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MPPT Based Battery Charging Using Solar Energy

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Abstract

With the depletion of fossil fuel energy sources, there is a growing need for renewable energy sources. In India, the government aims to increase their non-fossil energy capacity from the current 170 gigawatts to 500 gigawatts by 2030, with the goal of meeting half of the country's energy needs using renewable sources. However, solar photovoltaic (PV) systems have low efficiency and high capital costs, hampering their widespread adoption, despite India having a solar power capacity of 64.38GW. Maximum Power Point Tracking (MPPT) techniques are utilized to address these issues by optimizing the power output of PV arrays under varying atmospheric conditions by tracking the maximum power point. This research delves into the P&O MPPT technique in detail and presents validated results from both hardware and software for a single MPPT system, showcasing its effectiveness in enhancing the efficiency of solar PV systems. In addition, a schematic is provided to extract the maximum obtainable solar power from a PV module and utilize the energy for a DC application, demonstrating the potential of solar energy as an important untapped resource in tropical countries like India.

Keywords: Maximum power point, Photovoltaic system, DC-DC power converters, Battery, Arduino.

INTRODUCTION

Solar energy is a renewable energy source that is widely regarded as the cleanest and most abundant. It has low operational costs when compared to other forms of power generation, and can be harnessed almost anywhere on earth at one time or another. The manufacturing process for solar panels is highly efficient, as the energy they produce over their lifetime far outweighs the energy required for their fabrication. Solar energy can be utilized in two primary ways: firstly, by capturing the heat for solar thermal energy, which is useful in space heating; and secondly, by converting solar radiation to electrical energy through the use of solar photovoltaic cells. This latter method is the most widely used and practical. Solar energy can be utilized as a standalone power generation system, or connected to the grid if one is available nearby. It is particularly useful in rural areas where access to power grids is limited.

LITERATURE SURVEY

2020 saw the completion of a study on various maximum power point tracking (MPPT) methods for solar PV systems by Redwan Ahmed and Shadhon Chandra Mohonta. They compared the performance of five different MPPT controllers in a model where a boost converter and a DC load were connected. All the 5 techniques with the proposed PV solar system were simulated in MATLAB Simulink, and the result was that the artificial neural network (ANN) MPPT controller produced reduced voltage and power fluctuations and had the efficiency of 97.55%

In 2019, Ashita Victor, Dharmendra kumar Mahato, Amit Pundir, and Geetika Jain Saxena published a paper in which they compared the design, simulation of different types of solar charge controllers (the voltage regulator- based controller, pulse width modulation (PWM) based controller) for optimized efficiency. It was concluded that the MPPT based controller is more efficient due to its minimal loss of power across its circuit, ability to work for both high and low voltage ratings of the solar panel and optimal performance at high irradiance and low temperature. The Thus, MPPT based charge controller can be used for efficiently charging lead-acid batteries, as it can deliver maximum power to the battery.

SOLAR PANEL

Here in this project Monocrystalline PV Module is used and the electrical specification of the Solar panel is as shown below.

Table: Electrical Specifications of Solar Panel

Maximum power-Pmax	3 watts
Voltage at Pmax- Vmax	3.5 V
Current at Pmax-Imax	0.375 A
Short-circuit current -Isc	0.470 A
Open circuit voltage- Voc	10V

BOOST CONVERTER

A DC-to-DC converter is necessary for matching the input resistance of a panel with

the load resistance. A buck converter is highly effective for this purpose. The efficiency decreases for buck-boost converter and further for a boost converter. But for grid-tie applications or for charging a 12V battery, a boost converter is the best option.
The boost converter is constructed with an IRFZ44 N- channel MOSFET, a 1N4007 diode, a 4.7 micro-Farad capacitance, and a 100 milli Henry inductance. The 555 IC works in astable mode and provides the triggering pulse to the MOSFET.

