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PERTURB AND OBSERVE BASED PV SYSTEM WITH PWM INVERTER AND ITS THD ANALYSIS

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ABSTRACT

This paper presents a Matlab/Simulink model of PV system including maximum power point tracking, boost converter and a control system. A VSI (Voltage source inverter) has been applied for current control. The proposed system consists of two main controllers; a boost converter and a PWM based voltage source inverter. Perturbation and observation (P&O) is used as MPPT method and it determines the system operating point according to rapid change in atmospheric conditions. The gating pulse from P&O algorithm is used in the boost converter for boosting the output to be provided as an input to PWM inverter. The use of the P&O approach is to meet high quality output, minimum THD, fast response and high robustness. Finally the inverter is connected with isolation transformer and LC filters to reduce the total harmonics distortion (THD). The performance of the proposed model is verified by simulation.

Keywords: Maximum Power Point Tracking (MPPT), Photovoltaic (PV) System, and DC-DC Converter, PWM Inverter, THD, LC Filter.

I. INTRODUCTION

The characteristic voltage and power of a photovoltaic (PV) array is nonlinear and time varying due to the changes caused by the atmospheric conditions, therefore a maximum power point tracking algorithm is adopted to maximize the output power [1-3]. P&O based PV system has been used as the input source for the proposed inverter topology [4-5]. The major issue lies in converting the available DC sources into AC sources with better power quality aspects such as THD, power factor, etc. The inverter has not only been designed to meet minimum THD, fast response, flexibility of design, but it uses switches for generation of three phase power using three phase transformer[6]. In the present work, PWM inverter with LC filter and Isolation transformer has been designed to reduce the THD to meet the required power to be supplied to the grid. The work has been carried out/simulated in MATLAB/SIMULINK environment.

II. SYSTEM CONFIGURATION

The PV system generates directly power from the solar energy and its output changes depending upon the temperature and irradiance. So, to maintain maximum power at the output side voltage is boosted by controlling the current of the array [7].

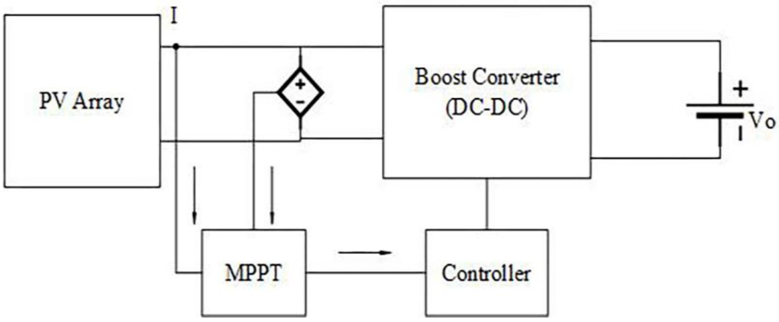

Fig.1. System Configuration

Figure 1 shows a PV system where the PV array feeds to DC-DC converter. The output of the converter is represented by a constant DC voltage source. The output power of the PV array is regulated by the converter. The MPPT block observes the power at the terminals of the array and controls the input voltage or the input current of the converter forcing the PV array to operate at the maximum power point.

III. MATHEMATICAL MODELLING OF PV CELL

The equivalent electrical circuit of an ideal PV cell can be treated as a current source parallel with a diode, as shown in fig.2.

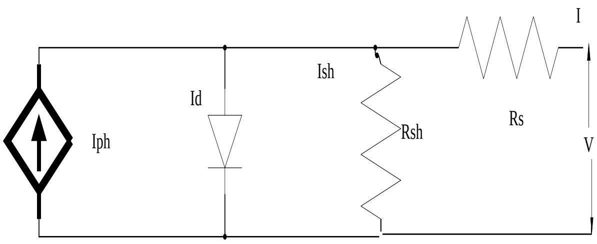

Fig.2. Equivalent Electrical Circuit of a Solar Cell

The basic equation from the theory of semiconductor which mathematically describes the I-V characteristics of the ideal PV cell is [8]:

$$I = I_{pv,cell} - I_d \tag{1}$$

where,

$$I = I_{pv,cell} - I_{0,cell}[\exp(\frac{qV}{\alpha kT})] - 1 \tag{2}$$

$$I = I_{pv} - I_0[\exp(\frac{V + R_S I}{Vt\alpha}) - 1] - (\frac{V + R_S I}{R_p}) \tag{3}$$

Where,

$I_{pv,cell}$: Current generated by the incident light, I_d : The Shockley diode equation

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$I_{0,cell}$: The reverse saturation current of the diode, q : Electron charge (1.60217646*10^-19c)

k : Boltzmann constant (1.3806503*10^-23), T : Cell Temperature in Kelvin (k)

V : Solar cell output voltage (V), R_S : Solar cell series resistance (Ω)

R_p : Solar cell parallel resistance (Ω).

