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Maximum Power Point Tracking along with Perturb and Observe method in Hybrid Micro-Grid

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***Abstract*— This paper presents the optimum utilization of renewable energy sources. In renewable energy sources wind mill and photovoltaic cell plays a key role. Increasing demand of electricity it is very important to develop micro-grids to diversify the generation. Fast tracking of global maximum power point is a challenge, many research is going on this direction. Maximum power point highly depends on atmospheric conditions, so maximum power point tracking (MPPT) technique should be good enough to track maximum power point in dynamic atmospheric conditions. Maximum power point tracking (MPPT) technique is utilized to extract more power from PV cells. This paper discussed about the Perturb and Observe (P&O) MPPT method. Results show the better operating performance of micro-Grid in stability issue and optimum power extraction from the solar cell. The P&O methods can quickly and accurately track the maximum power output of PV cell system. Moreover, an efficient power sharing among the energy sources are successfully demonstrated with more efficiency, a better transient and more stability, even under different load conditions and disturbance. The PV grid can provide a reliable, high quality and more efficient power to consumer.**

Keywords*— *Maximum Power Point, Photovoltaic cell, Micro grid, Perturb and Observe.

I. INTRODUCTION

Normally in PV applications, a number of solar cells or an array of solar panels connected to a load without a MPPT controller will often result in less power extracted as well as wastage of power, which ultimately results in the need to install more panels for the same power requirement. For smaller / cheaper devices that have the battery connected directly to the panel, this will also, result in premature battery failure or capacity loss, due to the lack of a proper end-of-charge procedure and higher voltage. In the short term, not using an MPPT controller will result in a higher installation cost and, in time, the costs will escalate due to eventual equipment failure. Even with a proper charge controller, the prospect of having to pay 30-50% more up front for additional solar panels makes the MPPT controller very attractive. Therefore, most feasible way to increase the efficiency of a solar panel is to use a Maximum Power point Tracker (MPPT), a power electronic device that significantly increases the system efficiency [1-2].

This is “Perturb and Observe with reference voltage based” and implements it by using a DC-DC Converter. We have found various types of DC-DC converter. Among them, we have selected the most suitable converter, which is “Buck” converter, for our design. PV generation systems generally use a DSP controlled charge controller connected between PV and load. A charge controller continuously maintains the charging voltage on the batteries and provides constant voltage. Therefore, a good, solid, and reliable PV charge controller is a key component of any PV battery charging system to achieve systems maximum efficiency [3]. Whereas DSP based designs are able to provide more control that is intelligent and thus increases the efficiency of the system. For extracting maximum power from the photovoltaic solar panels operation, some method needs to be implemented [4].

A novel technique for efficiently extracting maximum power from photovoltaic (PV) panels is presented. The tracking capability has been verified experimentally with a solar panel under a controlled experimental setup [5]. The issues of ensuring global power optimization for cascaded dc-dc converter architectures of photovoltaic (PV) generators irrespective of the irradiance conditions. Validation has been achieved by MATLAB/Simulink numerical simulation in the case of a single-phase grid-connected PV system, where individual MPPTs have been implemented by an extreme-seeking control, a robust and less-knowledge-demanding perturb-and-observe method [6-7]. There are many ways of distinguishing and grouping methods that seek the MPP from a photovoltaic (PV) generator. The indirect methods have the particular feature that the MPP is estimated from the measures of the PV generator's voltage and current PV, the irradiance, or using empiric data, by mathematical expressions of numerical approximations [8-9].

Many maximum power tracking (MPT) techniques have been considered in the past but techniques using microprocessors with appropriate MPT algorithms are favored because of their flexibility and compatibility with different PV arrays [10]. Although the efficiency of these MPT algorithms is usually high, it drops noticeably in cases of rapidly changing atmospheric conditions [11]. The work was carried out by both simulation and experiment, with results showing that the developed incremental conductance algorithm has successfully tracked the MPOP, even in cases of rapidly changing atmospheric conditions, and has higher efficiency than ordinary algorithms in terms of total PV energy transferred to the load [12].

