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PV Panel Based Micro Inverter Using Boost Control Topology with PWM and MPPT (Perturb and Observe) Method

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Abstract - Over the past years, the energy demand has been steadily growing and so methods of how to cope with this staggering increase are being researched and utilized. One method of injecting more energy to the grid is renewable energy, which has become in recent years an integral part of any country's power generation plan. Thus, it is a necessity to enhance renewable energy resources and maximize their grid utilization, so that these resources can step up and reduce the over dependency of global energy production on depleting energy resources.

This paper focuses on solar power and effective means to enhance its efficiency using different controllers. In this regard, substantial research efforts have been done. However, due to the current market and technological development, more options are made available that can boast the efficiency and utilization of renewables in the power mix.

In this paper, an enhanced maximum power point tracking (MPPT) controller has been designed as part of a Photovoltaic (PV) system to generate maximum power to satisfy load demand. The PV system is designed and simulated using MATLAB (consisting of a solar panel array, MPPT controller, boost converter, and a resistive load). New electrical codes require rapid solar system shutdown so first responders or firefighters are safe from high voltage when they need to be on rooftops or servicing power lines. Microinverters comply with these rapid shutdown requirements and have this capability embedded into each module. Each controller will be tested under two different scenarios; the first is when the panel array is subjected to constant amount of solar irradiance along with a constant atmospheric temperature and the second scenario has varying solar irradiance and atmospheric temperature. The performance of these controllers is analyzed and compared in terms of the output power efficiency, system dynamic response and finally the oscillations behavior.

Microinverters and the add-on optimizers have the ability to track the production of each individual panel, while with a standard inverter you only can track the production of the whole system. If you were to expand your system in the future, microinverters are simple to add one at a time. Each panel and microinverter pair can be easily added to your existing solar array without needing to worry about purchasing, siting, and installing additional string inverters.

Keywords: *Maximum Power Point Tracking, Perturb and Observe, DC-DC Converters, Photovoltaic System.*

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1. Introduction

In today's modern life solar panels and microinverters play a pivotal role. They are user friendly as well as environmentally friendly. They can be installed from a single house to number of cities. Photovoltaic system can be either stand-alone or connected to utility grid. The disadvantage of this PV generation depends on atmospheric conditions such as solar irradiance and temperature. Maximum power point trackers (MPPTs) play an important role in photovoltaic (PV) power systems because it is maximizing the output power of a PV system for a given atmospheric conditions. MPPT is maintaining operating point at the maximum power point using a different MPPT algorithm. MPPT can minimize the overall photovoltaic (PV) system cost. To maximize the output of a PV system, continuously tracking the maximum power point (MPP) is necessary.

This paper is organized as follows: First, it will discuss about our main circuit its configuration and working. Second portion will discuss about control scheme and how it will control our output voltage. In the third portion we shall discuss graphs at different irradiance and loads. And at the end conclusion and future work.

2. Principle

According to the theory of maximum power transfer, the power delivered from source to the load is maximum when the source internal impedance matches with the load impedance.

$$Z_S=Z_L$$

So, the impedance from the converter side needs to match the internal impedance of the solar array [2]. At that time the operating point is at the Maximum power point (MPP) so maximum power is obtained from the photovoltaic array.

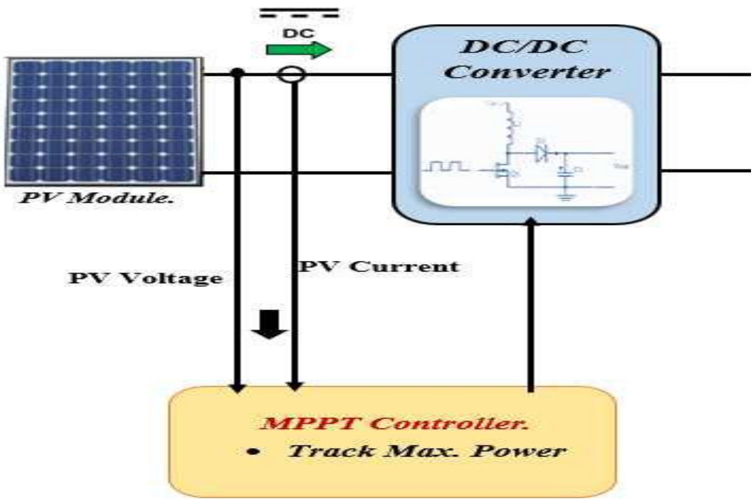

Fig. 1. Block diagram of Solar system using MPPT

3. Perturb and Observe (P&O)

The P&O algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle [12]. In this algorithm a slight perturbation is introduced to the system. This perturbation causes the power of the solar module varies. If the power increases due to the perturbation, then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses.