The cells which are connected in parallel will increase the current whereas the cells connected in series provide improved output voltage.

IV. PERTURBATION AND OBSERVATION ALGORITHM

P&O algorithm reads the values of voltage and current from solar PV module to evaluate maximum power to be tracked. The value of voltage and power at k^{th} instant is stored in the memory. Then next value at $(k+1)^{th}$ instant is measured again and power is compared with the previous measured values. The power and voltage at $(k+1)^{th}$ instant is subtracted with the values from k^{th} instant [9].

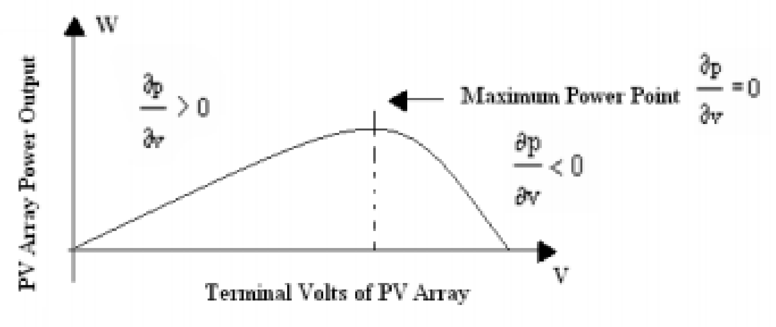

Fig.3. P-V Characteristics of Photovoltaic Cell

From fig. 3, it is observed that right hand side of the curve where the voltage is almost constant the slope of $\delta P/\delta V < 0$ is negative whereas in the left hand side, the slope $\delta P/\delta V > 0$ is positive. The right side of the curve is nearer to zero (lower duty cycle) whereas the left side of the curve is nearer to unity (higher duty cycle). Depending on the sign of $\delta P_{pv}(P_{pv} - P_{pv}(k+1))$ and $\delta V_{pv}(V_{pv} - V_{pv}(k+1))$ after subtraction the algorithm decides whether to increase the duty cycle or to reduce the duty cycle. The MPPT algorithm has been implemented at dc-dc boost converter side. The logic has been elaborated according to the flow chart of P&O algorithm, shown in fig. 4 [9]. The duty cycle lies in between 0 and 1. According to the change in the power δP_{pv} and the change in the voltage δV_{pv}, the duty cycle of the converter is changed as given in the following logic [12],

If δP_{pv} >0 and δV_{pv} >0 then $\alpha = \alpha - \delta\alpha$

If δP_{pv} >0 and δV_{pv} <0 then $\alpha = \alpha + \delta\alpha$

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If $\delta P_{pv} < 0$ and $\delta V_{pv} < 0$ then $\alpha = \alpha + \delta\alpha$

If $\delta P_{pv} < 0$ and $\delta V_{pv} > 0$ then $\alpha = \alpha - \delta\alpha$

where $\alpha =$ duty cycle and $\delta\alpha$ is perturbation.

