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Design and Implementation of Perturb and Observation Maximum Power point Transfer (MPPT) algorithm for Photovoltaic system

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ABSTRACT

The electricity crisis in India is still at large with over 300 million people still having no means to electricity. According to FICCI power shortages costs around 68 million in GDP. India is endowed with a vast solar energy potential. India receives one of the highest global solar radiations – energy of about 5,000 trillion kWh per year is incident over India's land mass with most parts receiving 4-7 kWh per m2 per day. The use of solar power will aid in solving the problem of power outage in remote places. Solar energy is a clean, non-polluting, efficient and sustainable energy source which has long term reliability. The efficiency and the reliability of a photovoltaic (PV) plant depend upon efficiency of PV panel, efficiency of inverter and efficiency of Maximum power point transfer (MPPT).Many researchers have developed algorithms to harvest maximum power from the sun. The most popular maximum power point algorithms (MPPTs) are perturb & observation, incremental conductance, fuzzy logic control to name a few.

In the present work, perturb & observe MPPT algorithm is chosen to analyze its performance in the photovoltaic applications. The P&O algorithm is implemented in microcontroller and applied to the buck converter. The microcontroller estimates the input power and the converter output power to validate the performance of the p & o algorithm for photovoltaic applications. This paper contains hardware prototype results and respective waveforms using Perturb and Observation MPPT method.

Keywords - PV cell, MPPT, P&O algorithm, Microcontroller, Voltage and current sensor, PV & IV Curve

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I. INTRODUCTION

Solar power is the utilization of the sun's vitality either specifically as warm vitality or using photovoltaic cells Sun powered vitality; it is perfect clean energy and non-polluting. Many forms don't emanate any ozone harming substances or dangerous waste during the time spent delivering power. It is a manageable energy source that can be depended on as long as possible. Sun based energy is practical and proficient. The effectiveness of a PV plant is influenced predominantly by three factors: the productivity of the PV panel (in business PV boards it is between 8-15%), the proficiency of the inverter (95-98 %) and the efficiency of the maximum power point tracking (MPPT) Algorithm (which is more than 98%). Enhancing the effectiveness of the PV panel and the inverter isn't simple as it relies upon the innovation accessible, it might require better Components, which can increment definitely the cost of the establishment. Rather, enhancing the Maximum power point tracking (MPP) with new control calculations is simpler, not costly and should be possible even in plants which are as of now being used by refreshing their control calculations, which would prompt a quick increment in PV control and subsequently a decrease in its cost. MPPT calculations are important on the grounds that PV exhibits have non linear voltage-current characteristics with a one of a kind point where the power delivered is most extreme. This point relies upon the temperature of the panels and on the irradiance conditions. The two conditions change amid the day and are likewise unique relying upon the period of the year. Moreover, irradiance can change quickly because of changing climatic conditions, for example, mists. It is imperative to track the MPP precisely under every single conceivable condition with the goal that the most extreme accessible power is constantly achieved. The goal of this venture is to implement and analyse the

Perturb and Observation Maximum Power Point (MPPT) calculations for Photovoltaic System. The block diagram of the proposed system is shown in the underneath Figure 1

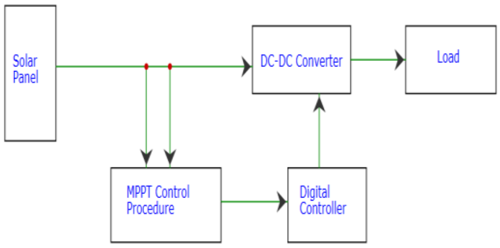


Fig 1. Block diagram

II. RELATED WORK

Renewable energy resources increasingly becoming more popular especially power generation from solar. Solar irradiation is the main factor that influence the electricity generation in photovoltaic (PV) systems. Many controllers are developed with MPPT algorithms to maximize the output power of the PV panels in the past. The evaluation of the existing MPPT algorithms with an over view of extended range of operating conditions carried out. The relative performance studies of both perturb & observation and Incremental Conductance (IC) techniques carried out with respect to dynamic and steady state perspective. The performance study of these techniques has revealed that the P & O algorithm has a faster dynamic performance over a distinct wide operating conditions compared to the incremental conductance technique [1].