When the stable condition is arrived, the algorithm oscillates around the peak power point. In order to maintain the power variation small, the perturbation size is remained very small. The technique is advanced in such a style that it sets a reference voltage of the module corresponding to the peak voltage of the module.

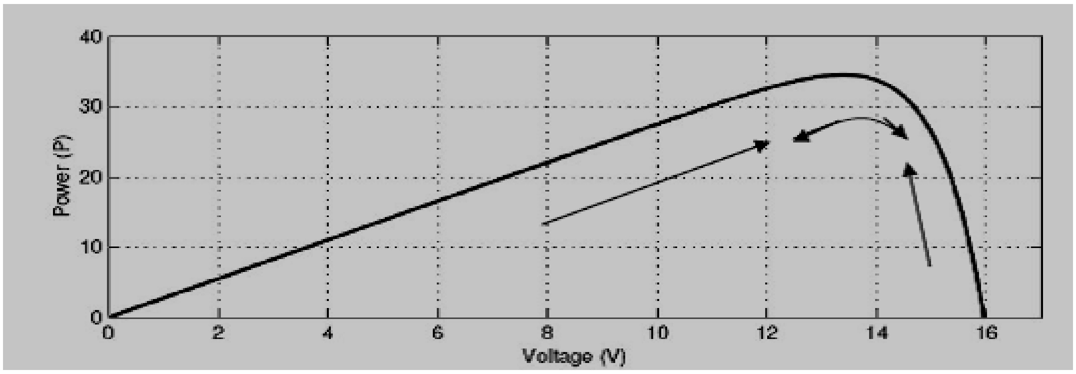

Fig. 2. Graph Power versus Voltage for Perturb and Observe Algorithm

4. Control Scheme:

As previously mentioned, this is one of the simplest methods to implement and only requires a voltage and current sensor to calculate the power and compare it to the previous cycle power. First, power is calculated using voltage and current and then compared to the previous value of the power. If the difference is equal to zero, then the same voltage will be returned, and the algorithm will try to oscillate around the same MPPT. If there is a change in power, the algorithm will then go forward and check the difference in voltage levels. In the case of a positive power difference, the algorithm will notice and direct the voltage to the same direction (increase or decrease) as the previous case. Hence, if the voltage difference is positive then the algorithm will keep increasing the voltage and vice versa. However, in the case of negative power difference, the algorithm will do the complete opposite and will direct the voltage to the other direction. This means that if the voltage change is negative then the algorithm will increase the voltage and finally if the change in voltage is positive the algorithm will decrease the voltage. Thus, the four cases that the algorithm is required to evaluate and react to are as follows:

1. $\Delta P > 0$ and $\Delta V > 0$ Increase the voltage.
2. $\Delta P > 0$ and $\Delta V < 0$ Decrease the voltage.
3. $\Delta P < 0$ and $\Delta V > 0$ Decrease the voltage.
4. $\Delta P < 0$ and $\Delta V < 0$ Increase the voltage.

The algorithm can manipulate the operating voltage freely by varying the duty cycle ratio. Any change in the duty cycle will consequently have an inverse effect on the input resistance of the DC/DC converter and thus will alter the operating voltage to satisfy the four cases mentioned above [5]. Table 1 illustrates the relationship between the duty cycle, input resistance, output power, and the voltage in the next cycle as shown below.

Table 1. Effect of Duty Cycle on Input Resistance, Output Power, and the Next Cycle's Voltage

Change in Duty Cycle	Change in Input Resistance	Effect on Output Power	Next Cycle's Voltage Change
Increase	Decrease	Increase	Decrease
Increase	Decrease	Decrease	Increase
Decrease	Increase	Increase	Increase
Decrease	Increase	Decrease	Decrease

As shown in Table 1, any change in the duty cycle will have an inverse effect on the input resistance of the converter and hence have an inverse effect on the operating voltage. The algorithm then observes the effect of that change in the duty cycle on the output power to calculate the right command in the next cycle. The output power can increase or decrease depending on whether the current operating voltage level is before or after the knee point in the power graph as shown in Figure 2. If the operating level is beyond the knee point or the MPP, then an increase in the voltage will decrease the output power and vice versa. For example, in the third case in Table 1, a decrease in the duty cycle causes an increase in input resistance or operating voltage and results in an increase in the output power. This means that the current operating level is before the MPP and by increasing the voltage the output power will increase and thus in the next duty cycle the algorithm will opt to increase the voltage which can be achieved by reducing the duty cycle.

