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Simulation/Modelling of MPPT Charge Controller for Solar Inverter using Matlab

Nandini Pundir
Department of Electrical & Electronics Engineering, Inderprastha Engineering College, Ghaziabad, Uttar Pradesh, India

Abstract: Among the renewable sources present solar energy is the most abundant form of resources that would not be exhausted anytime soon. So to emulate the energy, solar cells convert sunlight into electricity which depends on solar insolation level and temperature that lead to the variation of the maximum power point (MPP).

Herein, to improve photovoltaic (PV) system efficiency and increase the lifetime of the battery, a solar charge controller with maximum power point tracker (MPPT) is designed for harvesting the maximum power available from the PV system under given insolation and temperature conditions. Among different MPPT techniques, perturb and observe (P&O) technique gives excellent results and thus is used in this project. The Perturb and Observe method is used to calculate the maximum power point and the Boost converter is used for the step-up of the panel voltage. We have also simulated a flying capacitor multilevel inverter to convert the DC supply into AC supply.
Keywords: MPP, photovoltaic system, P&O, Boost Converter

I. INTRODUCTION

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts.

A. Solar Power

The tapping of solar energy owes its origins to the British astronomer John Herschel who famously used a solar thermal collector box to cook food during an expedition to Africa. Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells or with concentrating solar power plants.

II. IMPLEMENTATION AND MODELLING OF PV MODULE

A photovoltaic cell or photoelectric cell is a semiconductor device that converts solar radiation directly into DC electrical energy. The efficiency of a photovoltaic cell is determined by the material‟s ability to absorb photon energy over a wide range, and on the band gap of the material. Photovoltaic cells are semiconductors that have weakly bonded electrons at a level of energy called valence band.

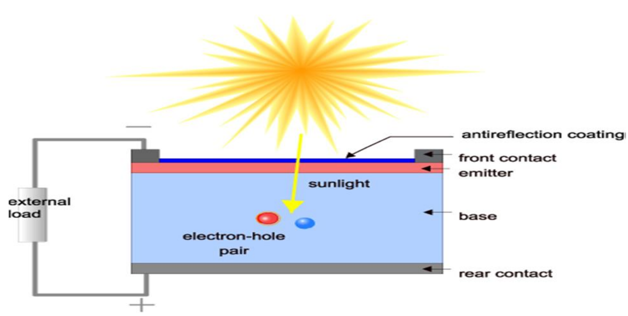

Fig. 2.1 Concept of Photovoltaic

A PV module is an assembly of photo-voltaic cells mounted in a framework for installation. Photo-voltaic cells use sunlight as a source of energy and generate direct current electricity. A collection of PV modules is called a PV Panel, and a system of Panels is an Array. Arrays of a photovoltaic system supply solar electricity to electrical equipment.

Four parameters (I_L, I_0, Rs, and Rsh) must be determined to obtain the I-V relationship (the reason the model is called a four-parameter model). Equivalent Equation masks the complexity of the actual model, for the four parameters are functions of temperature, load current and solar irradiance.

Procedures for determining the four parameters are given herewith. Light Current I_L states that I_L can be calculated as:

$$I_L = \frac{\phi}{\phi_{ref}}\left[I_{L,ref} + \mu_{I,SC}\left(T_C - T_{C,ref}\right)\right]$$

Where

ϕ = irradiance (W/m2),

ϕ ref = reference irradiance (1000 W/m2 is used in this study),0

I_L, ref = light current at the reference condition (1000W/m2 and 25°C),

Tc = PV cell temperature (°C),

Tc,ref = reference temperature (25 °C is used in this study),

$\mu_{I,SC}$ = temperature coefficient of the short-circuit current (A/°C);

Both I_L,ref and I,SC are available on the manufacturer datasheet, Saturation Current $I_{0;}$ this can be expressed in terms of its value at reference conditions

Saturation Current Io :

$$I_0 = I_{0,ref}\left(\frac{T_{C,ref}+273}{T_C+273}\right)^3 \exp\left[\frac{e_{gap}N_S}{q\alpha_{ref}}\left(1-\frac{T_{C,ref}+273}{T_C+273}\right)\right]$$

where,

I_o,ref = saturation current (A) at reference conditions,

egap = band gap of the material (1.17 eV for Si materials),

Ns = number of cells in series of a PV module,

q = charge of an electron (1.60217733×10-19 C),

α ref = the value of at reference conditions.