II. DESIGN OF MPPT SOLAR SYSTEM AND ITS HARDWARE

A. System Description

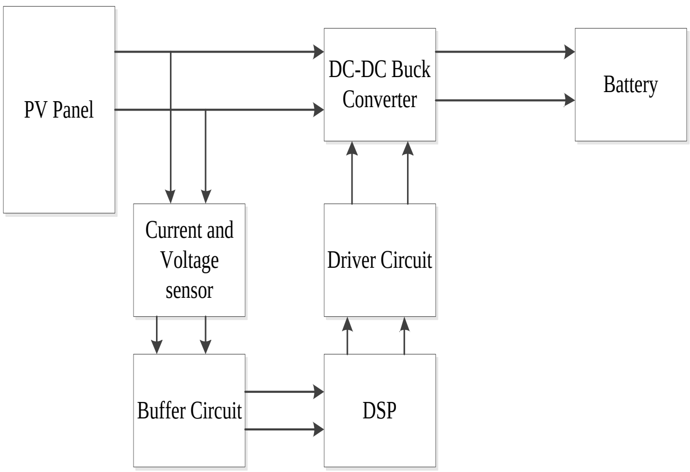

Fig. 1. Block Diagram of MPPT Solar System

A complete system block diagram of MPPT controller as shown Fig. 1. It consists of following major components:

a) Solar panel or PV array
b) DC-DC converter (Buck Converter)
c) Digital Signal Processor (Maximum Power Point Tracker)
d) Buffer Circuit
e) Driver Circuit
f) Auxiliary power supply
g) Voltage and Current Sensor
h) Battery

B. Perturb and Observe method

Among all the papers, much focus has been on hill climbing and perturb and observe (P&O) methods. Hill climbing involves a perturbation in the duty ratio of the power converter, and P&O a perturbation in the operating voltage of the PV array. In the case of a PV array connected to a power converter, perturbing the duty ratio of power converter perturbs the PV array current and consequently perturbs the PV array voltage. Hill climbing and P&O methods are different ways to envision the same fundamental method. From Fig. 2, it can be seen that incrementing (decrementing) the voltage increases (decreases) the power when operating on the left of the MPP and decreases (increases) the power when on the right of the MPP. Therefore, if there is an increase in power, the subsequent perturbation should be kept the same to reach the MPP and if there is a decrease in power, the perturbation should be reversed. This algorithm is summarized in Table I. In [13], it is shown that the algorithm also works when instantaneous (instead of average) PV array voltage and current are used, as long as sampling occurs only once in each switching cycle. The process is repeated periodically until the MPP is reached. The system then oscillates about the MPP. The oscillation can be minimized by reducing the perturbation step size. However, a smaller perturbation size slows down the MPPT. A solution to this conflicting situation is to have a variable perturbation size that gets smaller towards the MPP. In digital signal processor (DSP) control is used to optimize the magnitude of the next perturbation. In a two-stage algorithm is proposed that offers faster tracking in the first stage.

Table 1. Summary of Perturb and Observe Algorithm

Sr. No	Perturbation	Change in Power	Next Perturbation
1	Positive	Positive	Positive
2	Positive	Negative	Negative
3	Negative	Positive	Negative
4	Negative	Negative	Positive