The performance evaluation of MPPT technique P & O had been carried out with buck and buck boost dc-dc converters in Simulink/MatLab [2]. The control of buck and buck boost converters operation was directly controlled from the MPPT tracker. The results have indicated that the P & O with buck converter yielded better results than that with buck boost converter as far performance concerned. The paper presents the behavior of the buck and buck boost converters due to sudden change in operating conditions with direct control.

A MatLab/Simulink model of P & O, Incremental Conductance MPPT algorithms is presented in [3]. A theoretical analysis of a variable step size incremental conductance MPPT algorithm is also presented. In this paper the performances of these algorithms while driving a dc-dc boost converter under various operating conditions is carried out. The paper doesn’t cover any special features to improve the conversion efficiency of the dc-dc boost converter.

A comparative Performance Analysis of P&O and Incremental Conductance MPPT Algorithms under Rapidly Changing Weather Conditions are presented in [4]. The dc –dc boost converter is used in the experiment. The paper presents the Simulink/MatLab and Experimental prototype used in the work. The study concludes that the incremental conductance MPPT is 3 times faster than that of P & O under rapid variable conditions.

Most of the PV systems utilize dc-dc converters to match the source and load impedance to achieve the maximum power transfer. The analysis of these converters with respect to their design elements such as inductance and capacitance plays a significant role in achieving MPPT [5]. These elements must be properly sized to achieve optimal efficiency.

The MPPT technique is very important for the extraction of maximum power from the sun, but even then these MPPT techniques are affected by rapidly changing weather condition and load affecting the efficiency and operation. P & O algorithm is the most commonly used MPPT algorithm because of its simplicity to use and implement but is affected by the oscillations at the output. Which in-turn has paved the path for the development of modified P & O algorithm, where the proposed P & O algorithm is based on load technique to determine the change in power is either from the load or rapidly changing weather condition [6].

The use of off- grid solar power system is very much used in rural places where grid based electricity is a problem. Recently researches on PID-based MPPT controller for off-grid solar photovoltaic (PV) system are being explored. The Ziegler-Nichols (Z-N) Reaction Curve Tuning Method is used to get the tuned response, and from that the tuned execution parameters and also the perfect PID get parameters. The prevalence the PID based controlled MPPT framework over the P&O MPPT and the non-MPPT frameworks for all the different flag inputs is exhibited. Specifically, the recreated reaction of the PID-based framework has a most limited settling time of 22.7 ms (showing the quickest framework reaction) and zero over-shoot (speaking to least misfortunes) [7].

The maximum power point tracking technique with open loop method is used for solving the problems present in two of the most used techniques : the perturb and observe (P&O)and incremental conductance algorithms. The primary disadvantages of the P&O procedure are its poor dynamic reaction and swinging around the most extreme power point amid unfaltering state task furthermore swinging of working point subsequent to achieving MPP. The incremental conductance method has a moderate dynamic reaction time. The open circle MPPT method utilized in this work goes for giving an enhanced dynamic reaction time when contrasted with the already said systems. It doesn't experience the ill effects of high execution many-sided quality also. [8]

A high efficient micro-controlled buck converter with maximum power point tracking for photovoltaic systems is presented in [9]. Here a buck converter is controlled by using P&O technique for the maximum power point tracking of the PV panel. The system is implemented using microcontroller device. The results show a good performance of the control technique and the improvement of the efficiency of the system.

The analysis and comparative study on the three main MPPT algorithms have been carried out in [10]. The system is developed using the PV solar module and DC-DC buck – boost converter with the algorithms of perturbation and observation (P&O), incremental conductance (INC) and hill climbing (HC), respectively with different climate condition and algorithms. From the carried out work it can be observed that the photovoltaic system can track the maximum power precisely using the MPPT algorithms discussed in [10]. P&Q MPPT algorithm has fast dynamic response and well regulated PV output voltage than hill climbing algorithm. As the resolving process of INC algorithm is more complicated than the other two algorithms, thus, the time needed by INC algorithm is also a little longer than the other two algorithms.