5. System Architecture

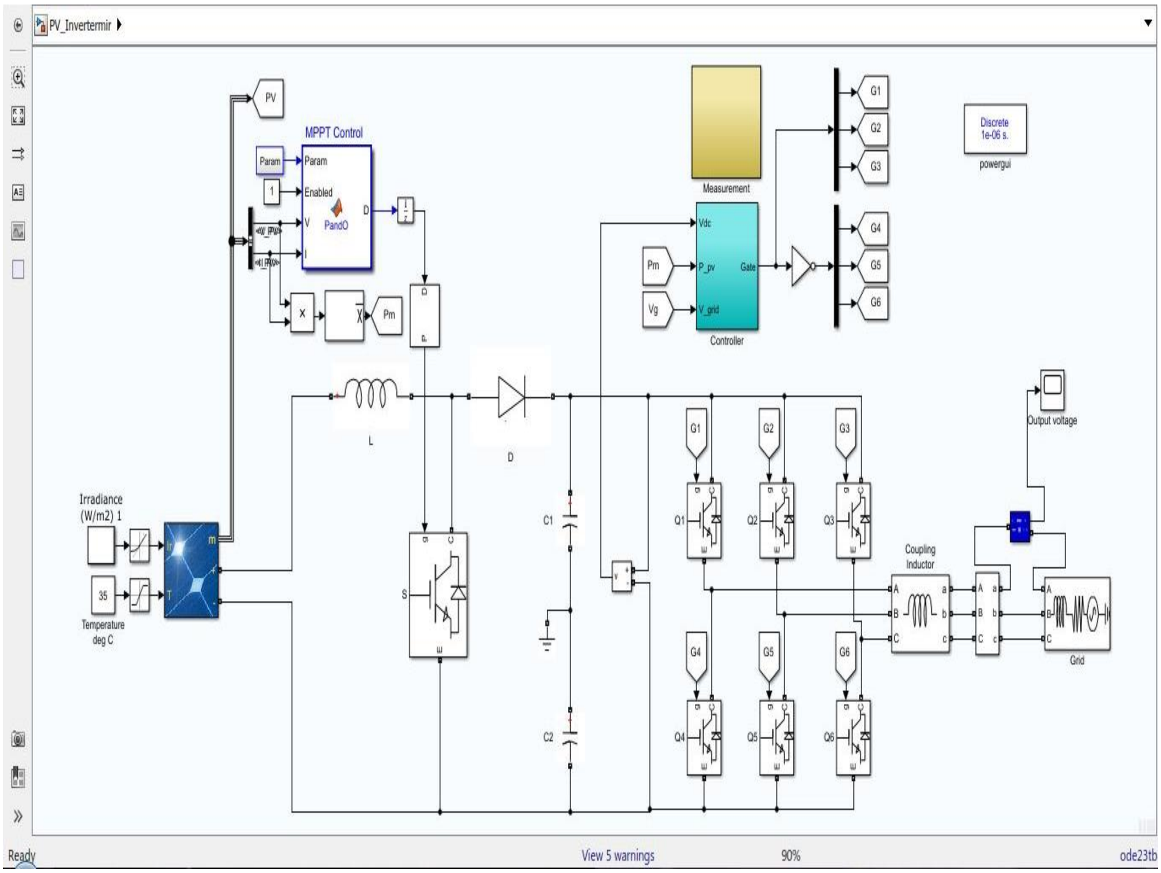

Fig. 3. Complete MATLAB circuit of MPPT P&O algorithm with 3-phase AC output

The modules in a PV system can be wired in series or in parallel depending on the output or power required. Wiring them in series increases the voltage while wiring them in parallel increases the current. The power, voltage, and current values are utilized to calculate the number of modules to be connected in series in a string and how many parallel strings are needed to reach the targeted output power. Therefore, the design has to have six modules connected in series in a string and 57 parallel strings to reach the required output power, which is 150 kW.