The critical inductor value required for the the circuit to be in continuous conduction mode is calculated using the below formula

$$L = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{\Delta I_L \times f_S \times V_{OUT}}$$

V_{IN} = typical input voltage
V_{OUT} = desired output voltage
f_S = minimum switching frequency of the converter
ΔI_L = estimated inductor ripple current

Assuming a desired ripple current of 20% of the average output current, or ΔIL = 0.2 x (Vout / RL), where RL is the load resistance, and a value of RL is given by RL = Vout/max charging current of the battery.
Max charging current is usually around 10% to 20% of the battery's rated capacity (C-rate). For a 1.3Ah battery, this would correspond to a charging current of around 0.13A to 0.26A.

The critical capacitance value required for the the circuit to be in continuous conduction mode is calculated using the below formula

$$C_{OUT(min)} = \frac{I_{OUT(max)} \times D}{f_S \times \Delta V_{OUT}}$$

$C_{OUT(min)}$ = minimum output capacitance
$I_{OUT(max)}$ = maximum output current of the application
f_S = minimum switching frequency of the converter
ΔV_{OUT} = desired output voltage ripple

D = Duty Cycle = Ton/T or it can also be derived uisng the required input and output voltages of the boost converter using the below formula

$$D = 1 - \frac{V_{IN(min)} \times \eta}{V_{OUT}}$$

$V_{IN(min)}$ = minimum input voltage
V_{OUT} = desired output voltage
η = efficiency of the converter, e.g. estimated 80%

