American International University- Bangladesh
Department of Electrical and Electronic Engineering
EEE: Renewable Energy Technology Laboratory

Title: Simulation of Maximum Power Point Tracking (MPPT) for Photovoltaic System.

Abstract:

In this experiment students will learn constant voltage based algorithm for Maximum Power Point Tracking (MPPT) for solar energy system. Students will simulate this MPPT algorithm in MATLAB Simulink. A buck-boost convert will be used as maximum power point tracker to achieve the system specifications.

Introduction:

When a load is connected to a PV array, how much power can be delivered to the load can be figure out from the I-V curve of the PV array. The maximum power point (MPP) is the spot near the knee of the I-V curve, and the voltage and current at the MPP are designated as Vm and Im. For a particular load, the maximum point is changing as the I-V curve is varying with the temperature, insolation, and shading. Because solar power is relatively expensive, it is important to operate panels at their maximum power conditions. In fact, DC-DC converters are often used to "match" the load resistance to the Thevenin equivalent resistance of the panel to maximize the power drawn from the panel. These "smart" converters are often referred to as "tracking converters". However, there are several well established MPPT algorithm such as constant voltage based algorithm, incremental conductance, perturb and observe etc.

Theory and Methodology:

Constant Voltage Based Algorithm:

This lab requires students to use a buck boost converter with the given operating conditions and incorporate a MPP algorithm to get the most from the available power from the PV panel. Fig. 1 shows an example of the insolation characteristics of a PV panel. The MPP is achieved by calculating the measured voltage and current of the PV panel. An accurate MPPT is a real time computing device that calculated the current power and stores this data to compare the next calculated power to determine the operating points until it reaches the MPP.

For example, suppose at the measurement period the insolation is 0.5 kW/m^2 as shown in fig. 1. At present, the operating point of MPPT is at 12V and 1A, i.e. the blue dot. The MPPT then calculates the current power, which is equal to 12V × 1A = 12 W. It compares to the previous point which is the orange dot and the power equals 8V × 0.5A = 4W. Therefore, the blue dot has higher power than the orange dot. The MPPT should move to the right. The process continues until it reaches the MPP, i.e. the black dot, and stay at this point unless the insolation again.