$I_{0,ref}$ can be calculated as: $$I_{0,ref} = I_{L,ref}\exp\left(-\frac{V_{oc,ref}}{\alpha_{ref}}\right)$$

Thermal voltage timing completion factor (α)

$$\alpha = \frac{T_C + 273}{T_{C,ref} + 273}\alpha_{ref}$$

Reference value of Thermal voltage timing completion factor

$$\alpha_{ref} = \frac{2V_{mp,ref} - V_{oc,ref}}{\frac{I_{sc,ref}}{I_{sc,ref} - I_{mp,ref}} + \ln\left(1 - \frac{I_{mp,ref}}{I_{sc,ref}}\right)}$$

Series resistance Rs is manufacturer-provided; if not, this equation can be used to estimate it [14]

$$R_S = \frac{\alpha_{ref}\ln\left(1 - \frac{I_{mp,ref}}{I_{SC,ref}}\right) + V_{OC,ref} - V_{mp,ref}}{I_{mp,ref}}$$

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Where,
Vmp,ref = maximum power point voltage (V) at reference conditions
Imp,ref = maximum power point current (A) at reference conditions,
Isc,ref= short-circuit current (A) at reference conditions.
αref = reference value of thermal voltage timing completion factor (V)
Voc,ref= open circuit voltage(V) at reference con