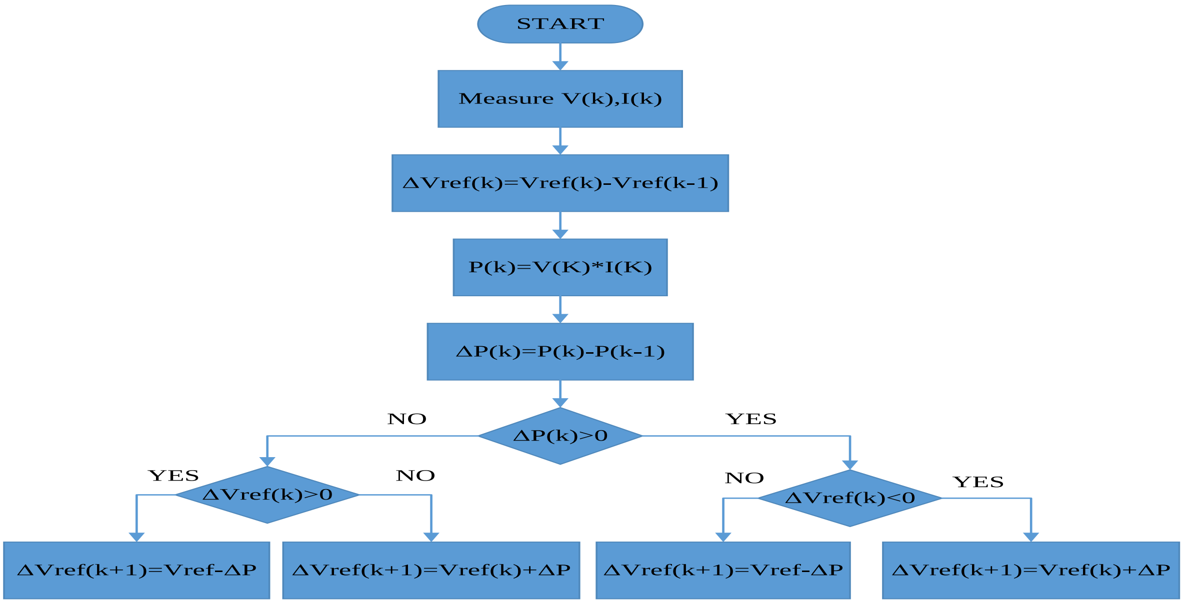

Fig.4. Flow Chart of Perturb and Observe Algorithm For MPPT

V. DC-DC BOOST CONVERTER

A boost converter is a step-up DC-DC power converter, which converts a low input voltage to a high output voltage. In this situation, the output current is lower than source current. Converter operation can be divided into two modes; first mode begins, when the transistor is switched on, the current increases linearly in the boost inductor, and when the diode is in off state, mode second begins, when the transistor is switched off, the energy stored in the inductor is discharged through the diode to the source load [10-11]. The classical relationship between input and output voltage of a boost converter at steady state condition is given by:

$$\frac{V_0}{V_i} = \frac{1}{1-D} \tag{4}$$

Where, duty cycle D lies between 0 and 1 [12].

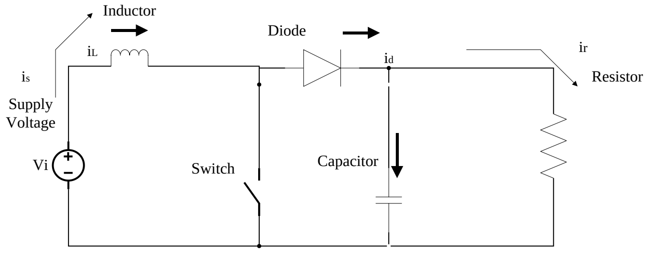

Fig.5. Boost Converter Circuit

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VI. THREE PHASE PWM INVERTER CIRCUIT

The three phase voltage source inverter helps in generating less harmonic distortion in the output voltage utilizing the phase to phase AC load. The circuit model of three phase VSI is shown in fig. 6 and the six valid switch states are given in Table I. In three phase VSI, the switches of any leg of the inverter (TA+ and TA- , TB+ and TB- , or TC+ and TC-) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity. The states (1 to 6 as in Table 1) produce AC output voltage [13]. In order to generate a given voltage waveform, the inverter moves from one state to another. The selection of the states in order to generate the given waveform is done by the modulation technique which will ensure the use of only the valid states [14].