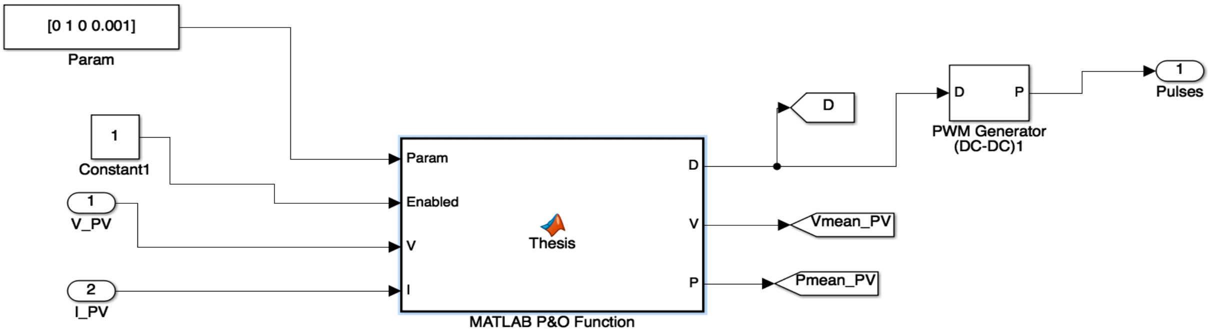

Fig. 4. Simulink/MATLAB P&O Function

In the first scenario, the solar panel will be subjected to a constant solar irradiance of 1000 W per square meter and will have a constant internal temperature of 25 ℃ as shown in Figure 5. This allows for a simple and reliable comparison of the algorithms' performance in terms of accuracy and speed to get the desired power output, which is 150 kW.