The literature survey indicates that there is a need for Hardware Implementation of P&O Algorithm with practical load and natural sunlight. The main goal to track the MPP and keep the load constant even though there is variation in irradiance level. And since there is a need for pollution free, environmental friendly energy, the implementation and evaluation of P&O Algorithm with a photovoltaic cell for any DC Load with cost-effective and compact design is necessary.

III. MAXIMUM POWER POINT TRACKING

This is a method used in Solar PV arrays to expose uniform solar irradiance and maintain a maximum power output for a period of time. The maximum power output can clearly be seen at the 'knee' of the curve. This is the position that is most sought after and is achieved when maximum voltage and maximum current are achieved at the same time. MPPT is a method to ensure that maximum voltage and maximum current is reached as much as possible and overall to make maximum utilization of PV modules and minimize the power failure due to environmental conditions This is done by having the solar array track the path of the sun and also by making sure that none of the solar array becomes partially shaded at any stage due to cloud, branches of trees etc., and if this does occur a system is in place to adjust the panel and get it back to output the maximum current and voltage and hence the maximum output power. Details of the two methods used to track the MPP are given below; the method that is being used in this project is the Perturb and Observe (P&O) method.

In the event that irradiance levels vary all through the sun based exhibit, this outcomes in different neighborhood maxima focuses being delivered. These outcomes in nonlinearity of the PV trademark bends, which implies there is more than one 'knee' in the P-V bends. Numerous nearby maxima are bad to track as it lessens the adequacy of the following framework, and these outcomes in general misfortune in influence yield. Applications of MPPT are mentioned below:

a) Daily usable device such as Laptop, mobile and laptop charging
b) Domestic Lighting Application.
c) Electric Vehicle Application
d) Automotive and any DC Load application.

IV. PERTURB AND OBSERVE ALGORITHM

The P&O Algorithm is of the methods used in MPPT. It is done by seeing the array of output power and determining the next action, which is to increase or decrease the array operating voltage. This method has been widely used in today's technological devices to achieve the maximum amount of power from a solar panel. Due to the existence of more than one local maximum power point, when panel doesn't receive uniform amount of sunlight due partial shading, its effectiveness is mainly reduced. while working voltage of a PV cluster is bothered in a specific provided guidance and the power drawn from the PV exhibit rises, which implies that the working point has moved towards the MPP and subsequently the working voltage must be additionally annoyed a similar way or disaster will be imminent if the power drawn from the PV exhibit diminishes, the working point has moved far from the MPP and consequently, the bearing of the working voltage irritation must be turned around.

The rise in the operating voltage and the power output increases, the system will continue this till the power output reduces. Then the voltage is decreased to get the system back to its maximum power output. Thus this continues continuously when results in the power output value oscillating up to the MPP continually and never stabilizing.

Usually the P&O algorithm uses fixed iteration step sizes, but this has been a limitation of the system as it is impossible to provide performance requirements of fast dynamic response and good accuracy during the steady state at the same time. The reasons for this are, if the step size is too big, the oscillations around the MPP will increase during

steady state and this will result in lost power generation, if the step size is too small the highest generation cannot be restored quickly enough during changing operation conditions. Variable step sizes are now being implemented to overcome this problem. The Figure2 shows the P & O algorithm flow chart.
The advantages of this method include
a) Very simple and easy to implement and does find true MPP.
b) It can be taken as either an Analog or Digital technique of MPPT.
c) Most commonly used so information is widely available.
d) Provides predictive and accurate solutions to MPPT under PSC.