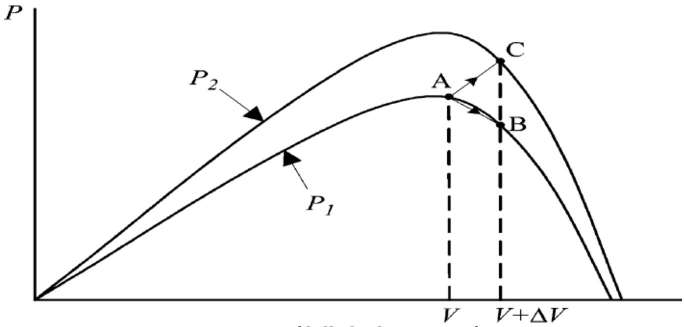

Fig. 2. Divergence of hill climbing/P&O from MPP

Divergence of hill climbing/P&O from MPP as shown in Fig. 2 and finer tracking in the second stage. On the other hand, bypasses the first stage by using a nonlinear equation to estimate an initial operating point close to the MPP. Hill climbing and P&O methods can fail under rapidly changing atmospheric conditions [8] as illustrated in Fig.4.1. Starting from an operating point A, if atmospheric conditions stay approximately constant, a perturbation ΔV in the PV voltage V will bring the operating point to B and the perturbation will be reversed due to a decrease in power.

However, if the irradiance increases and shifts the power curve from P1 to P2within one sampling period, the operating

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point will move from A to C. This represents an increase in power and the perturbation is kept the same. Consequently, the operating point diverges from the MPP and will keep diverging if the irradiance steadily increases. To ensure that the MPP is tracked even under sudden changes in irradiance uses a three-point weight comparison P&O method that compares the actual power point to two preceding ones before a decision is made about the perturbation sign. In the sampling rate is optimized, while in, simply a high sampling rate is used. In toggling has been done between the traditional hill climbing algorithm and a modified adaptive hill climbing mechanism to prevent deviation from the MPP. Two sensors are usually required to measure the PV array voltage and current from which power is computed, but depending on the power converter topology, only a voltage sensor might be needed. In the PV array current from the PV array voltage is estimated, eliminating the need for a current sensor. DSP or microcomputer control is more suitable for hill climbing and P&O even though discrete analog and digital circuitry can be used. In this method the voltage and current of the solar panel is sensed. According to sensed values of current and voltages power is calculated. Once the power is known, the slope of P-V curve or the operating region is carried out and the duty cycle D is changed in the respective direction and will reach at MPP [3].

In voltage source region,

$$\frac{dP}{dV} > 0, \qquad D = D + \Delta D$$

In current source region,

$$\frac{dP}{dV} < 0, \qquad D = D - \Delta D$$

At MPP,

$$\frac{dP}{dV} = 0, \text{ D=D or } \Delta D=0$$

The fig. 3 shows schematic diagram shows how the operating point moves towards the maximum power point (MPP).

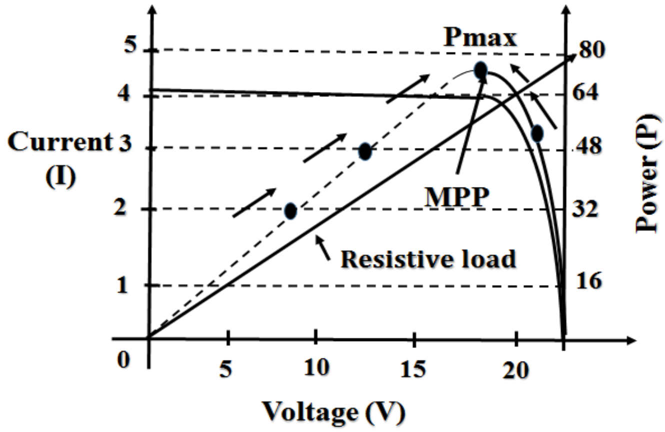

Fig. 3. Schematic of operating point moves towards MPP

If $\frac{dP}{dV}$ is greater than zero, the duty cycle is increases. This means the slope is positive and module is operating at constant current region. When the slope is negative, the duty cycle is decreases. The module will operating in constant voltage region. The MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe. One disadvantage of this algorithm is the increased complexity when compared to P&O.