The Simulation of PV Module has shown below

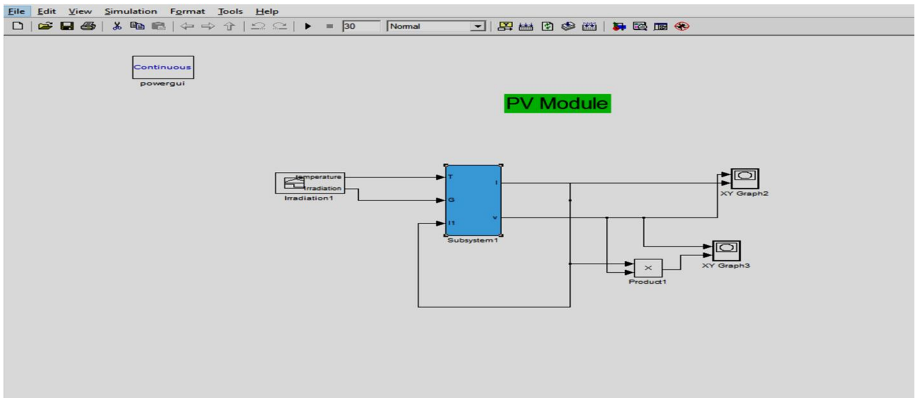

Fig 2.2 : Simulation of PV Module

A. I-V characteristics of PV Module
The characteristic below shows the I-V characteristics of the PV module.

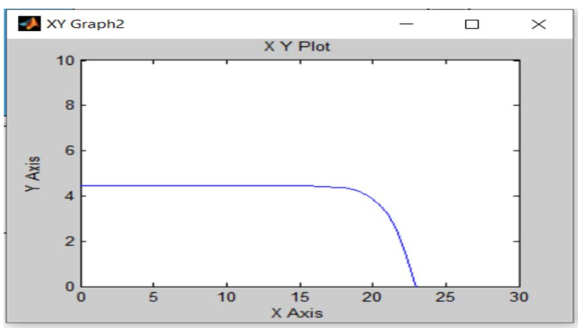

Fig 2.3 : I-V characteristics of PV module

B. P-V Characteristics of PV Module
The characteristics below show the P-V characteristics of the PV module.

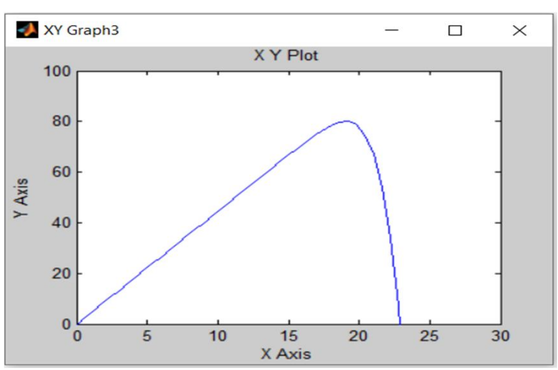

Fig 2.4 : P-V characteristics of PV module

III. PERTURB AND OBSERVE ALGORITHM

The perturb and observe(P&O) is based on the observation of the array output power and on the perturbation (increment or decrement) of the power based on increments of the array voltage or current.

In this method a slight perturbation is introduced. This perturbation causes the power of the solar module to change. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the method oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small.

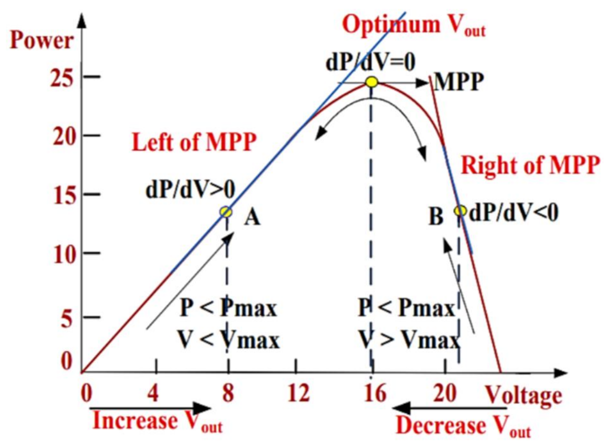

Fig. 3.1 : Sign of dP/dV at different positions of the power characteristic curve

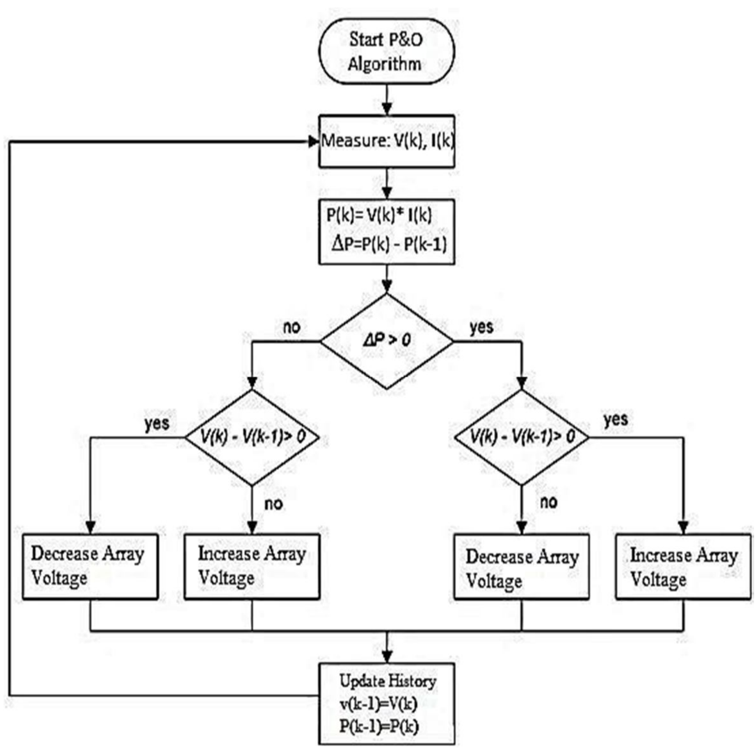

Fig 3.2 : Flowchart of Perturb & Observe algorithm

The operating voltage of the PV system is perturbed by a small increment of ΔV, and this resulting change in ΔP. If ΔP is positive, the perturbation of the operating voltage needs to be in the same direction of the increment. On the contrary, if ΔP is negative, the obtained system operating point moves away from the MPPT and the operating voltage needs to move in the opposite direction of increment.