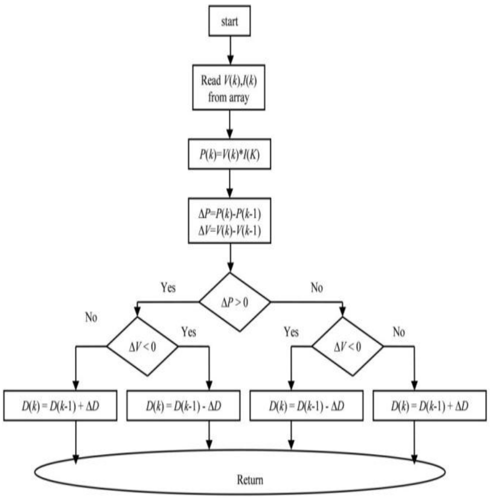


Fig 2. Flow diagram of P&O Algorithm

V. HARDWARE IMPLEMENTATION.

The Figure 3 shown below represents the block diagram of the hardware implemented. The solar panel consists of the solar cells which are used to convert the solar energy into the electrical energy. Panel used here is 20W, 21V and 1.2A polycrystalline solar panel consisting of 36 Solar cells.

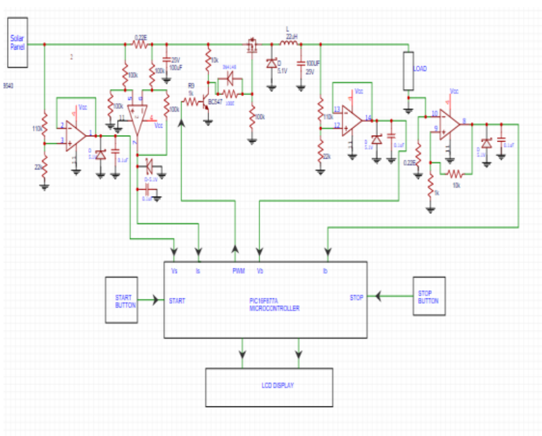


Fig 3. Block diagram of hardware implementation

The DC-DC converter used in this project is a Buck converter for which the specifications are shown in table 1

Table 1. Parameter specifications of Buck Converter

Parameter	**Specification**
Input Voltage	17.7V
Output Voltage	12V
Switching Frequency	450KHz
Duty Cycle	0.5763
Inductor	24µH
Capacitor	10µF

The calculation and design is as follows:-

Duty Cycle is given by:

$$D = \frac{12}{17.7} \times \frac{85}{100} = 0.5763$$

$I_{ripple} = 0.3*I_L$
$= 0.3*1$
$= 0.3$Amps

$$L = \frac{(Vin - Vo)}{Fs} \times \frac{D}{Ir}$$

$$= \frac{(17.71 - 12)}{450 \times 10^3} \times \frac{0.5763}{0.3}$$

$$= 24.4 \times 10^{-6}$$

L = 24uH

Output Capacitor:

$$Co = \frac{(Ir * \Delta T)}{\Delta V - (Ir * ESR)}$$

$$= \frac{0.3 * 1.28 * 10^{-6}}{50 * 10^{-3} - (0.3 * 0.03)}$$

C_O= 10uF

$$\Delta T = \frac{D}{Fs}$$

$$= \frac{0.3}{450 * 10^3}$$

=1.28us

ESR = 0.03E

$\Delta V = 50mV$

Input Capacitor:

$$Cin = \frac{\Delta T}{Vr/_{Ir} - ESR}$$

$$= \frac{1.28 \times 10^{-6}}{\frac{0.2}{0.3} - 0.12}$$

= 2.2uF

Diode Current:

$$I_d = (1 - D) * I_l$$

= (1- 0.5763)*1

= 0.4237Amps

The typical buck converter circuit is shown in Figure 3

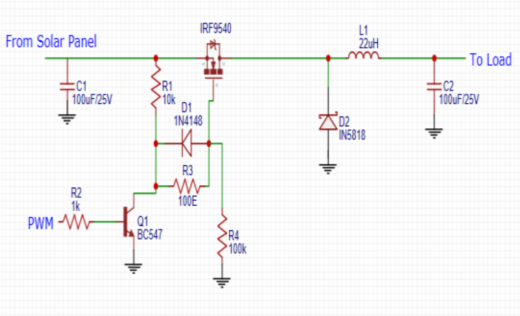


Fig. 3: Typical Buck Converter Circuit

The system uses current and voltage sensor circuits which are built using the LM324. Used on source and load side for measuring the analog values and sending it the microcontroller. The current and voltage sensor circuit are as shown below in Figure a & 5 respectively.