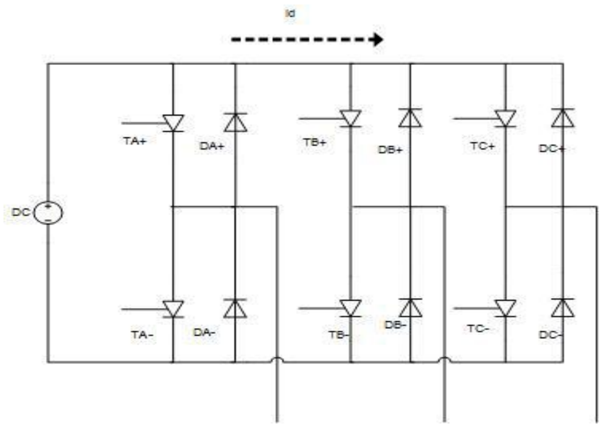

Fig.6. Three Phase Voltage Source Inverter

Table I. States of Switches for three Phase Vsi

State		Phase to Phase Voltage		
ON	OFF	V_{ab}	V_{bc}	V_{ca}
$T_{A+}T_{B-}T_{C-}$	$T_{A-}T_{B+}T_{C+}$	V	0	-V
$T_{A+}T_{B+}T_{C-}$	$T_{A-}T_{B-}T_{C+}$	0	V	-V
$T_{A-}T_{B+}T_{C-}$	$T_{A+}T_{B-}T_{C+}$	-V	V	0
$T_{A-}T_{B+}T_{C+}$	$T_{A+}T_{B-}T_{C-}$	-V	0	V
$T_{A-}T_{B-}T_{C+}$	$T_{A+}T_{B+}T_{C-}$	0	-V	V
$T_{A+}T_{B-}T_{C+}$	$T_{A-}T_{B+}T_{C-}$	V	-V	0

Output voltage from an inverter can also be adjusted by exercising a control within the inverter itself. The most efficient method of the same is pulse width modulation control used within an inverter

VII. SIMULATION RESULTS AND DISCUSSIONS

The simulated PVA model is shown in fig. 7. This model has fixed temperature and irradiance. Number of cells in series are 36; temperature of cell is 25^{0} C & irradiance is 1000W/ m^{2} .