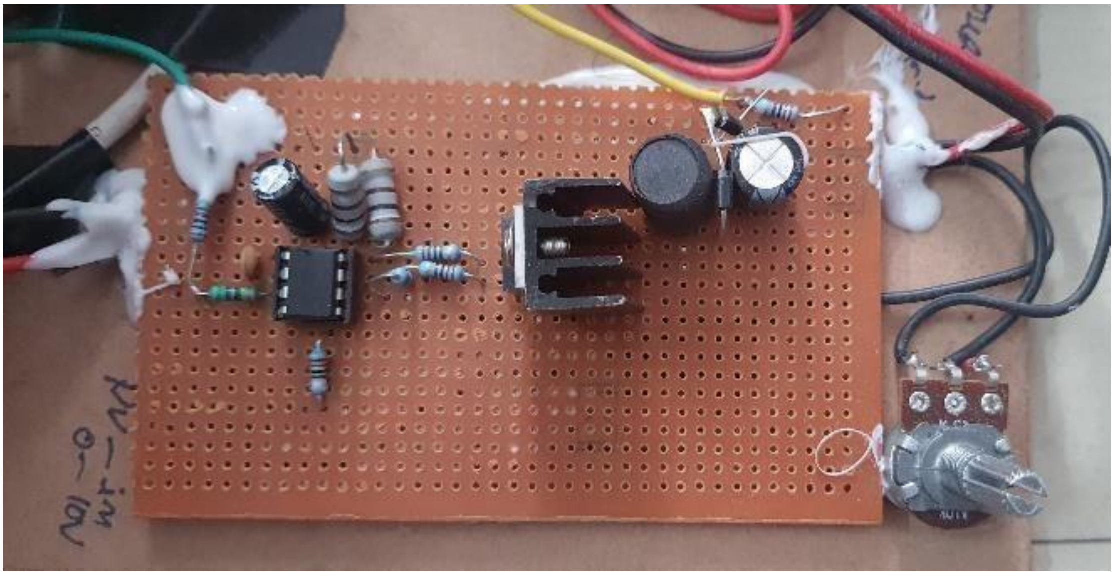


Figure 1: Boost Converter

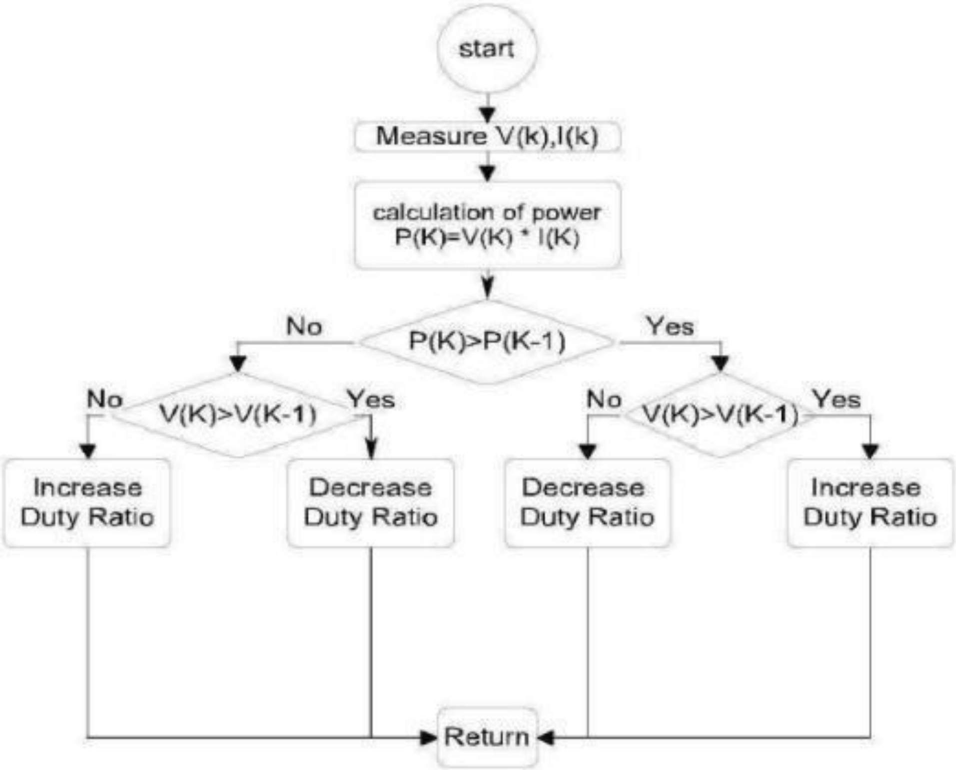
MPPT ALGORITHM (PERTURB AND OBSERVE)

An Overview of Maximum Power Point Tracking

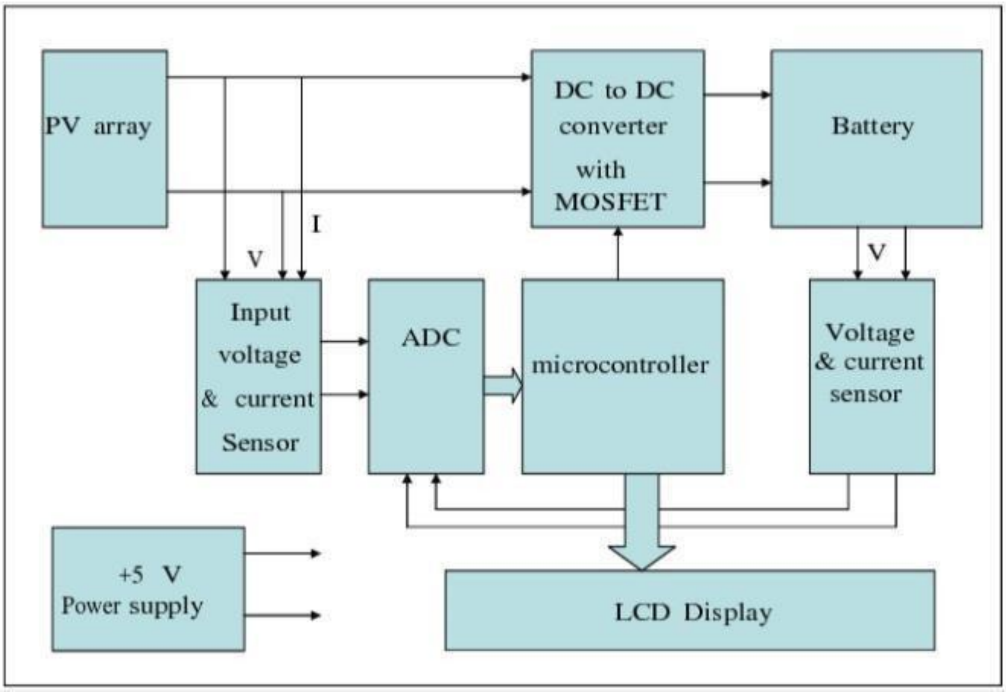
To obtain maximum power at the load, the thevenin impedance of the circuit (source impedance) must equal the load impedance. The maximum output solar panel voltage is 9V and the battery to be charged is 12V. To increase the voltage for charging the load, we are employing a boost converter connecting it to the solar panel output. We can match the source impedance to the load impedance by correctly adjusting the boost converter's duty cycle. Among the different MPPT algorithms, selection of one algorithm can be done by checking the time taken by the algorithm to track the MPP, the cost and the ease of implementation. We can set an appropriate error threshold or employ a wait function, which may increase the time complexity of the algorithm.