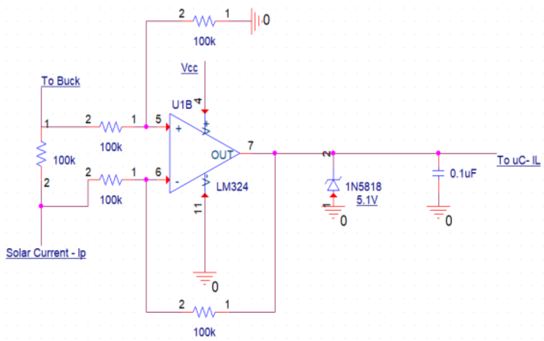


Fig. 4: Signal Conditioning Circuit for Current Sensor (Source Side)

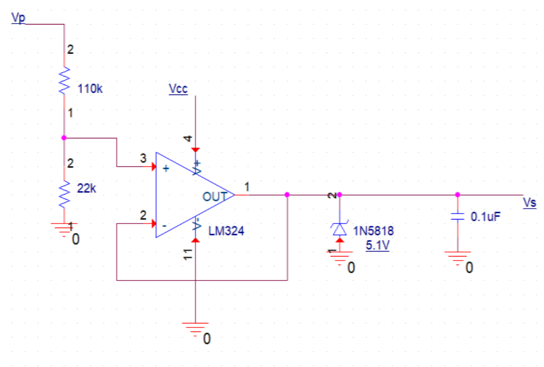


Fig. 5: Signal Conditioning Circuit for Voltage Sensing (Source Side)

MOSFET used in the buck converter is a P-type IRF540N and gate drive circuit is designed to drive MOSFET using BJT and these gate pulses are given to the MOSFET through the microcontroller PWM pulses. The microcontroller used in this prototype is PIC16F877A. It is 8 Bit 40 Pin Microcontroller with 20 MHz clock cycle. A LCD is used to present the values physically. The load used here is 7 Watt LED load which has intensity of 700 lumens. The system also consists of two push buttons for start and stop operation.

VI. WORKING METHODOLOGY

A PV System is implemented and evaluated using P&O Algorithm for MPPT using DC Load. The system consist Solar Panel for input to the system, signal conditioning circuits, a buck converter is used for conversion and change in voltage level to match the load.

Based on the set duty ratio which is 0.576, and is set using the output and input voltage relation of buck converter. The microcontroller generates the corresponding PWM signal which is then extended to the BJT to drive the power MOSFET. Accordingly the P&O Algorithm from the initially set duty ratio, voltage and current of the solar panel and there by measuring the instantaneous power which is termed as P_{NEW}, and then this P_{NEW} values is compared with P_{OLD} which is zero, if P_{NEW} is greater then Duty cycle is incremented and perturb is continued in same direct, and if less then duty cycle is reduced and perturb is continued in opposite direction. An hence MPPT is maintained. Corresponding to the set duty ratio. System continuously checks for the Solar Voltage, current and Load Voltage, current. If the Solar Voltage reduces any time reduces below 11V, the Load is not supplied with enough power there is no output. Hence the main aim of the P&O Algorithm is to maintain the minimum output power, such that the load remains constant by varying the duty ratio.

$$D = \frac{Vout}{Vin} * Efficiency$$

$$= \frac{12}{17.7} * \frac{85}{100}$$

$$D = 0.576$$

The Load used here is LED light and any DC Load up to 12W can be used. Thus the system has Solar Panel, Microcontroller unit, Buck Converter, and a DC Load. The system has application such as domestic lighting in rural areas as well as for electric vehicle.