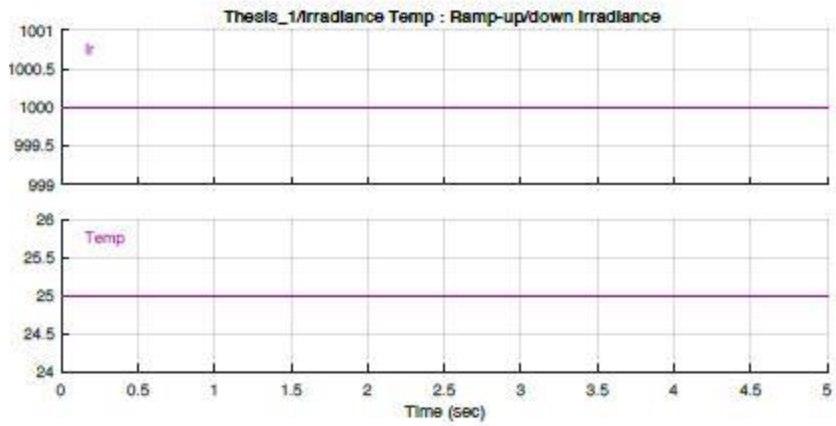

Fig. 5. Constant Irradiance and Temperature Signals

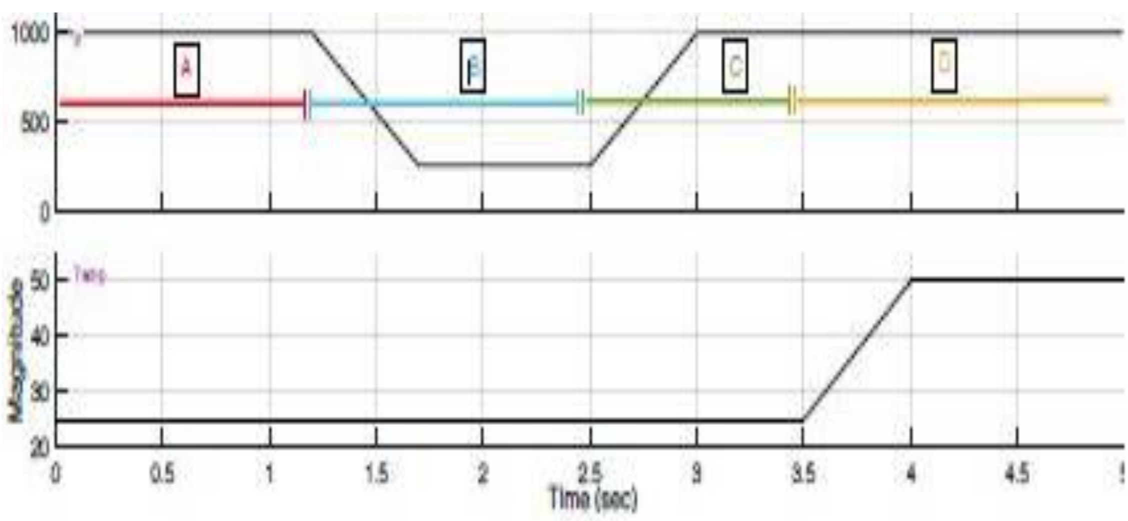

Fig. 6. Varying Irradiance and Temperature Signals

Table 2. Comparison Between the Four Periods in the Design

Period	Color Code	Irradiance Value (W/m^2)	Temperature Value (℃)	Time range (Sec)
A	Red	1000	25	0 – 1.2
B	Blue	250 ≤ IV < 1000	25	1.2 – 2.5
C	Green	250 < IV ≤ 1000	25	2.5 – 3.5
D	Yellow	1000	50	3.5 – 5

Scenario One: Constant Irradiance and Temperature

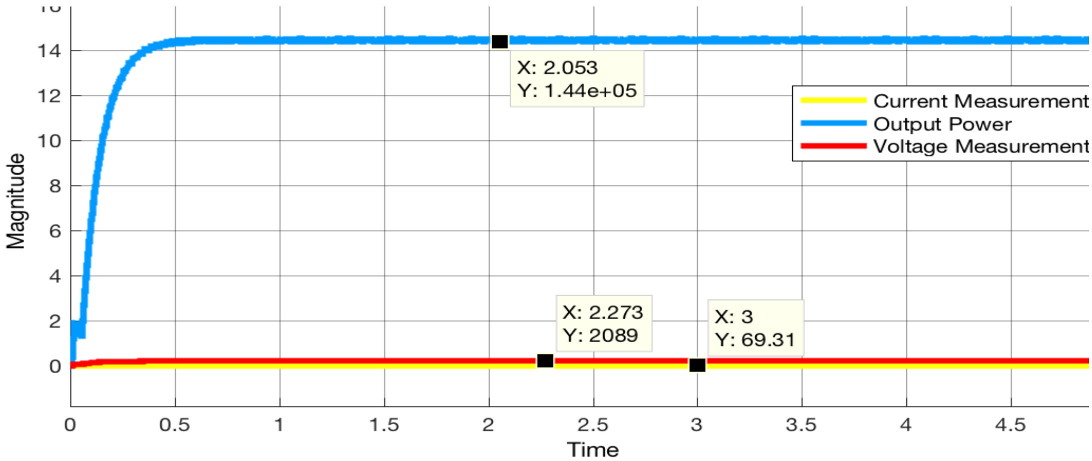

Fig. 7. Output Power Under Constant Conditions Using P&O MPPT

Using the P&O algorithm yields a fast response as expected where the rise time is about 0.197 seconds or approximately 0.2 seconds and the settling time is about 0.26seconds. The output power starts from zero and reaches a maximum value of 145,500W at time of 4.15 seconds.