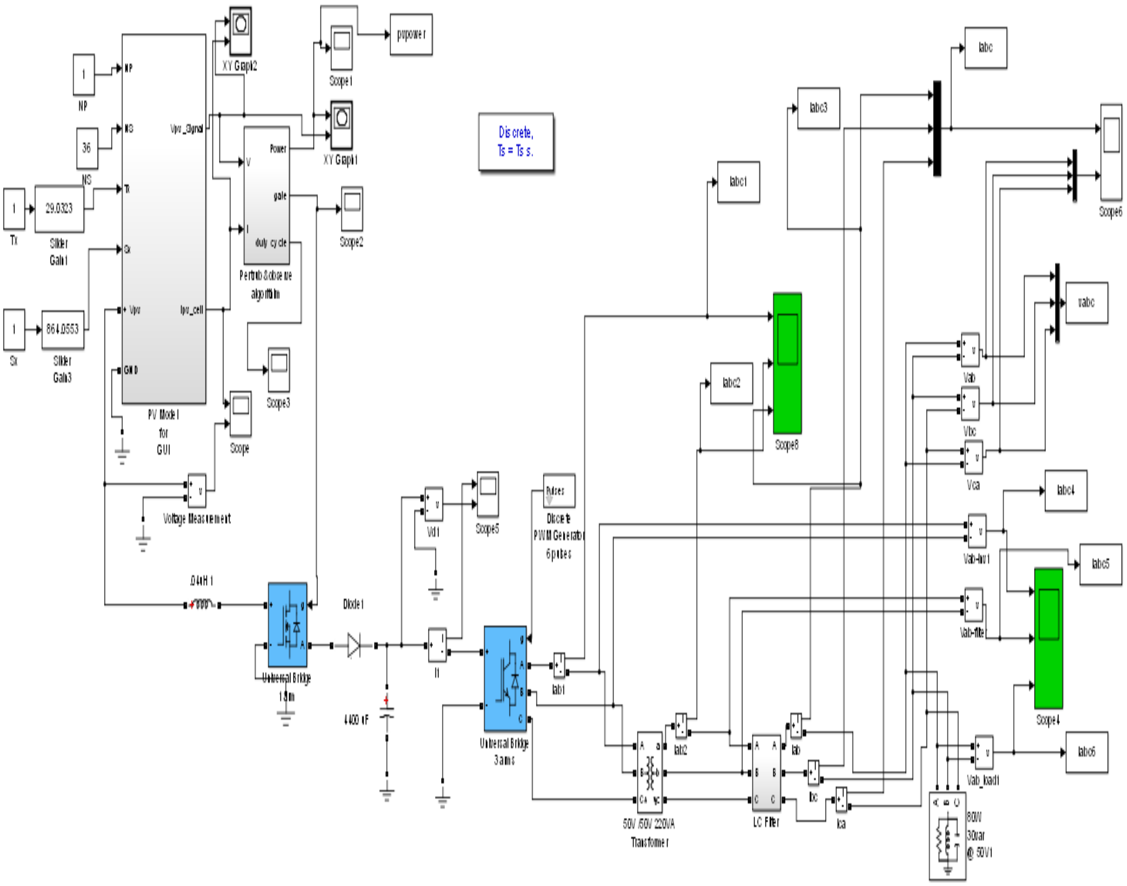

Fig.7. Complete Simulink Diagram of PVA System

The output of PV panel is connected with the boost converter. The output current and voltage of boost converter are shown in figs .8-9, respectively.

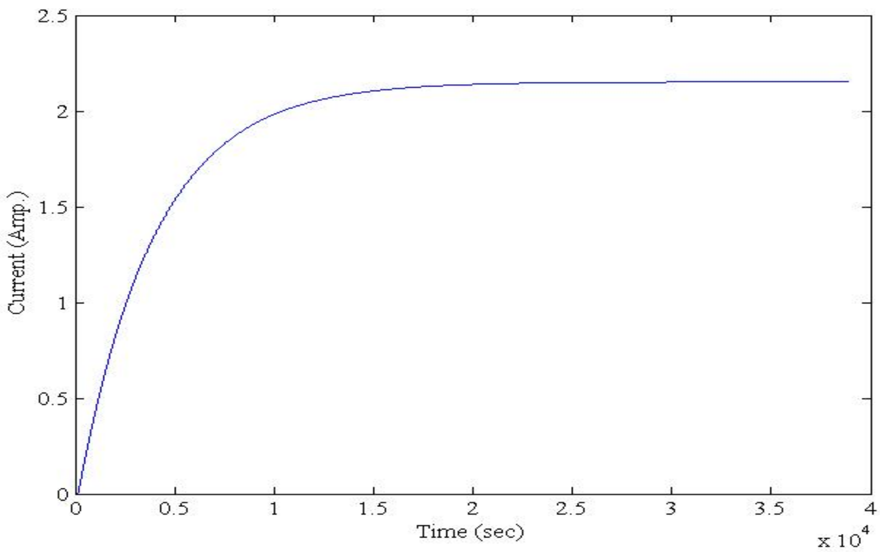

Fig.8. Boost Converter Output Current with P&O Algorithm

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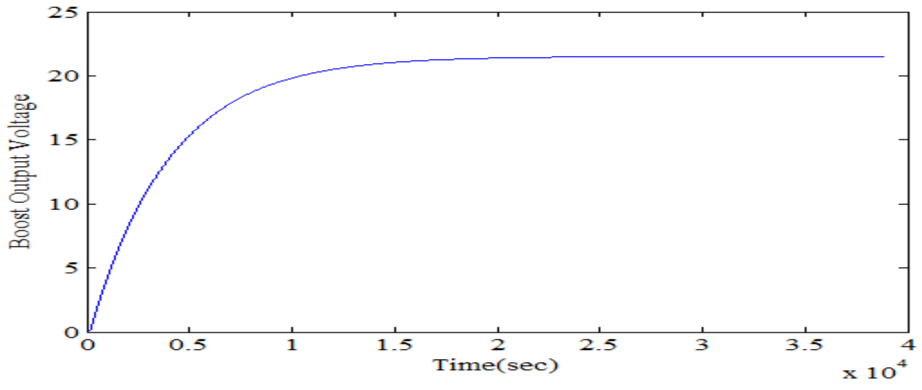

Fig.9. Boost Converter Output Voltage with P&O Algorithm

The output of boost converter is then fed to the inverter which converts DC to AC. The output from inverter is fed to the isolation transformer and LC filter and then to the load. The output voltage of the inverter is shown in figs. 10.