VII. RESULT AND ANALYSIS

The hardware prototype was tested under various conditions. The results and analysis were found satisfactory. The below Figure 6 shows the system under initial setup with a 7 Watt LED load. From the above circuit it can be seen that the system consist of a microcontroller unit, buck converter and the sensor circuits are mounted on the general PCB Board.

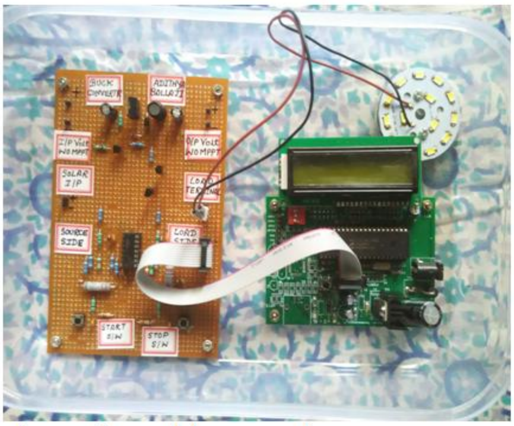


Fig 6 Hardware of the proposed system

The duty cycle is very important part of the P & O algorithm. The tracking of MPP depends on the varying of Duty cycle. The test setup is shown in below Figure 7.

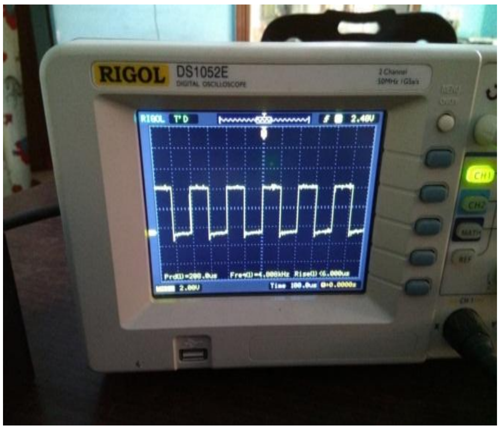


Fig 7 Duty cycle (gate pulses) to the Switch in buck converter

The below Figure 8 shows the hardware setup of P & O algorithm with a initial test load of 7W LED light. The LED light is able to produce 700 lumens and able to track MPP precisely.

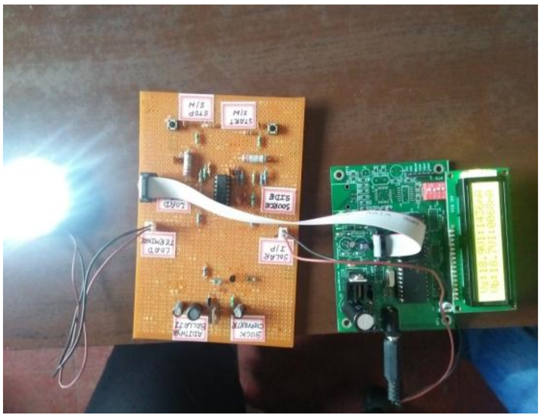


Fig 8. Hardware setup connected to LED Load at Vs = 18.2V & Is = 1460mA

The PV system has been tested for three conditions which are No load, 2W Resistive load and 7W LED. The tabular columns shown below are for these three conditions.

Table 2: Experimental Values of P&O Algorithm with NO-LOAD

SL	Vs	Is	Vb	Ib
1	18.5V	1.44A	18V	8mA
2	19.7V	1.45A	19.3V	2mA
3	20.1V	1.48A	20.1V	4mA

The above Table 2 shows the Experimental values of P&O Algorithm when NO- LOAD is connected, as it can be seen in the table the value of Ib is very small as there is no load to draw the more current.