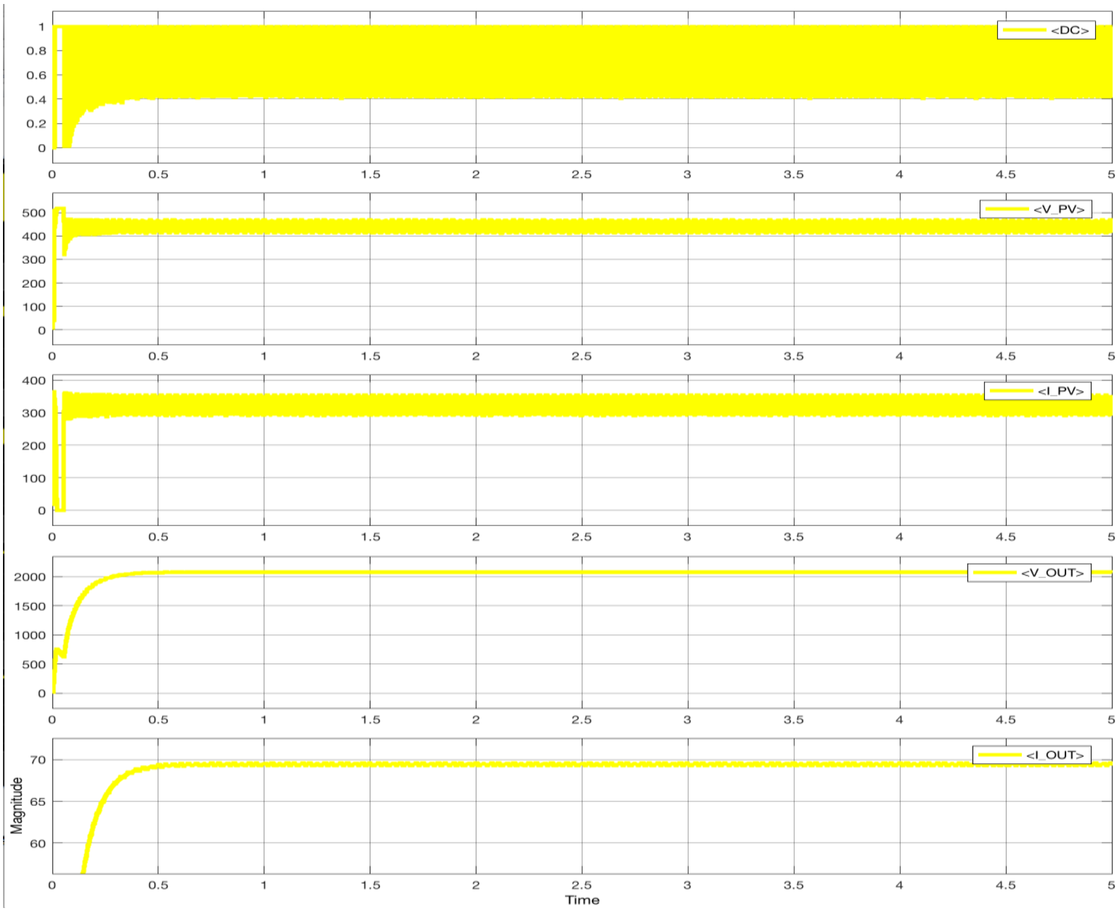

Fig. 8. P&O DC, Voltage and Current Diagrams Under Constant Conditions

Scenario Two: Varying Irradiance and Temperature

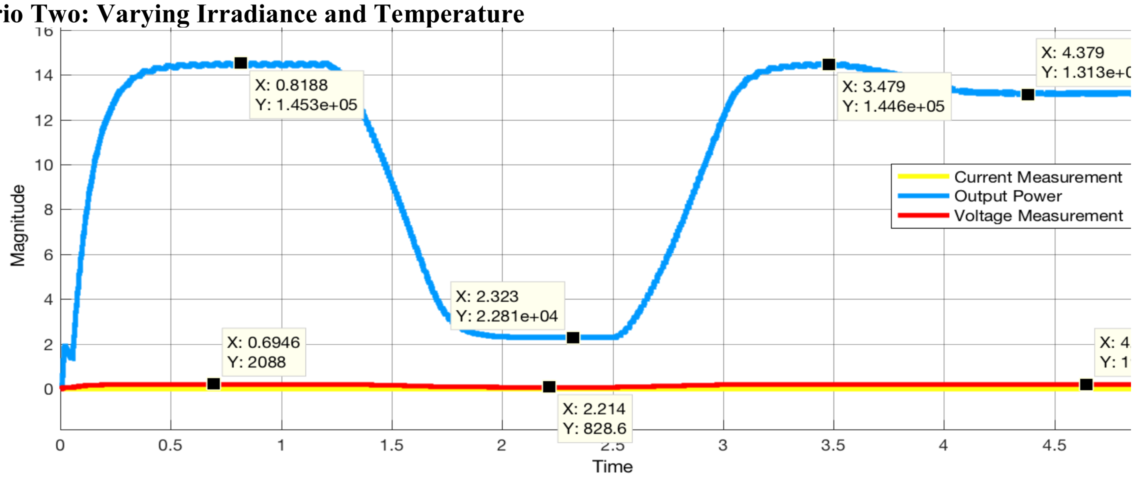

Fig. 9. Output Power Under Varying Conditions Using P&O MPPT

In fig. 9, period A has an irradiance of 1000 W per square meter and module temperature of 25 °C and has the output power curve increasing from zero to 144,700W of power. It drops down to about 22,990 W in period B when the irradiance is dropped to 250 W per square meter and the temperature is kept constant. In part C, the irradiance is increased again to 1000 W per square meter and thus the power output is close to that in part A which is 144,400 W. Part C is done in preparation for part D, where the irradiance is kept constant at 1000 W per square meter and the temperature is increased from 25 to 50 °C. This results in a power output drop from 144,400 W to 131,600W.