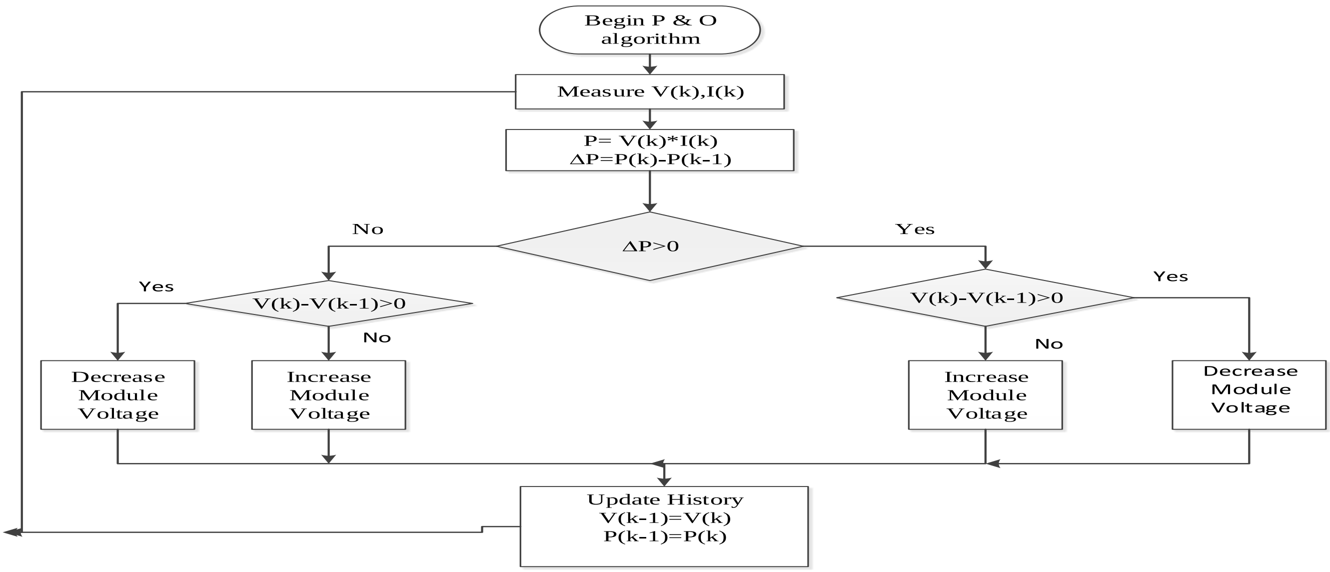

Fig. 4. Perturb and Observe Algorithm

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III. Hardware Implementation

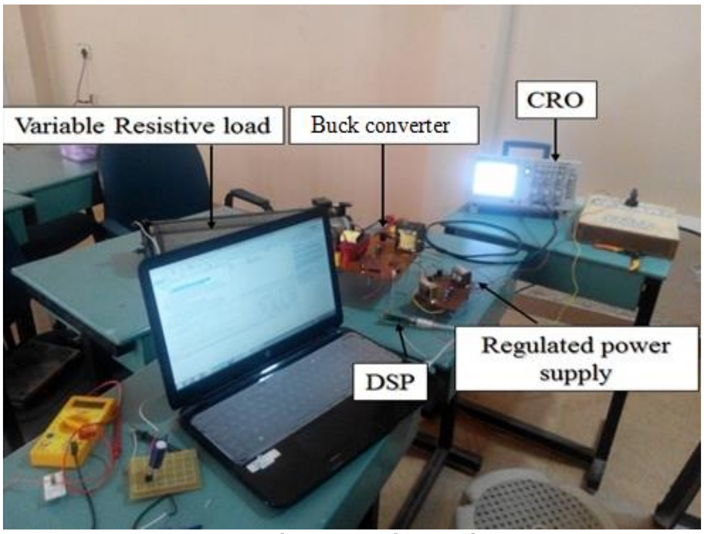

Fig. 5. Experimental set up open loop Buck converter

The PWM pulses are applied on the switch of the buck converter. The generated PWM pulses are shown in Fig. 6.