Table 3: Experimental Values of P&O Algorithm with 2W Resistive Load

SL	Vs	Is	Ps	Vo	Io	Pout
1	17.2V	1.44A	24.7W	19.1V	0.193A	3.6W
2	17.3V	1.44A	24.9W	16.9V	0.193A	3.2W
3	17.8V	1.43A	25.4W	19.0V	0.191A	3.6W
4	19.2V	1.44A	27.6W	17V	0.189A	3.2W
5	19.7V	1.44A	28.3W	18.4V	0.206A	3.7W

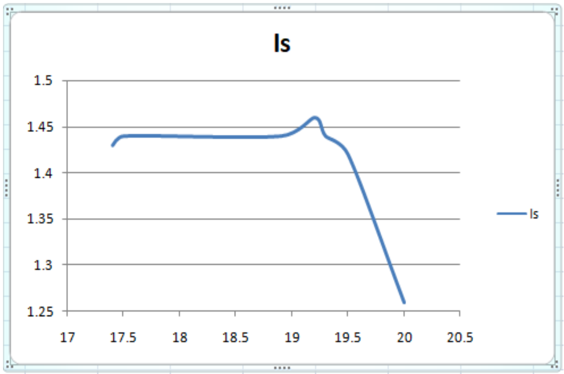
The above Table 3 shows the experimental value solar output and load output of P&O Algorithm with 2W resistive load and can be clearly seen the difference between the input power and output power. And since the load is connected the rise in the output current can be clearly seen.

Table 4: Experimental Values of P&O Algorithm with 7W LED

SL	Vs	Is	Ps	Vo	Io	Pout
1	17.4V	1.4A	25W	17.3V	0.7A	12.4W
2	17.5V	1.4A	25W	17.3V	0.7A	13.3W
3	18.9V	1.4A	27.1W	18.8V	0.7A	14.2W
4	19.2V	1.4A	27.6W	19V	0.7A	14.4W
5	20V	1.2A	25.8W	19.2V	0.7A	13.4W

The above Table 4 shows the experimental values of the P&O Algorithm when connected to 7W LED Load. The above values were near to the MPP. The output characteristics of solar panel at 25

Degree, 13:30 Hrs during Partly Cloudy Condition Figure 9 shows V-I characteristics and Figure 10 shows V-P characteristics



Fig, 9. V-I Characteristics of Solar Panel

The above IV characteristics were plotted using the current and voltage values. And the MPP was achieved at 1.46 Amps and 19.2 Volts verifying the operation of Perturb and Observe Maximum power point theorem.

Below Figure 10 shows the PV Curve with MPP. The operation and performance of the developed system has been checked and found satisfactory. All the menus and options were checked. The results have been satisfactory and are on expected line.

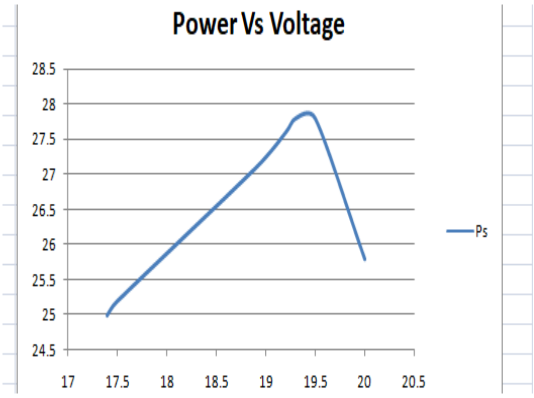


Fig 10. P-V Characteristics of Solar Panel

The above Figure 10 shows the PV characteristics graph. From the above graph it is proven that the system using Perturb and observe algorithm is able to track maximum power point and is able to supply constant power at all times.

VIII. CONCLUSION

The solar energy a renewable energy is now being used and implemented more with trending technologies. The efficient ways of absorbing, generating and utilization of the solar energy is on the rise. The MPPT technique used with P&O algorithm has been successfully designed and implemented in hardware in this paper. The results have been found satisfactorily and the loads demand is met using this by supplying a constant power at all the times. The future work depends on the development of the charge controller for using battery which can be implemented for bigger loads.

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