Table 3. P&O Efficiency Percentages of each Period

Period	Irradiance Value (W/m^2)	Temperature Value (℃)	Actual Output Power (W)	Theoretical Output Power (W)	Efficiency Percentage %
A	1000	25	144,700	150,600	96.08
B	250	25	22,900	36,460	62.81
C	1000	25	144,400	150,600	95.88
D	1000	50	131,600	135,300	97.27

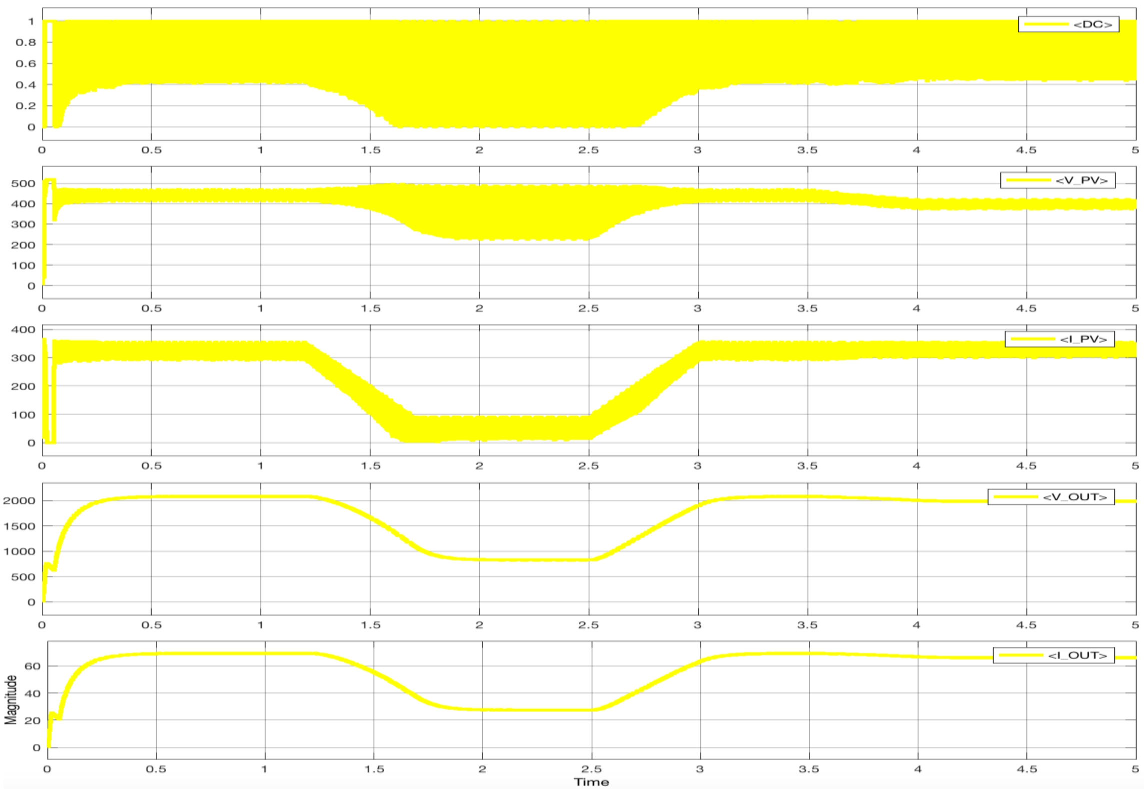

Fig. 10. P&O DC, Voltage and Current Diagrams Under Varying Conditions

The last part of this scenario (and section) is Fig. 10. This figure shows the duty cycle values, PV output voltage and current, and the system output voltage and current. Like the first scenario, the PV output voltage and current oscillate heavily until they pass through the boost converter, which allows for a boost in voltage, a drop in current, and removing the oscillations from both curves. Moreover, an observation in the PV voltage and current curves is that while a decrease in irradiance affects both these variables as shown in period B, the PV current is affected more.