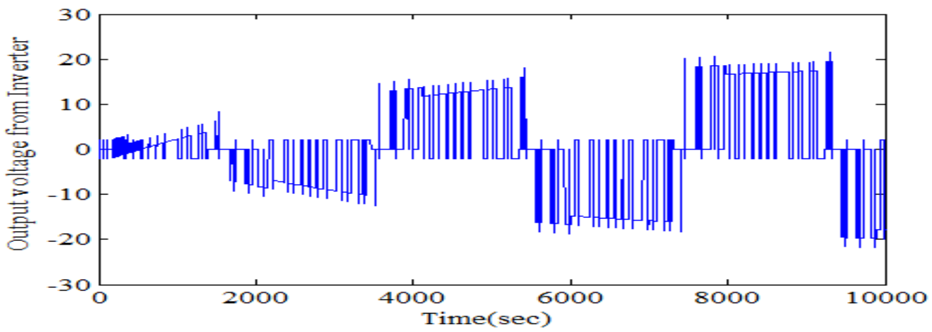

Fig.10. Output Voltage of the Inverter

The FFT analysis of this inverter output voltage is shown in fig.11.

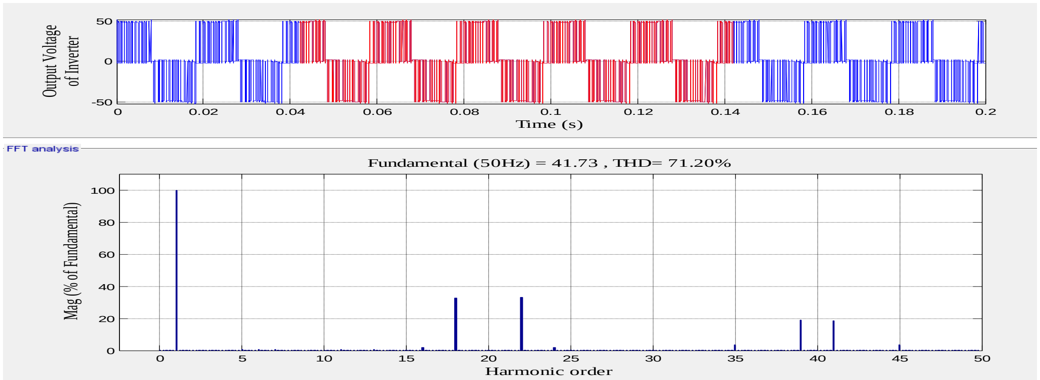

Fig.11. FFT Analysis of Inverter Output Voltage

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The input voltage applied to the Load is shown in fig.12