A. Block Representation Perturb & Observe Algorithm

Following figure shows block representation of perturb & observe algorithm

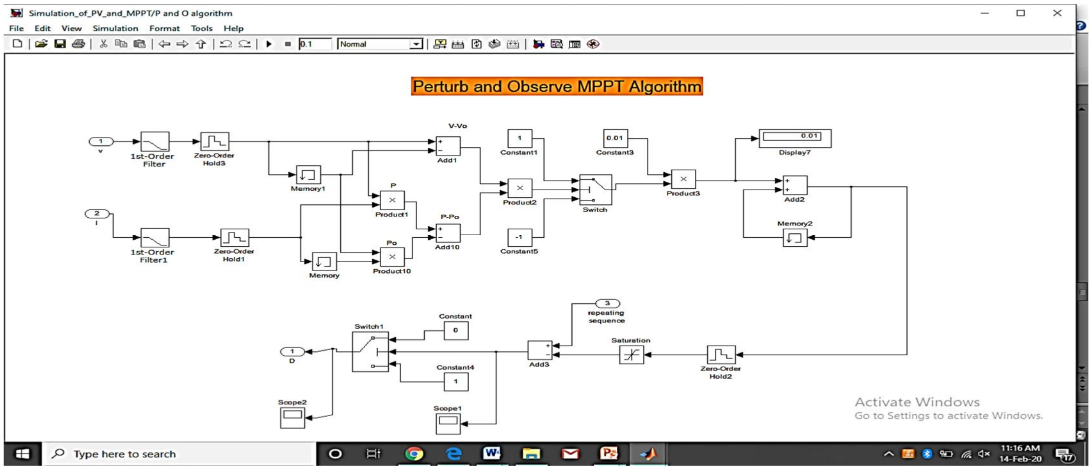

Fig 3.3 : Schematic of P and O Algorithm

IV. BOOST CONVERTER

The Boost converter is chosen for this project as a step up converter instead of a step down. The function of DC-DC Boost Converter is that its output voltage is larger than the input voltage.

The MPPT scheme is implemented in the control of DC–DC converters, i.e., it varies the duty cycle. The basic principle of adjusting the duty cycle is to match load impedance with input impedance seen by the DC– DC converter, i.e., impedance of solar PV.

A. Simulation of Boost Converter

Following figure represents the schematic of the DC/DC boost converter.

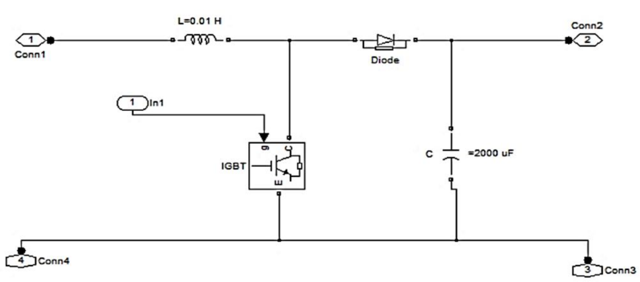

Fig 4.1 : Schematic of DC/DC Boost Converter

V. FLYING CAPACITOR CLAMPED MULTILEVEL INVERTER

Flying capacitor multilevel inverter usage of extra capacitor clamped to the power switches phase rail to provide the dc voltage level.

The topology consists of diodes, capacitors and switching devices. Although theoretically this topology has been designed to give infinite levels, due to practical limitations this only gives up to six levels of voltage. Each leg consists of switching devices which are generally transistors. Capacitors nearer to the load have lower voltage. Capacitors nearer to the source voltage (Vdc) have higher voltage.

A. Voltage Balancing of Capacitors

One of the major advantages of using a Flying Capacitor Multilevel Inverter is its ability to operate at voltages higher than the blocking capacity of each power cell consisting of a diode and switching element. Current coefficient of each limb is equal and opposite in polarity. That is why there is no net change in the charge of capacitors. The cell and capacitor voltage difference is maintained within a safe band and hence there is no chance of unbalancing the capacitor voltages.