The current drops from an average of 320 Amperes to an average of 80 Amperes, while the voltage only drops from an average of 450 Volts to about 350Volts. On the other hand, an increase in the temperature affects the PV voltage where it drops from 450 Volts to about 400 Volts; however, the temperature spike from 25 ℃ to 50 ℃ has an insignificant effect on the current that does not manifest on the curve. Finally, the voltage and current of the output system seem to react in a similar manner where they are both affected similarly during the drop in irradiance and rise in temperature. The output voltage starts at 2100 Volts in period A, drops to about 850 Volts in period B, goes back up to 2100 Volts in period C and finally reduces a bit more to 2000 Volts in period D. Likewise, the output current starts at 70 Amperes, drops to 28 Amperes, back to 68 Amperes, and finally reduces to about 66 Amperes.

6. Conclusion:

The core advantage of using microinverters is that theoretically, you can yield more solar electricity. The reason for this is that there are slight differences in currents between solar panels. When solar panels are in a string, the current is reduced to that of the least-producing panel in the string. P&O MPPT method is implemented with MATLAB-SIMULINK for simulation. The MPPT method simulated in this paper can improve the dynamic and steady state performance of the PV system simultaneously. Through simulation it is observed that the system completes the maximum power point tracking successfully despite of fluctuations. When the external environment changes suddenly the system can track the maximum power point quickly. Both buck and buck-boost converters have succeeded to track the MPP but, buck converter is much more effective especially in suppressing the oscillations produced due the use of P&O technique.

References

[1] A. e. a. Khamis, ""A review of islanding detection techniques for renewable distributed generation systems."," *Renewable and sustainable energy reviews,* pp. 483-493., 2013.

[2] S. K. Z. a. B. M.-I. Abapour, ""Evaluation of technical risks in distribution network along with distributed generation based on active management."," *IET Generation, Transmission & Distribution8.,* pp. 609-618., 4 (2013).

[3] "http://www.eere.energy.gov/RE/bio_resources.html," [Online].

[4] a. P. W. Quan Li, "A Review of the Single Phase Photovoltaic Module Integrated Converter Topologies with Three Different DC Link Configurations," *IEEE Transactions on Power Electronics,,* Vols. Vol. 23, , no. No. 3, pp.1320-1333., (2008) .

[5] e. a. s. b. kjaer, ""a review of single-phase grid-connected inverters for photovoltaic modules"," *ieee transactions on industrial application,* Vols. Vol. 41,, no. no. 5, , p. pp.1292–1306, sep. 2005.

[6] M. M. S.Sallem, "Energy management algorithm for an optimum," *control of a photovoltaic water pumping system, applied energy, , ,* vol. 86, pp. 2671- 2680, 2009.

[7] A. Betka and A. Moussi, "Performance Optimization of a Photovoltaic Induction Motor Pumping System,," *Renewable Energy,,* Vols. 29, pp. 2167-2181, 2004.

[8] A. M. A. B. N. T. A. Terki, "An improved efficiency of fuzzy logic control of PMBLDC for PV pumping system,," *Applied Mathematical Modeling,* Vols. 36, no.3, , pp. 934-944, 2012.

[9] A. M. A. B. N. T. A. Terki, "An improved efficiency of fuzzy logic control of PMBLDC for PV pumping system,," *Applied Mathematical Modeling, ,* Vols. 36, no.3, pp. 934-944, 2012.

[10] L. K. P. S. S. Sumathi, "Solar PV and Wind Energy Conversion Systems," 2015.

[11] E. O. A. B. a. A. L. V. Salas, "Review of the Maximum Power Point Tracking Algorithms for Stand-Alone

Photovoltaic Systems," *Solar Energy Materials & Solar Cells,* Vols. 90, pp. 1555 -1578, , 2006..

[12] R. D. Lalouni S, "Approch for maximum power point tracker of standalone PV system using fuzzy controller, in Proc.," *IREC 2011, Tunis, 20-22, ,* pp. I-6, 2011, .

[13] S. K. P. DEBASHIS DAS, "MODELING AND SIMULATION OF PV ARRAY WITH BOOST CONVERTER: AN OPEN LOOP STUDY," *NATIONAL INSTITUTE OF TECHNOLOGY,* pp. 15-25, 2011.