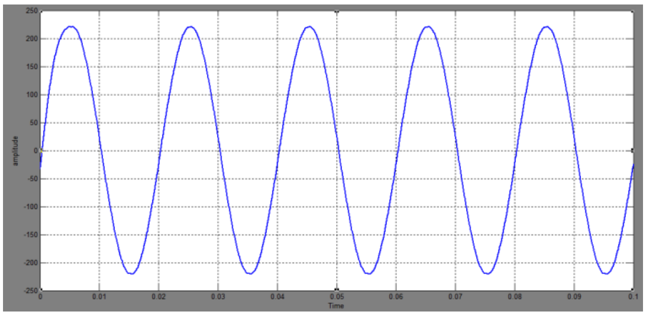

Fig-8.2(After passing through filter)

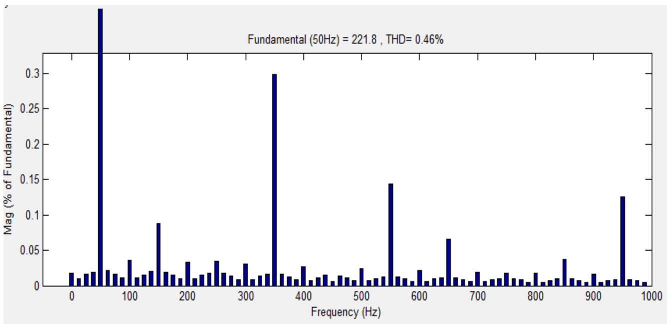

Fig-8.3(% of THD)

C.2. Using T-section low pass filter

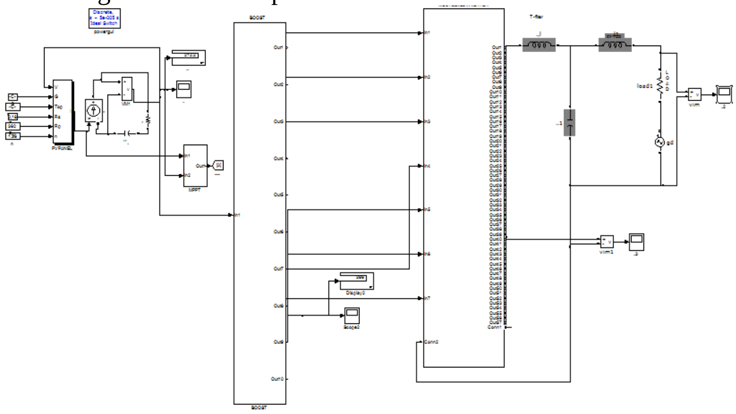

Fig-8.4

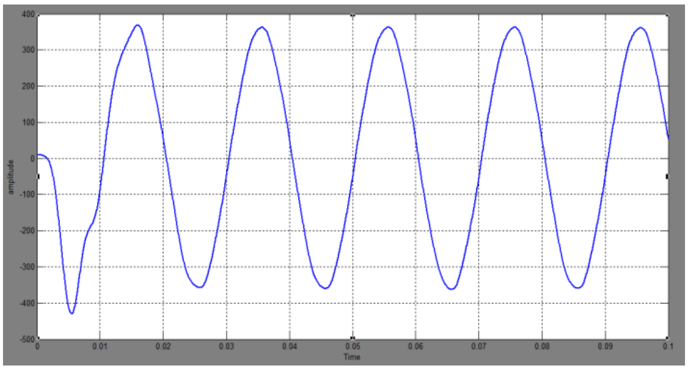

Fig-8.5(After passing through filter)

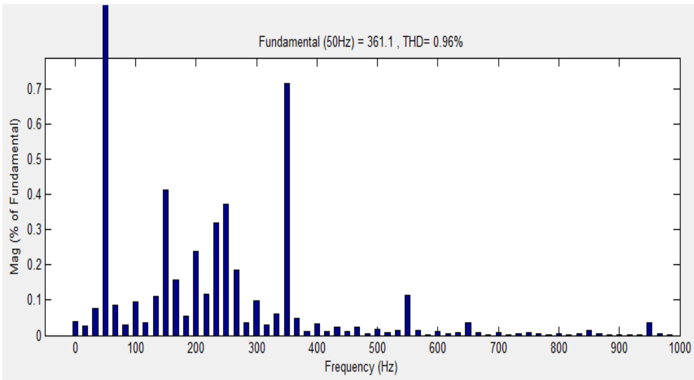

Fig-8.6(% of THD)