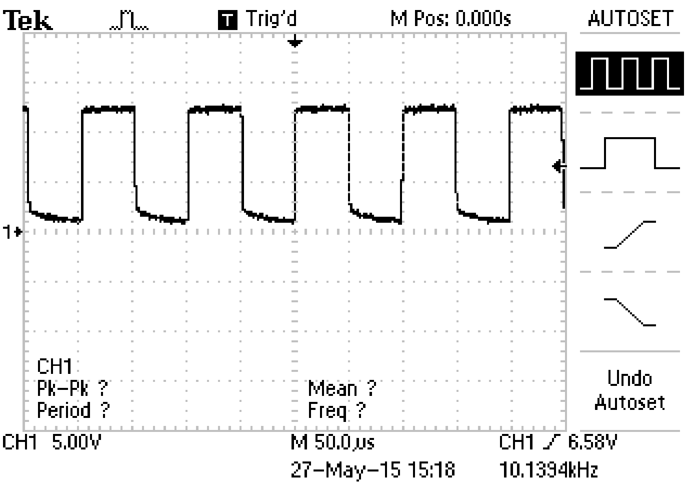

Fig. 6. PWM pulses

Buck converter is tested by applying various load condition and taking 50% duty cycle. Measured parameters are as shown below in the table 2.

Table 2. Measured parameters of buck converter

V_{in}	I_{in}	V_o	R_L	D
13.1	0.30	14.8	10	50%
16.3	0.44	17.8	7	50%
19.0	0.75	19.2	4	50%

The duty cycle is fixed at 50% and input voltage is increased at different levels. The output voltage at different load conditions is calculated and matched with theoretical values. The output voltage waveforms are shown in Fig. 7.

The converter is again tested at various duty cycle and fixed input voltages. By using PWM pulses the duty cycle is adjusted to operate the converter in buck and boost mode. The results of output voltages are given in Table 3.

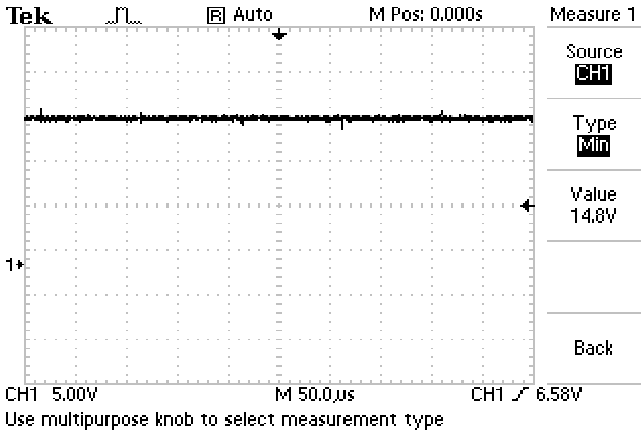

Fig. 7. Waveforms of output voltages (a) with R_L = 10 Ω

Table 3. Measured Values of Output voltages of buck converter at various duty cycles

V_{in}	I_{in}	V_o	R_L	D
18	0.18	16.1	20	40
18	0.31	16.3	20	50
18	0.43	16.8	20	60
18	1.18	16.8	20	65

From Table 3, it is cleared that, the buck converter is operated in buck mode. When duty cycle increases from 40 % to 65%, the output voltage is lower than the input voltage. This shows that the converter is operated in buck mode.