Perturb & Observe

The simplest algorithm is Perturb & Observe (P&O) as we only utilize one sensor, a voltage sensor, to sense the voltage of the PV array. It requires low implementation cost. The disadvantage is that when it gets extremely close to the MPP, it continues to perturb in both directions.



BLOCK DIAGRAM



WORKING PRINCIPLE

The solar panel in use has a 3W power rating and a 10V open circuit voltage. The solar panel is attached to the boost converter. On the opposite side of the boost converter, the DC load (battery) is connected. The voltage sensors are used to gauge the voltage coming from the solar panel and battery, respectively. The Arduino receives these two volts as input and it computes the power from both the solar panel and the battery and using P&O method it tracks the solar panel's greatest power point. The P&O method operates by cyclically changing the terminal voltage of the PV array and identifying the highest power that can be acquired from a PV module to charge a battery through a comparison of its output to that of the prior perturbation cycle. This technique enables the battery to receive the maximum possible current.

HARDWARE RESULTS

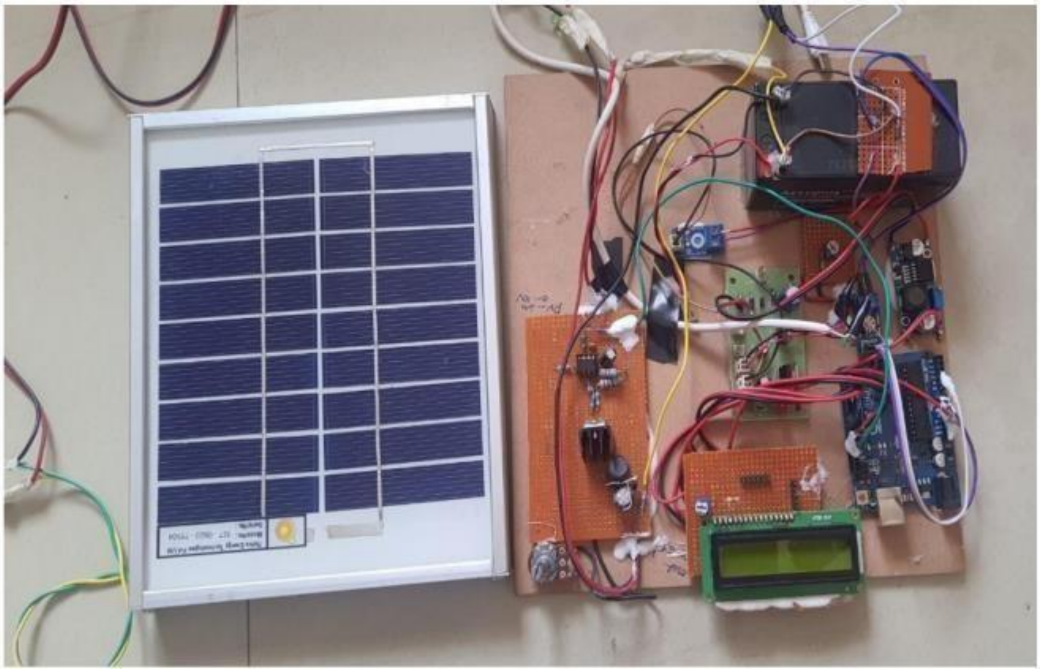


Figure 2. Complete Hardware implementation of MPPT solarcharge controller

We use a 3W solar panel to recharge a 12V battery. A 4.7uF capacitor, a 100mH inductor, and an IRFZ44 Mosfetare used to construct a boost converter, which is linked in series between the solar panel and the battery. The Mosfet is started by a 555 timer IC. The P and O MPPT technology, whose code is uploaded in the Arduino microcontroller, is used to regulate battery charging. The battery voltage and solar panel voltage are shown on a 16 by 2 LCD. When the Boost converter received the maximum input from the solar panel, 8.97V, the voltage was increased by 3V in order to charge the battery to its maximum rated voltage, 11.9V.