C.3. Using pi-section low pass filter

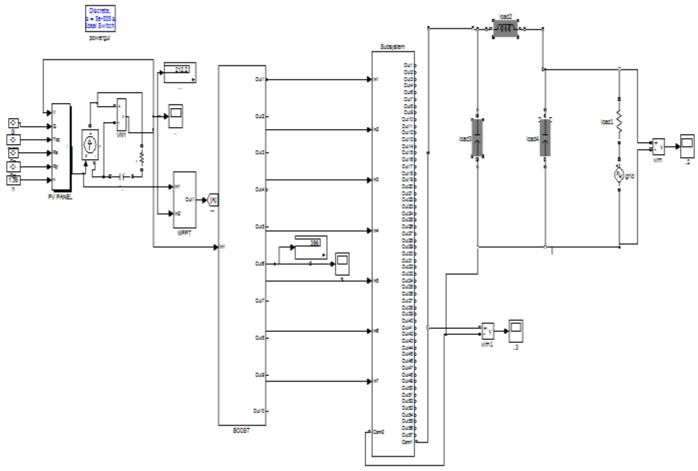

Fig-8.7

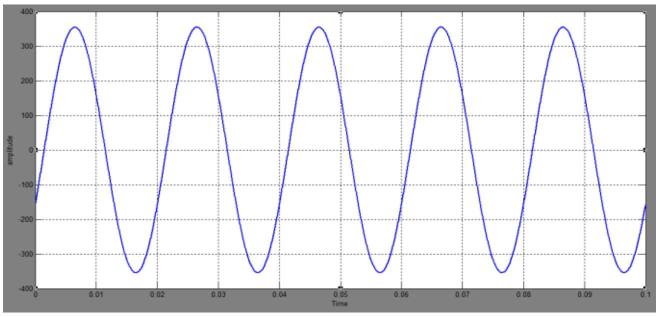

Fig-8.9(After passing through filter)

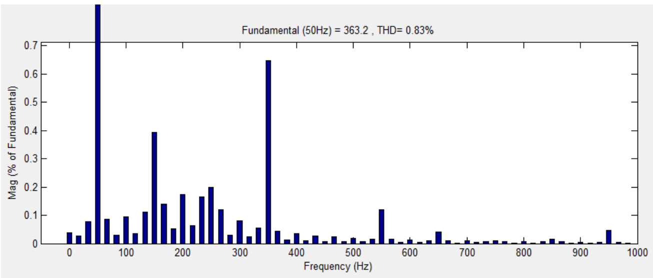

Fig-10 (% of THD

C.4.Using pi-section high pass filter

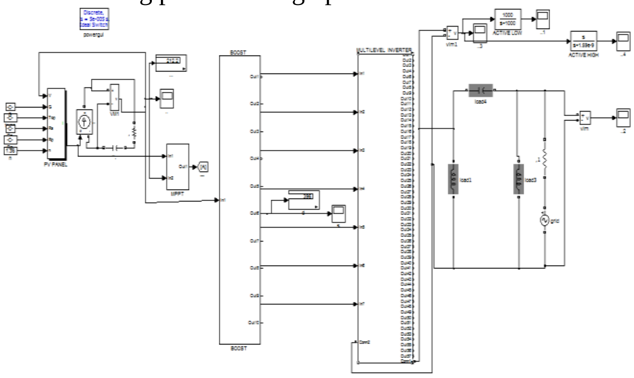

Fig-10.1

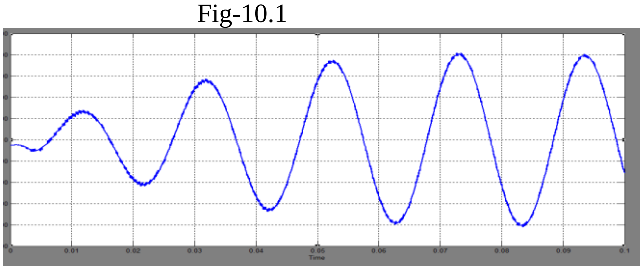

Fig-10.2(After passing through filter)

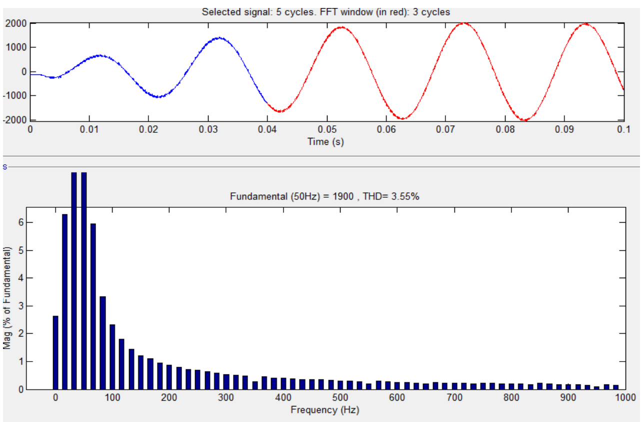

Fig-10.3(% of THD)