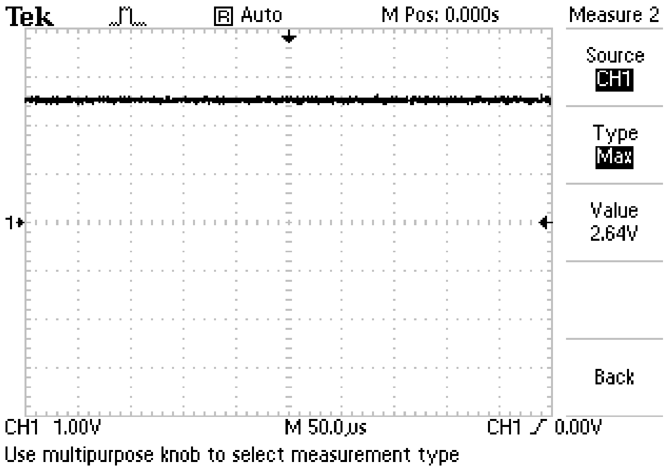

Fig. **8.** Waveforms of sensed current from PV panel

A. MPPT solar system hardware results

Readings of MPPT by P&O algorithm was taken as shown below from Table 4 to 8. Readings are taken with MPPT and without MPPT.

Table 4. MPPT in solar system on Date: 11/07/2019

Sr. No	Time in Hrs	Case1(Without MPPT)			Case2(With MPPT)		
		V(V)	I(A)	P(W)	V(V)	I(A)	P(W)
1	9:00 PM	17.00	0.80	13.60	16.80	0.90	15.12
2	10:00 PM	15.60	1.00	15.60	16.63	1.20	19.96
3	11:00 PM	17.10	1.10	18.81	16.30	1.40	22.82
4	12:00 PM	17.43	1.30	22.66	16.80	1.50	25.2
5	1:00 PM	17.14	1.20	20.57	16.70	1.40	23.38
6	2:00 PM	16.85	1.10	18.54	16.80	1.25	21.00
7	3:00 PM	15.40	0.90	13.86	16.60	1.00	16.60
8	4:00 PM	14.60	0.80	11.68	16.64	0.85	14.144

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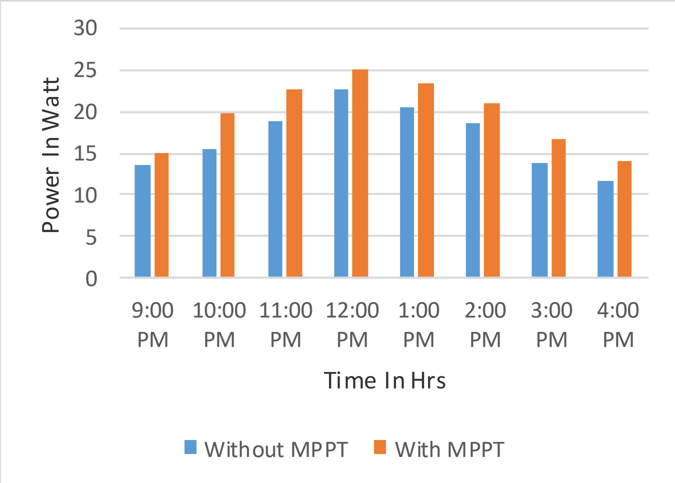

Fig. 9. Graphical representation of MPPT in solar system on Date: 11/07/201

Table 5. MPPT in solar system on Date: 12/07/2019

Sr. No	Time in Hrs	Case1(Without MPPT)			Case2(With MPPT)		
		V(V)	I(A)	P(W)	V(V)	I(A)	P(W)
1	9:00 PM	16.00	0.60	9.60	16.60	0.70	11.62
2	10:00 PM	15.60	1.00	15.60	16.65	1.10	18.315
3	11:00 PM	17.10	1.20	20.52	16.70	1.30	21.71
4	12:00 PM	17.00	1.30	22.10	16.80	1.50	25.20
5	1:00 PM	14.50	0.70	9.45	16.60	0.60	9.96
6	2:00 PM	16.80	1.20	20.16	16.80	1.25	21.00
7	3:00 PM	15.75	0.94	14.00	16.60	0.90	14.94
8	4:00 PM	15.50	0.90	13.95	16.64	0.85	14.14