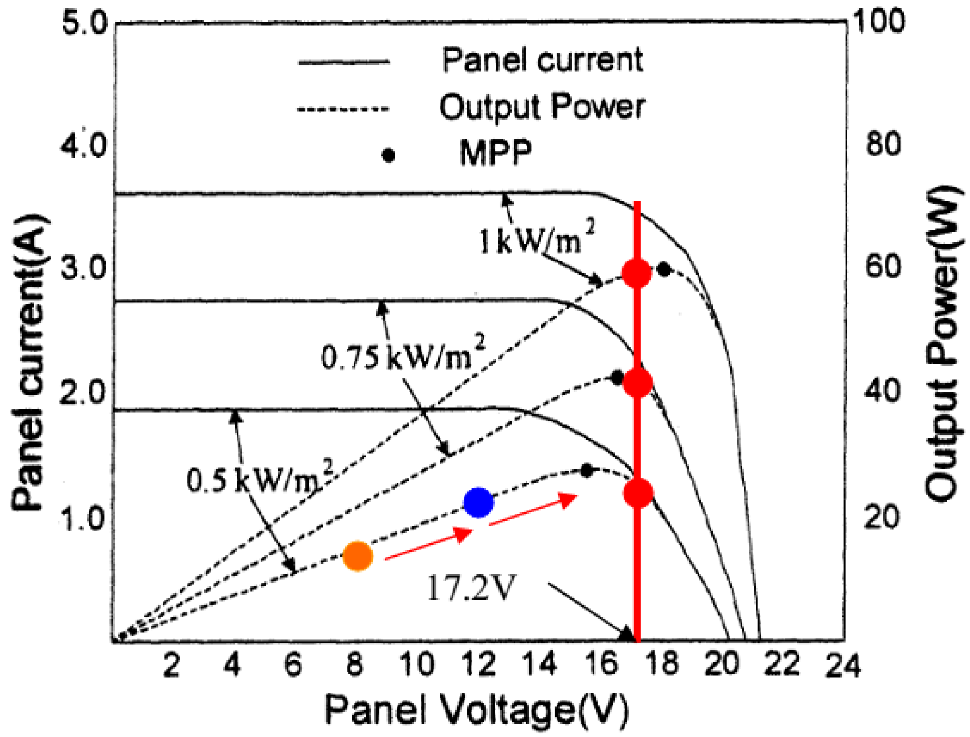


Fig. 1: Insolation Characteristics of a PV panel

To implement an accurate MPPT requires many components and often a micro-controller is used for collecting data, calculation and decision making. A simple constant voltage based MPPT algorithm is shown in fig. 2. Instead of measuring both current and voltage, only PV panel voltage is measured in this simple MPPT algorithm. The measured voltage V_{PV} is compared with a fixed reference voltage V_{ref} in a microcontroller. A PWM generator then compares this amplified error signal to a saw tooth waveform to generate the duty cycle for the buck boost converter. This process will continue until V_{PV} equals V_{ref}.

Let consider fig. 1 as an example again. When the PV panel voltage is lower than the voltage of the MPP and trying to reach it, the duty cycle for the buck boost converter needs to decrease. On the other hand, when panel voltage is higher than the voltage of the MPP and trying to reach it, the duty cycle needs to increase. When the panel voltage reaches the MPP of 17.2V (marked by the red line in fig. 1) for example, the MPPT will work along the red line and power points (red dots) are close to MPP.

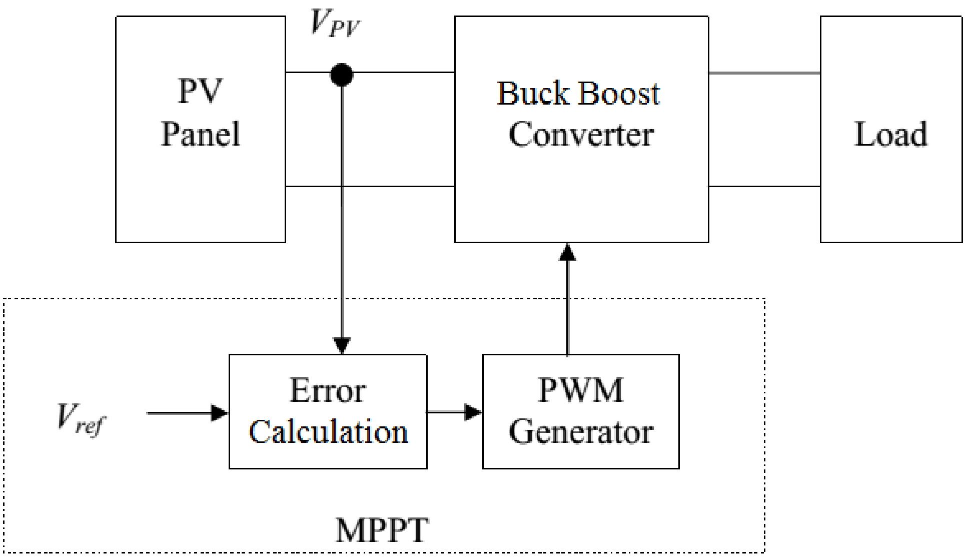


Fig. 2: MPPT using constant reference voltage based algorithm

Pre-Lab Homework:

Students should read the theory before coming to lab.

Apparatus:

Computer installed with MATLAB 2016 or higher with Simulink Simscape tool.

Block Diagram and Algorithm:

Fig. 3 represents the block diagram of the PV system with MPPT algorithm.

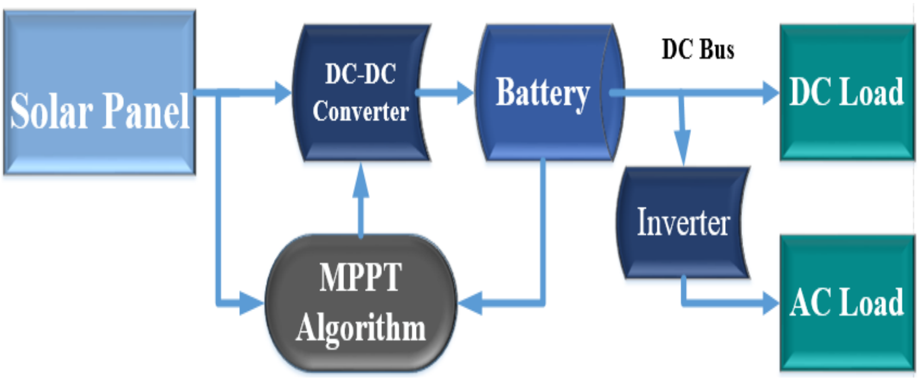


Fig. 3: Block diagram of the PV system with MPPT

The constant voltage based algorithm as discussed in theory section can be represented using flow chart as shown in fig. 4.