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B. Switching Strategy

To synthesize a sinusoidal waveform at the output, switching strategy needs to be defined. It is quite simple. Every voltage is applied at output with a certain electrical angle. Careful application of the angle gives low harmonic distortion and required amplitude at the output. More than one switching strategies are available for a single voltage level. Three conditions should be followed for the right choice.

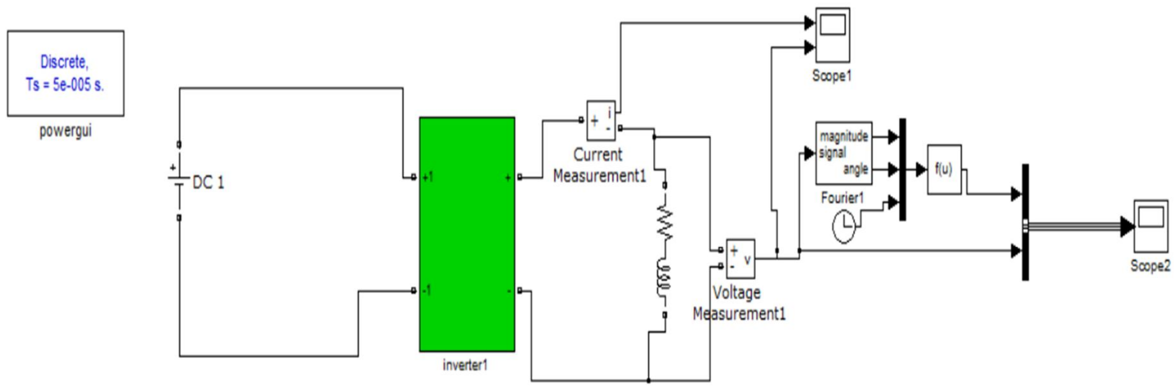

Fig 5.1: Schematic of Flying Capacitor Multilevel Inverter with scopes

C. Switching waveform for Inverter

Following figure represents the switching waveform of the inverter.