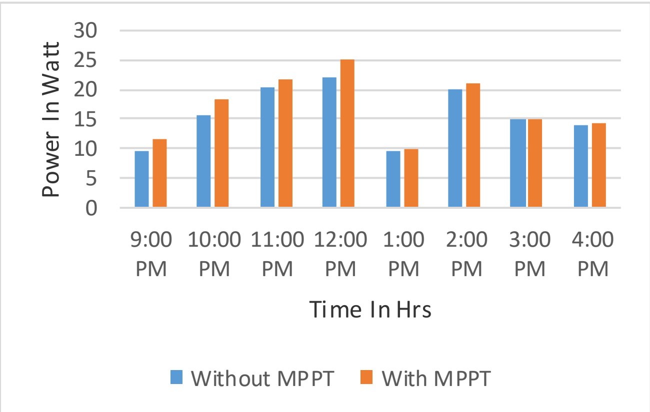

Fig. 10. Graphical representation of MPPT in solar system on Date: 12/07/2019

Table 6. MPPT in solar system on Date: 13/07/2019

Sr. No	Time in Hrs	Case1(Without MPPT)			Case2(With MPPT)		
		V(V)	I(A)	P(W)	V(V)	I(A)	P(W)
1	9:00 PM	16.00	0.30	4.80	16.00	0.30	4.80
2	10:00 PM	16.30	0.70	11.41	16.50	0.72	11.88
3	11:00 PM	16.40	0.51	8.36	16.30	0.59	9.62
4	12:00 PM	17.00	0.50	8.50	16.50	0.60	9.90
5	1:00 PM	17.14	0.80	13.71	16.70	1.00	16.70
6	2:00 PM	16.90	0.70	11.83	16.80	0.90	15.12
7	3:00 PM	16.40	0.90	14.76	16.60	1.00	16.60
8	4:00 PM	16.00	0.70	11.20	16.64	0.70	11.65

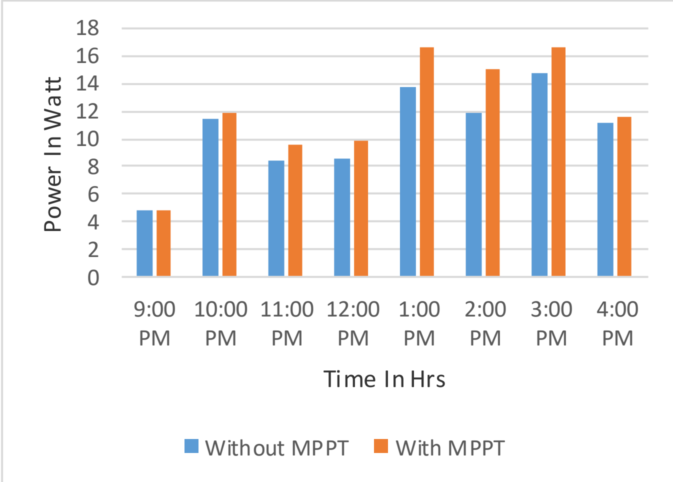

Fig. 9. Graphical representation of MPPT in solar system on Date: 13/07/2019

Table 7. MPPT in solar system on Date: 14/07/2019

Sr. No	Time in Hrs	Case1(Without MPPT)			Case2(With MPPT)		
		V(V)	I(A)	P(W)	V(V)	I(A)	P(W)
1	9:00 PM	16.80	0.80	13.44	16.80	0.90	15.12
2	10:00 PM	16.70	1.00	16.70	16.60	1.20	19.92
3	11:00 PM	17.10	1.10	18.81	16.70	1.30	21.71
4	12:00 PM	17.50	1.20	21.00	16.80	1.40	23.52
5	1:00 PM	17.40	1.12	19.49	16.70	1.20	20.04
6	2:00 PM	17.50	1.20	21.00	16.80	1.30	21.84
7	3:00 PM	17.00	1.10	18.70	16.80	1.20	20.16
8	4:00 PM	16.80	1.05	17.64	16.80	18.48	18.48