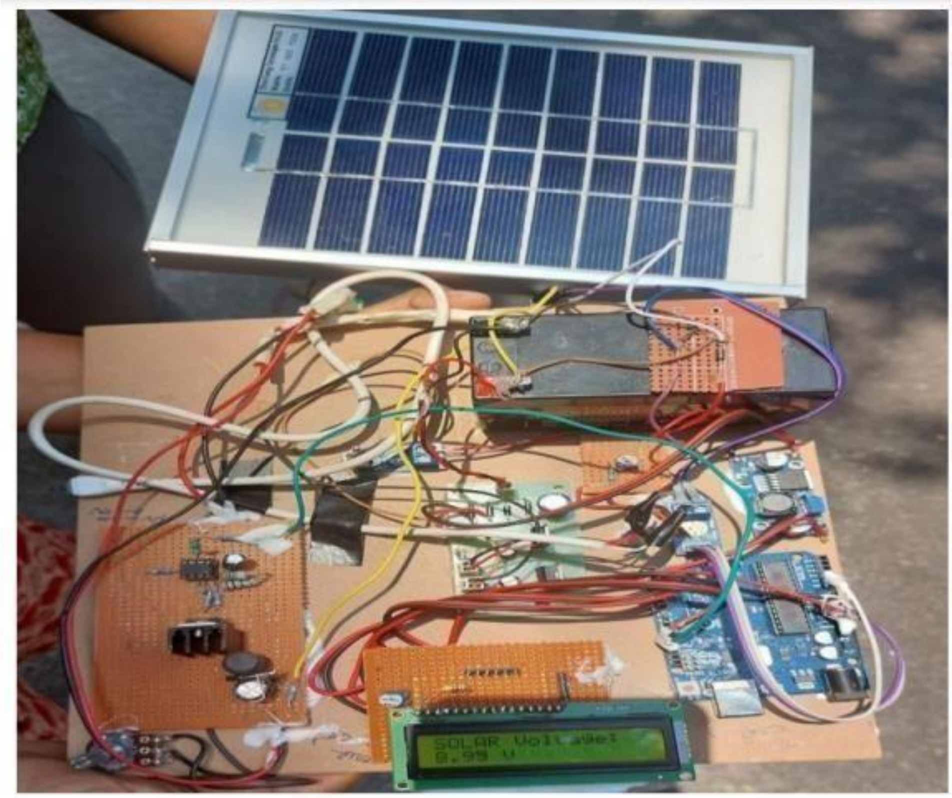


Figure 3: Solar Panel voltage = 8.95V

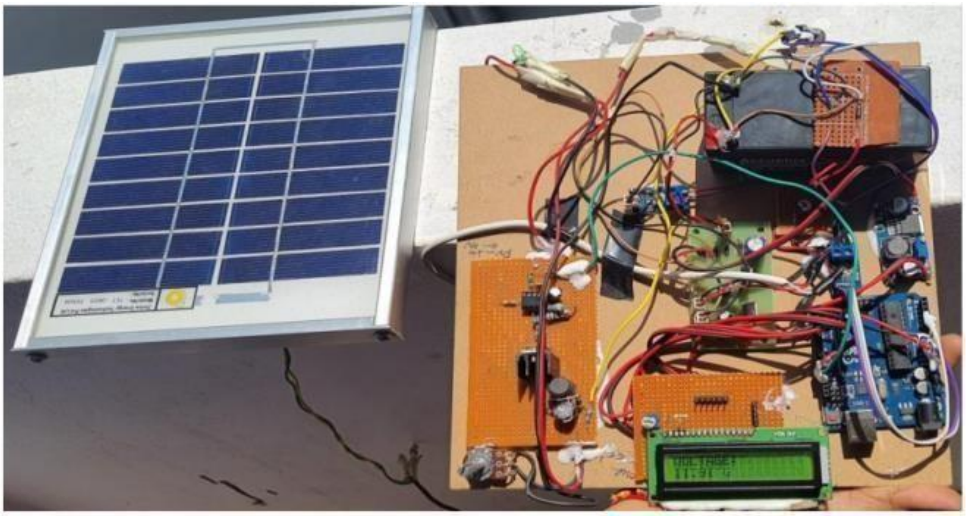
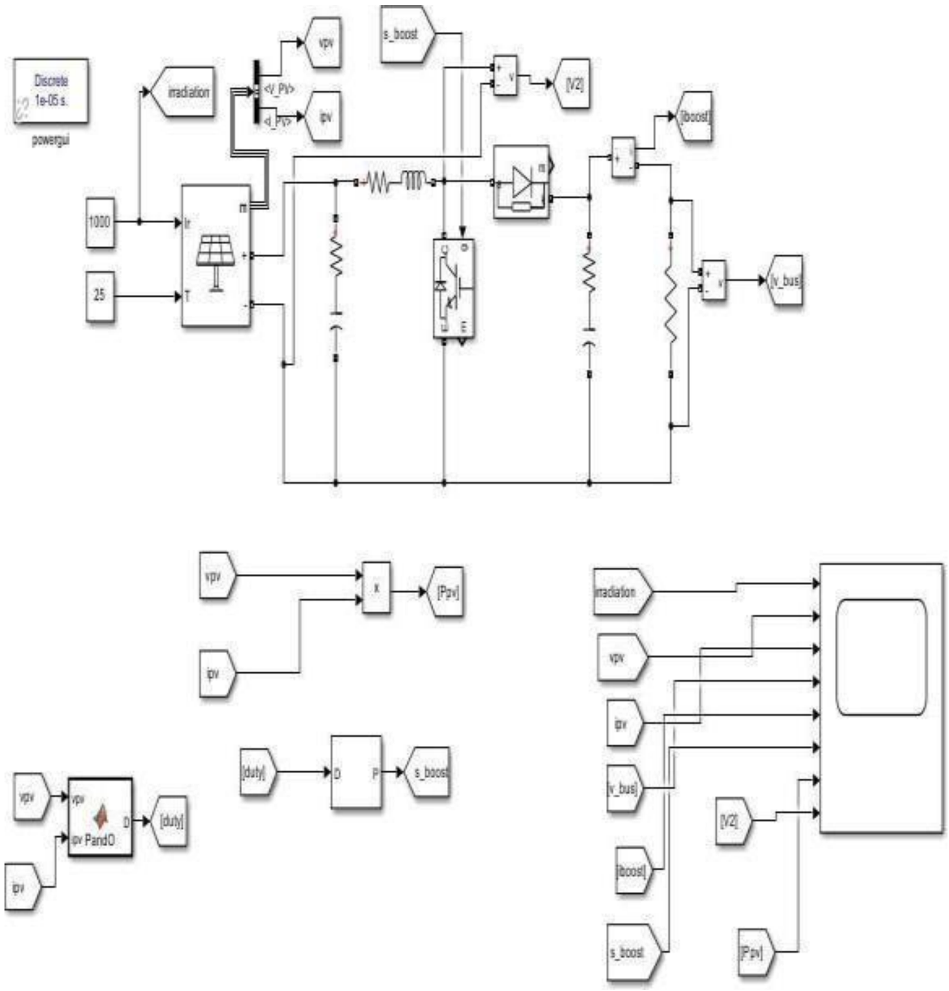