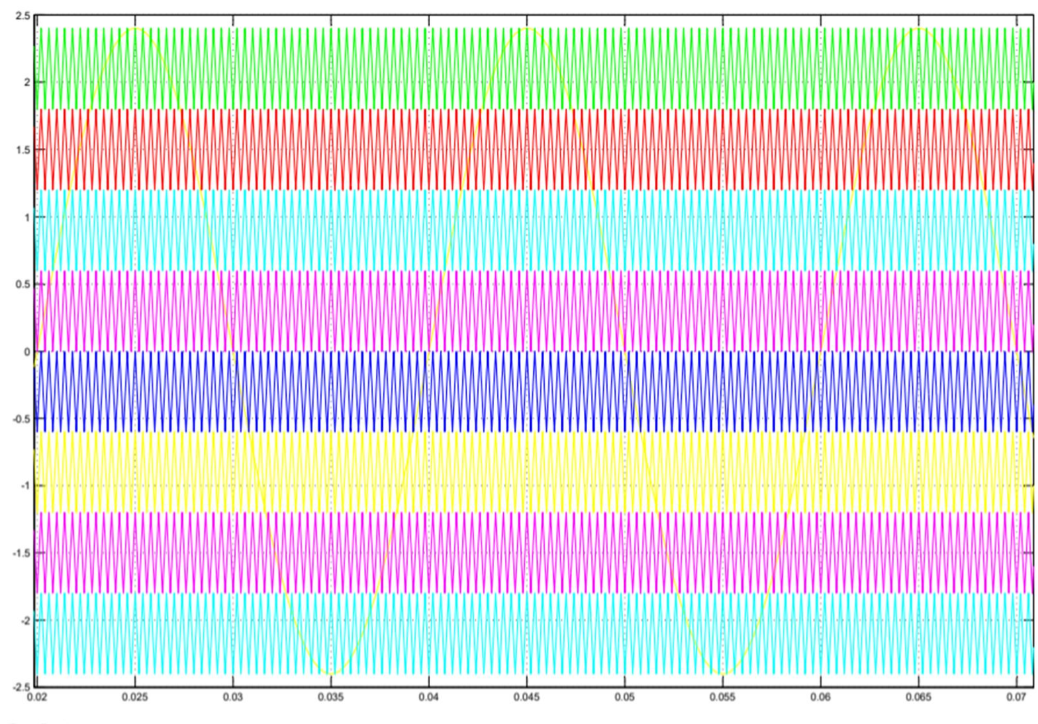

Fig 5.2 : switching waveform of inverter

VI. RESULTS

A. Changes in Physical Parameters

This graph shows the changes in physical parameters such as Irradiance and Temperature under varying conditions.

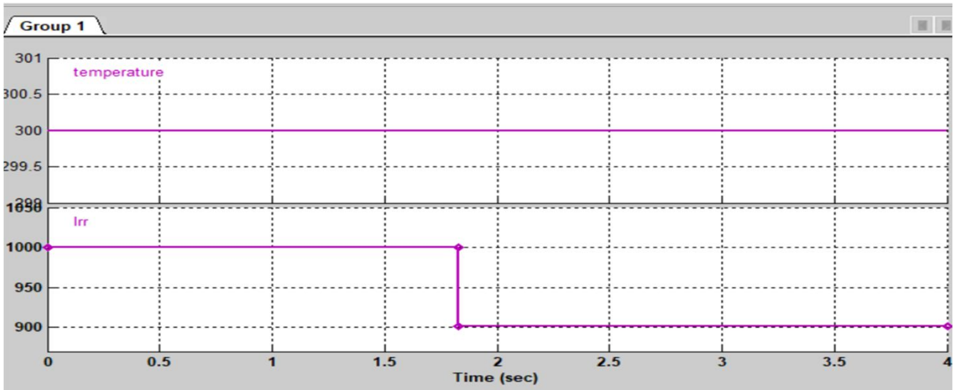

Fig 6.1: Changes in physical parameters

B. Panel/Input side Waveform

In the graph below, the upper waveform shows the power characteristics and lower waveform show panel voltage characteristics.

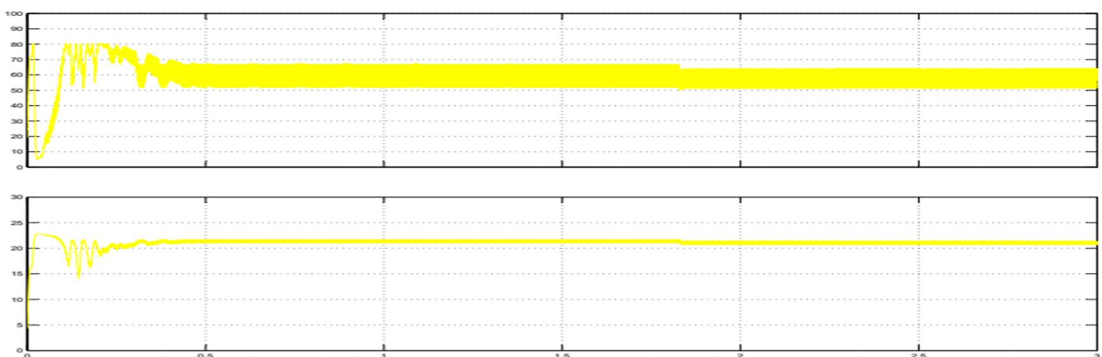

Fig. 6.2 Upper waveform show the power characteristics and lower waveform show panel voltage characteristics

C. Output Side Waveform

In the graph below, the upper waveform shows the power characteristics and the lower waveform shows boost voltage after the dc/dc converter.