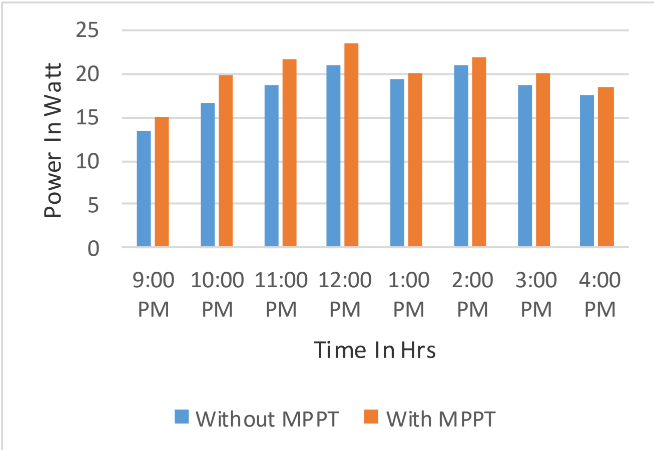

Fig.11. Graphical representation of MPPT in solar system on Date: 14/07/2019

Table 8. MPPT in solar system on Date: 15/07/2019

Sr. No	Time in Hrs	Case1(Without MPPT)			Case2(With MPPT)		
		V(V)	I(A)	P(W)	V(V)	I(A)	P(W)
1	9:00 PM	15.80	0.40	6.32	16.00	0.50	8.00
2	10:00 PM	16.00	0.20	3.20	16.63	0.30	4.99
3	11:00 PM	16.20	0.50	8.10	16.30	0.70	11.41
4	12:00 PM	16.30	1.20	19.56	16.60	1.30	21.58
5	1:00 PM	16.00	0.90	14.40	16.70	1.10	18.37
6	2:00 PM	16.60	1.30	21.58	16.80	1.40	23.52
7	3:00 PM	15.90	0.90	14.31	16.50	1.00	16.50
8	4:00 PM	14.50	0.70	10.15	16.64	0.70	11.65

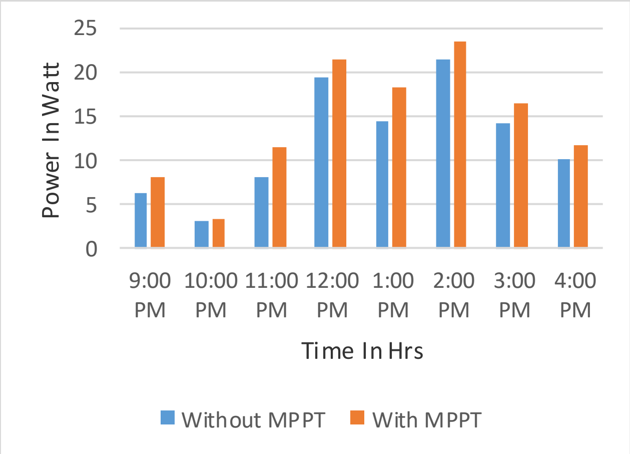

Fig. 9. Graphical representation of MPPT in solar system on Date: 15/07/2019

IV. CONCLUSION

Renewable energy source also called non-conventional type of energy are continuously replenished by natural processes. This system is the right solution for clean energy production. It shows that voltage and power can be well controlled in the system under a changing environment. This grid-connected system can fully utilize the characteristics of the proposed MPPT by P&O method PV panels to extract the maximum power from the solar energy sources. The P&O methods can quickly and accurately track the maximum power output of PV cell system. Moreover, an efficient power sharing among the energy sources are successfully demonstrated with more efficiency, a better transient and more stability, even under different load conditions and disturbance. The efficiency of the total system depends on the diminution of conversion losses and the increase for an extra DC link. The PV grid can provide a reliable, high quality and more efficient power to consumer.

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