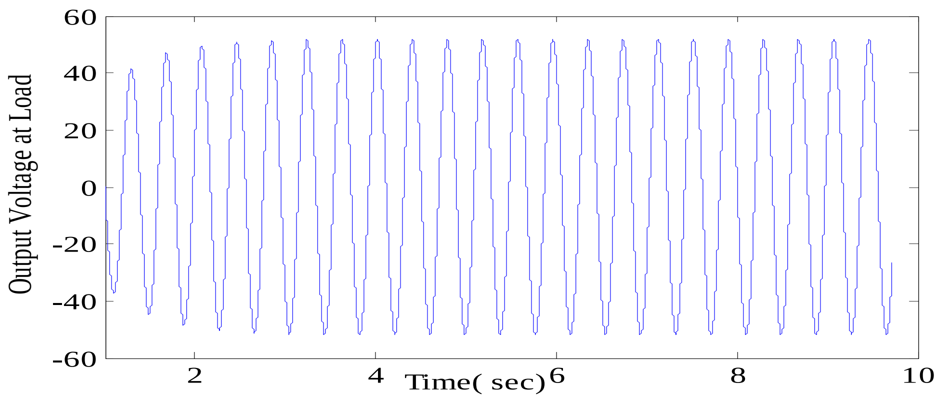


Fig.12. Input Voltage to the Load

The FFT analysis of the filter output voltage is shown in fig. 13

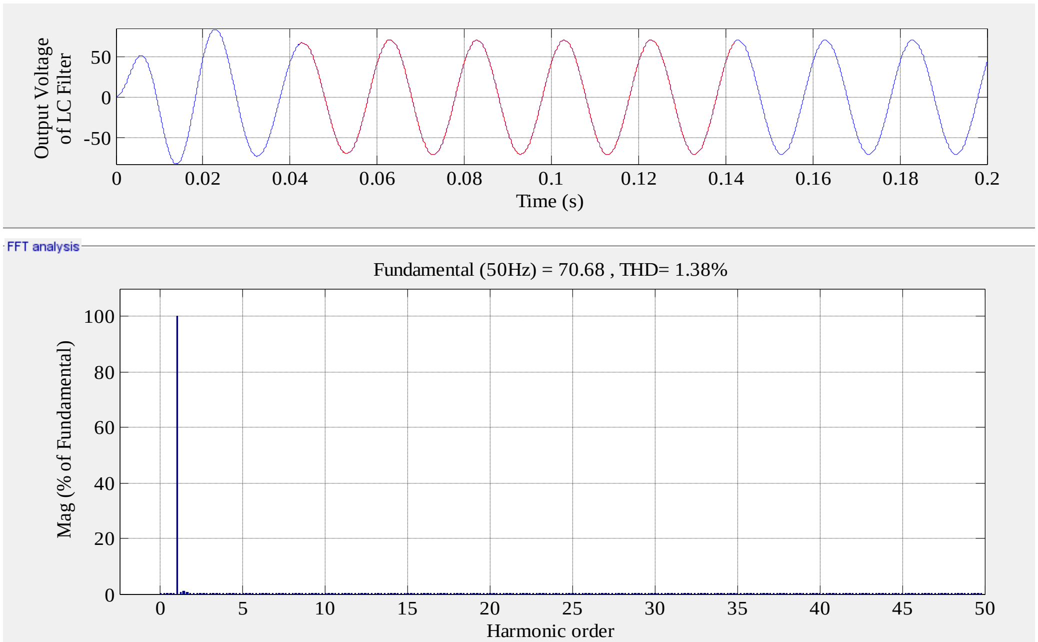
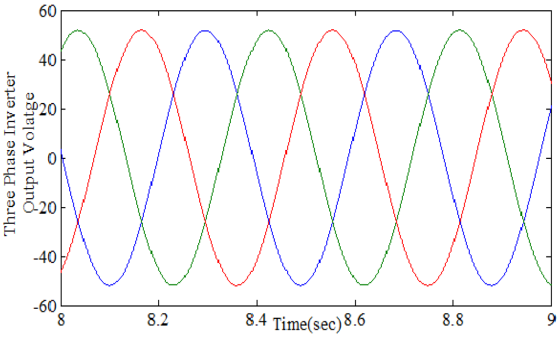


Fig. 13. FFT Analysis of Filter Output Voltage

The inverter output voltage waveform contains harmonics. By FFT analysis, it is found that total harmonic distortion is 71.20% and fundamental is only 41.73%. A filter is designed to filter out the harmonics contents of the inverter output.The output of the filter and its FFT as shown in fig. 13 indicates that the THD is reduced to 1.38% and the spectral contents are also absent.

The output voltage and current obtained from load after removing the harmonic distortion is shown in fig.14, 15 respectively.



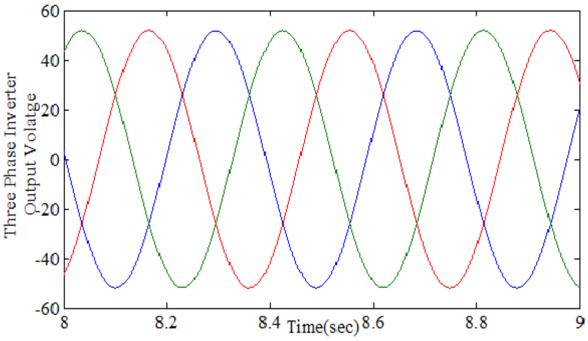


Fig. 14. Output Voltage Obtained From Load Fig. 15. Output Current Obtained From Load

VIII. CONCLUSIONS

The present work deals with P&O based PV system with three phase inverter. The P&O based MPPT algorithm has been used for tracking maximum power from the PV panel. The use of the P&O approach is to meet high quality output, minimum THD, fast response and high robustness. Finally, the inverter is connected with isolation transformer and LC filters to reduce the total harmonics distortion (THD). The performance of the proposed model has been verified with the simulation in MATLAB Simulink. Voltage harmonics of the system have effectively been minimized, according to the IEEE standard 929-2000, THD of voltage lies within 5%.

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