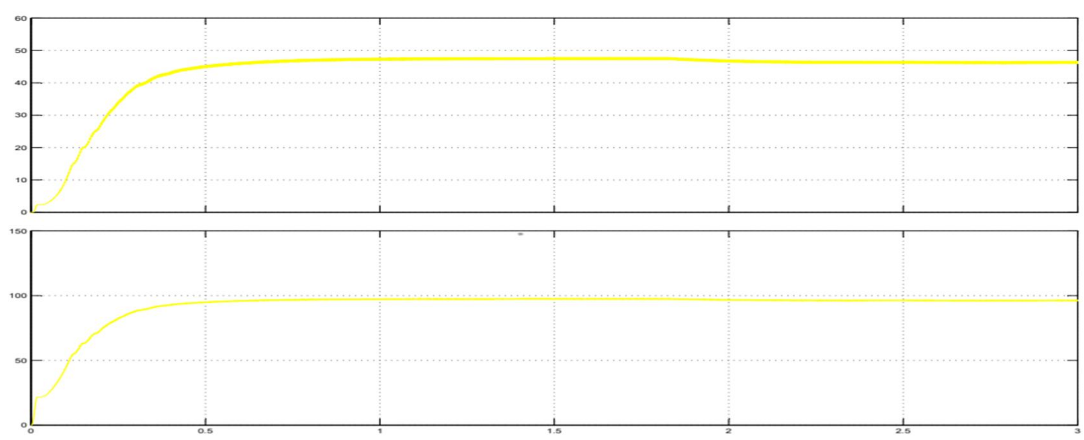

Fig. 6.3 Upper waveform show the power characteristics and lower waveform show boost voltage after the dc/dc converter

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D. Output side Waveform of Inverter

The graph below shows the AC Voltage characteristics of the inverter .

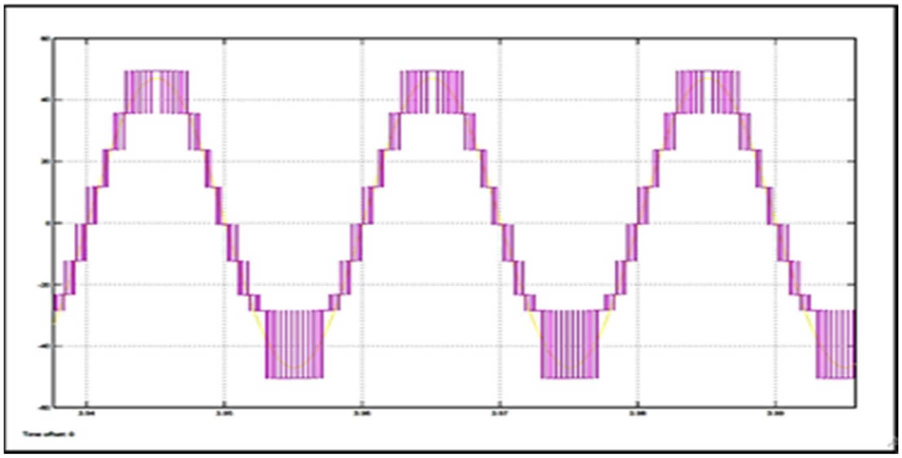

Fig 6.4: Output side AC Voltage waveform

VII. CONCLUSION

In this project we simulate a setup OF MPPT solar charge controller, it includes a PV MODULE, Boost converter and P and O algorithm.

The main motive of the project is extract the maximum power from the PV MODULE by using MPPT and boost the output Voltage and store the energy into the battery and the battery is connected to the inverter and change the DC supply in AC supply. We simulate a 80 Watt PV MODULE at Standard Temperature Conditions (STC , 1000W/m^2 , 25°C). Then PV Module connects with the Boost Converter for increasing the output Voltage. The P and O algorithm generates pulse according to variations in temperature and Irradiation and feeds the pulse into a Boost converter for the switching.

After connecting the 200 Ohm resistance as a load at the output side, the power and voltage readings at the panel side are respectively 60 Watt and 21 volt and the output side power and voltage are 49 watt and 97 volt.

These readings are recorded at 1000 W/m^2 and 27°C (300 K). The input side power and voltage waveform are shown in figure (5.1) and output side power and voltage waveform are shown in figure (5.2).