C.5. Using high pass T-section filter

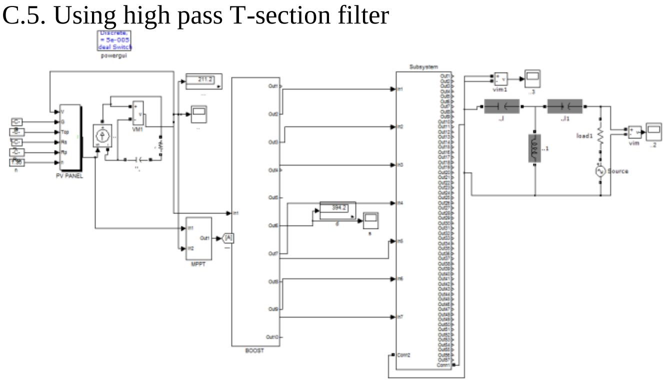

Fig-10.4

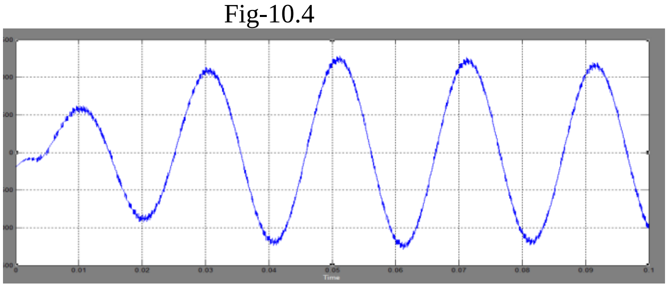

Fig-10.5(After passing through filter)

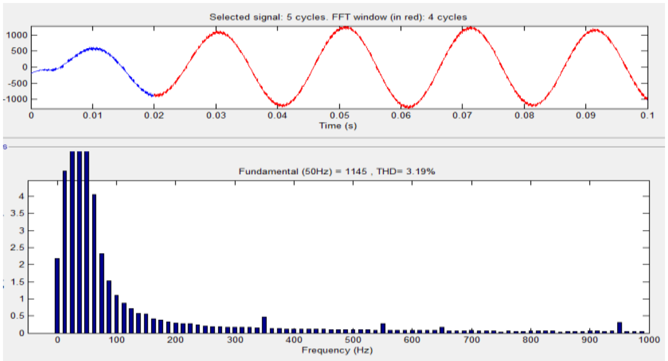

Fig-10.6(% of THD)

C.6. Using active filter

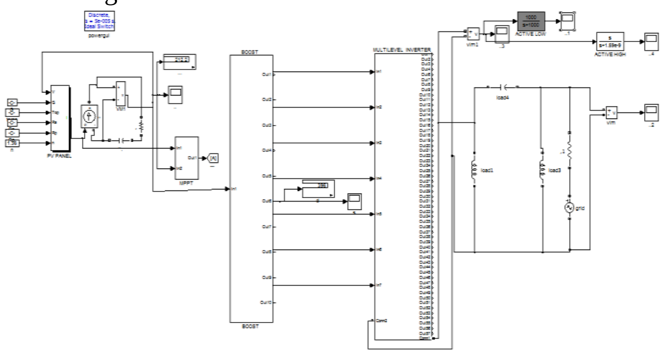

Fig-10.7

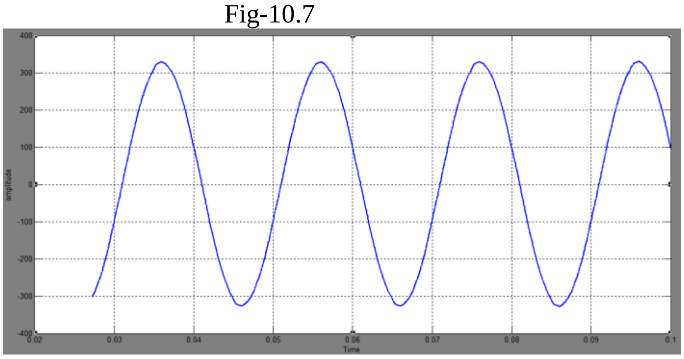

Fig-10.8(After passing through filter)

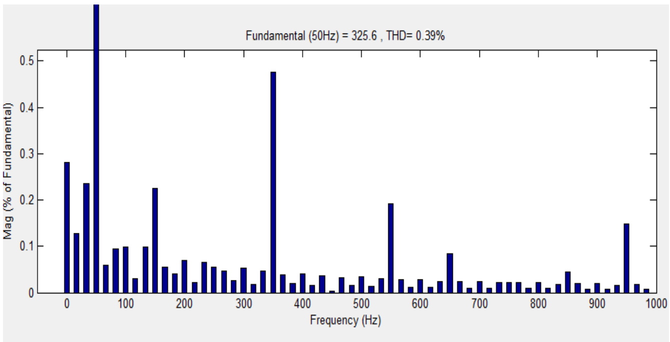

Fig-10.9(% of THD)

IV. CONCLUSION

This paper presents the design and simulation of fifteen levels inverter for a single-phase grid-connected system connected to a solar cell. Here MPPT controller is carried out in order to maximize the output power coming from a solar cell. Among different MPPT technique perturb and observe technique is taken out because of it's simplest method and less time complexity algorithm. The pulse width modulation technique has been extensively employed to re. In order to fed good quality of power to the utility system, grid voltage and grid current must be in the same phase. This can be done when there is a synchronisation between grid frequency and inverter frequency. The controller action incorporates the synchronization of grid frequency with the inverter frequency which helps in reduction in harmonics and in improving total harmonic distortion. For synchronization PI controller, PID controller, fuzzy logic controller are used to synchronize grid frequency with the inverter frequency.

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with a ratio of quantities and units. For example, write "Temperature (K)", not "Temperature/K".