Figure 4: Battery Voltage =11.9V

SOFTWARE USED: -

Arduino IDE, Embedded C programming language

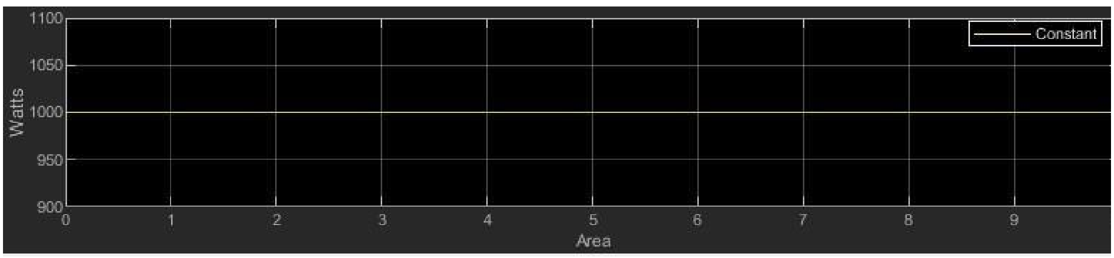
MATLAB SIMULINK SCHEMATIC DIAGRAM: -



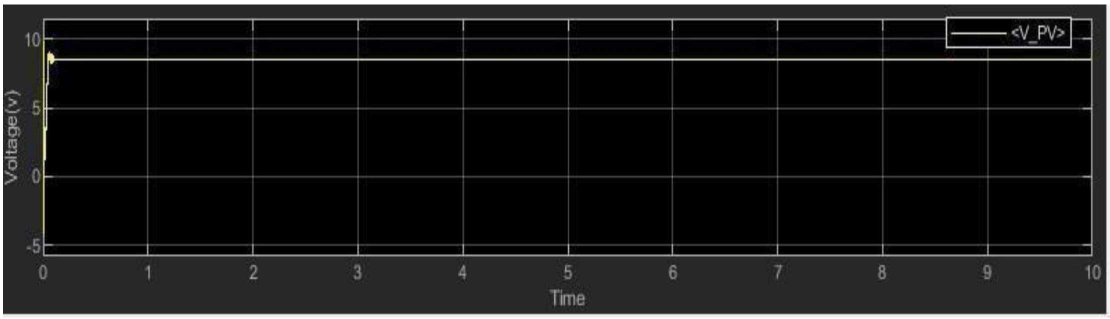
The P&O technique of MPPT is used, therefore a program is written in P&O matlab function that compares the previous and present powers and gives output accordingly, the output can be observed in scope which is shown in the observation from simulink.

SIMULATION RESULTS:

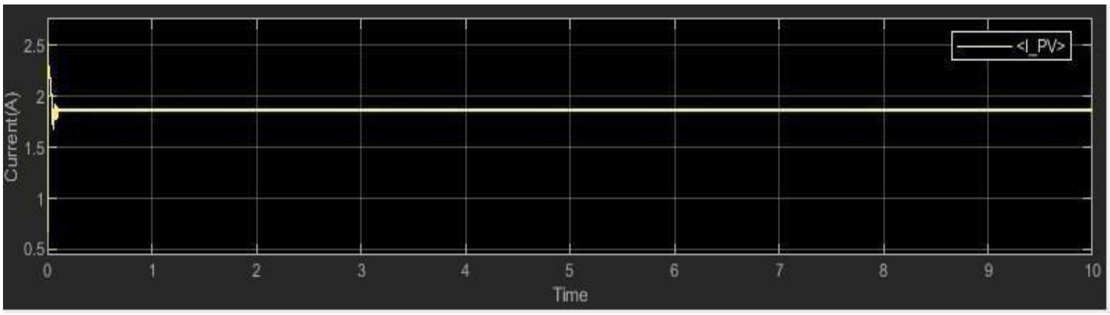
Graph 1-Irradiance



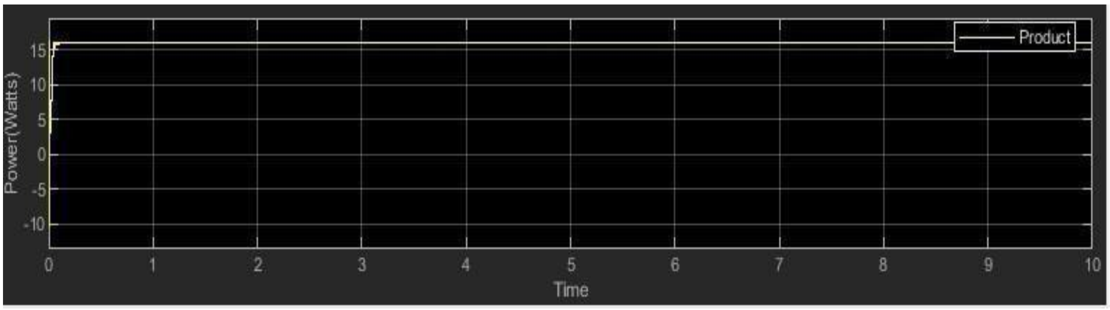
Graph 2-Voltage from solar panel



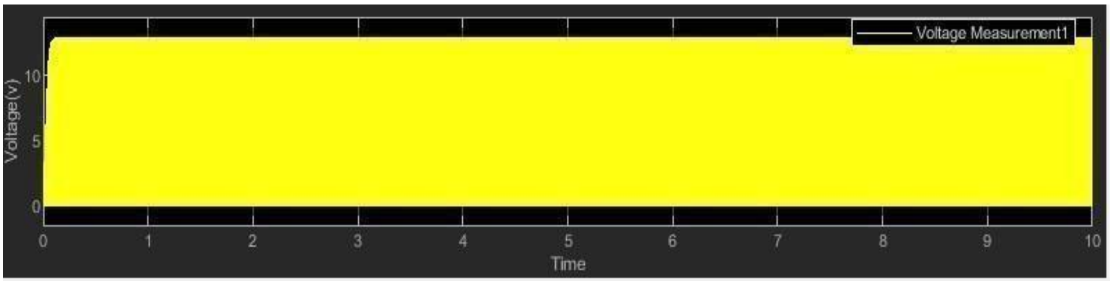
Graph 3-Current from solar panel



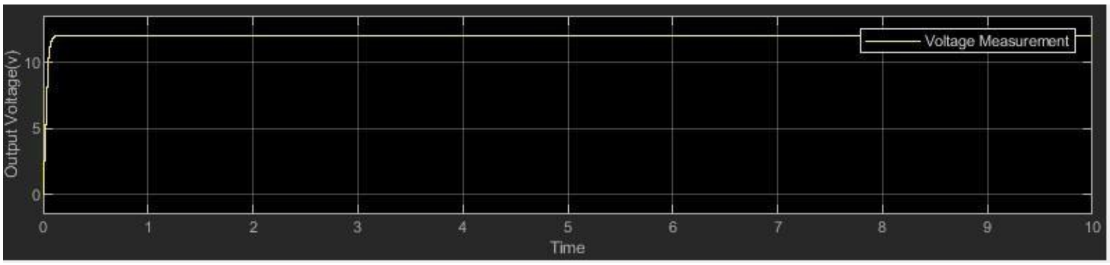
Graph 4-Power



Graph 5-Voltage from boost converter



Graph 6-Output Voltage



CONCLUSION

The project is carried out to make effective use of the PV array, which must track the highest power point under various climatic circumstances. As a result, the P&O approach, one of the MPPT techniques, is employed. The lead acid battery charging is promptly and effectively controlled by the P&O method. In order to give the most power, the control algorithm uses the P&O approach to operate at its peak power point in accordance with solar irradiance and match the load to the source impedance. When using a solar charge controller with MPPT, the circuit efficiency is 20–25% higher than when using a circuit without MPPT. Additionally, it reduces the additional energy needed for mechanical tracking.

REFERENCES

[1] D.P Hohm, M. E. Ropp, "Comparative Study of Maximum Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking TestBed", Photovoltaic Specialists Conference, 2000. Conference Record of the Twenty- Eighth IEEE, pp 1699 – 1702, 15-22 Sept. 2000.

[2] G.C Hsieh, C.Y. Tsai, and H.I. Hsieh, "Photovoltaic Power- Increment Aided Incremental- Conductance Maximum Power Point Tracking Controls," in Proc. IEEE PEDG, pp. 542-549, Aalborg, Denmark, 2012.

[3] Comprehensive Analysis of MPPT Techniques using Boost Converter for Solar PV Systemby R. Ahmed and S. C. Mohonta, 2020 2nd International Conference on Sustainable Technologies for Industry 4.0 (STI), Dhaka, Bangladesh, 2020, pp.1doi:10.1109/STI50764.2020.935 0398.

[4] Performance Analysis of Solar Photovoltaic System using Various MPPT Techniques byDeepti Meena; Rajesh Kumar, 2022 1st International Conference on Sustainable Technology for Power and Energy Systems (STPES), SRINAGAR, India, 2022, pp. 1-5, doi: 10.1109/STPES54845.2022.10006489.