And also we simulate a flying capacitor multilevel inverter for converting the DC supply in AC supply. The specification of the inverter is 100V DC/~50V AC .

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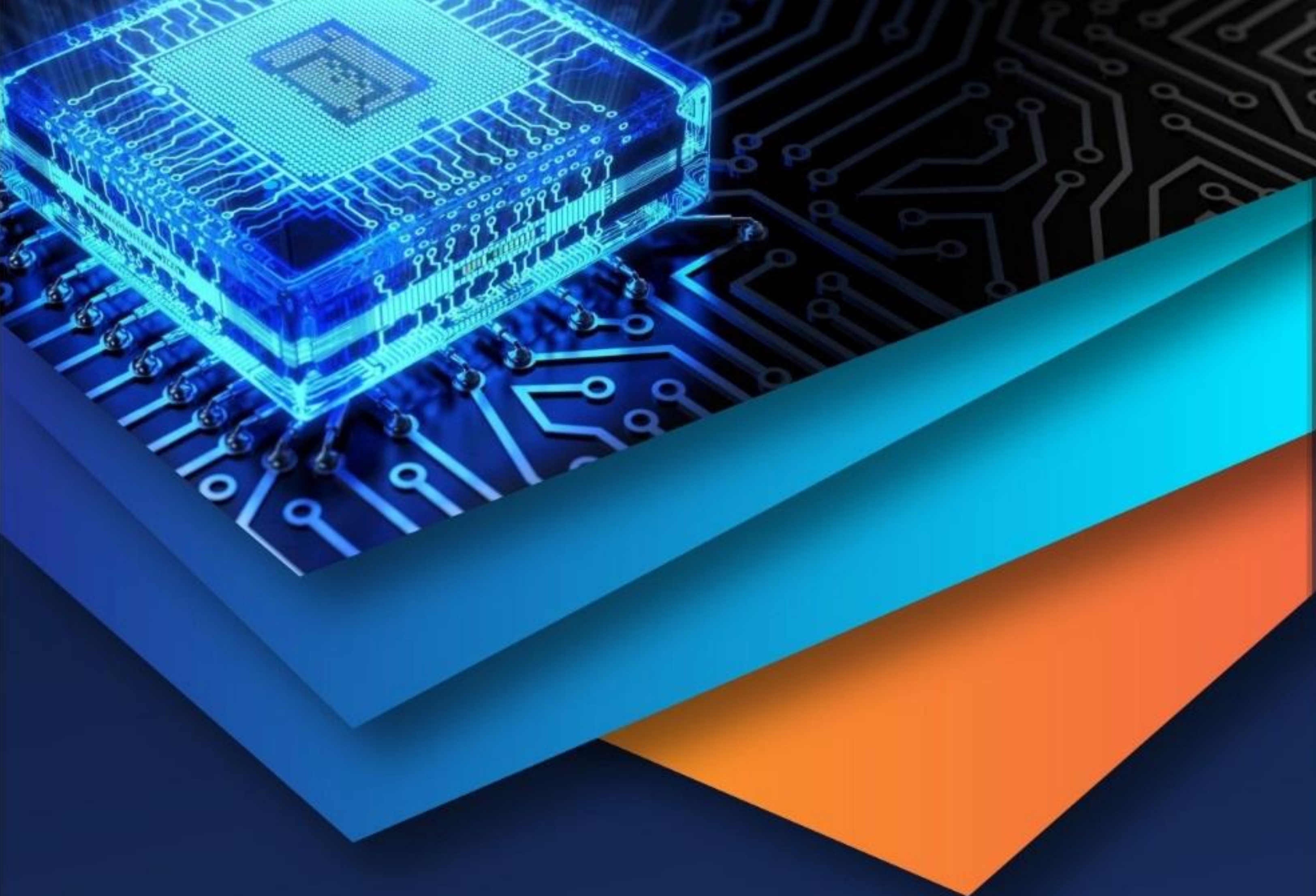

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