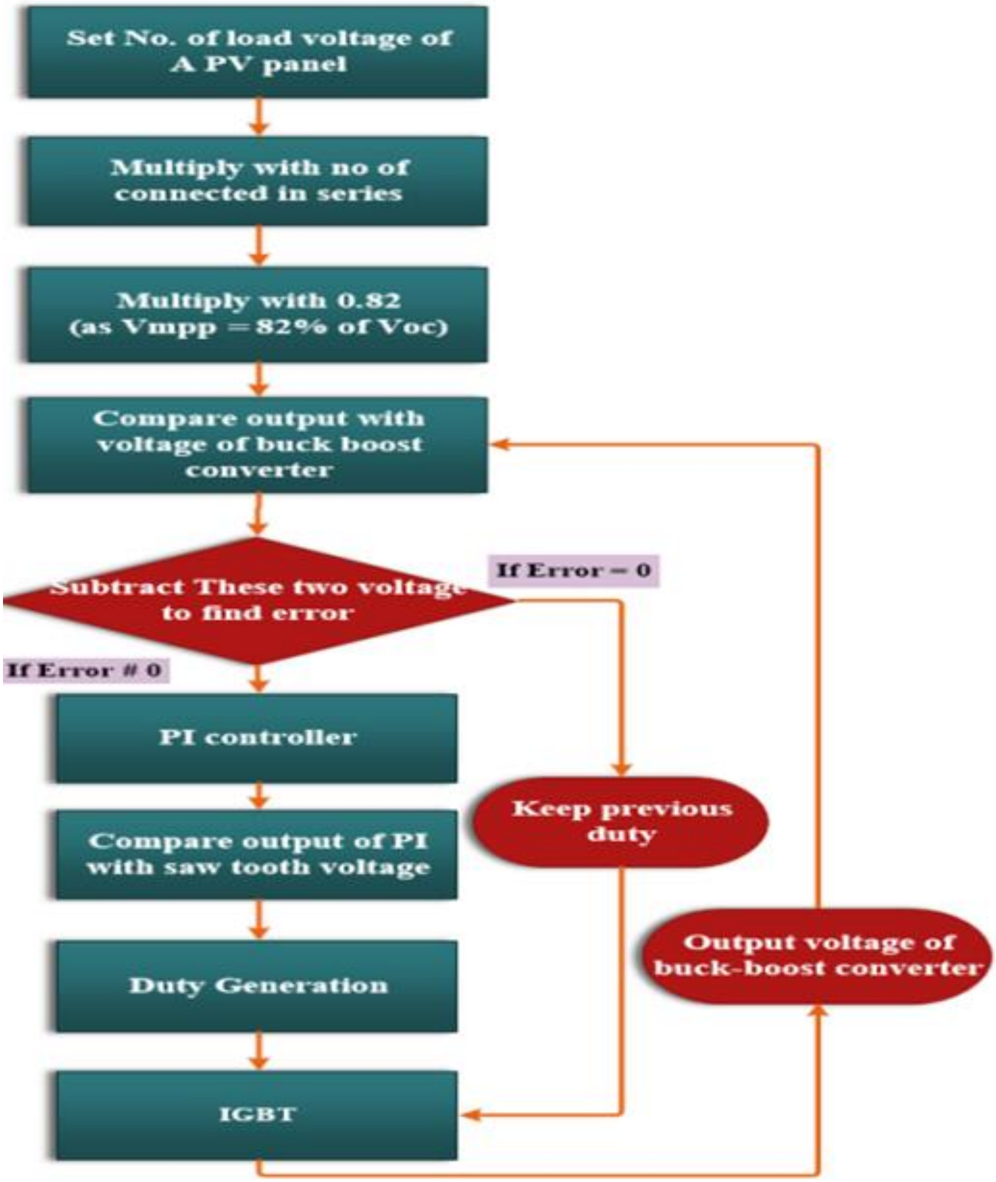


Fig. 4: Constant Voltage Based algorithm

Simulation:

For the simulation purpose, use one parallel string and two series connected modules per string. Each module has the following data and I-V and P-V characteristics curve as shown in fig. 5.

Table. 1: Module Data

Maximum Power (W)	213.15 W
Cells per module	60
Open circuit voltage, V_{OC}	36.3 V
Short-circuit current, I_{SC}	7.84 A
Voltage at maximum power point, V_{mp}	29 V
Current at maximum power point, I_{mp}	7.35 A

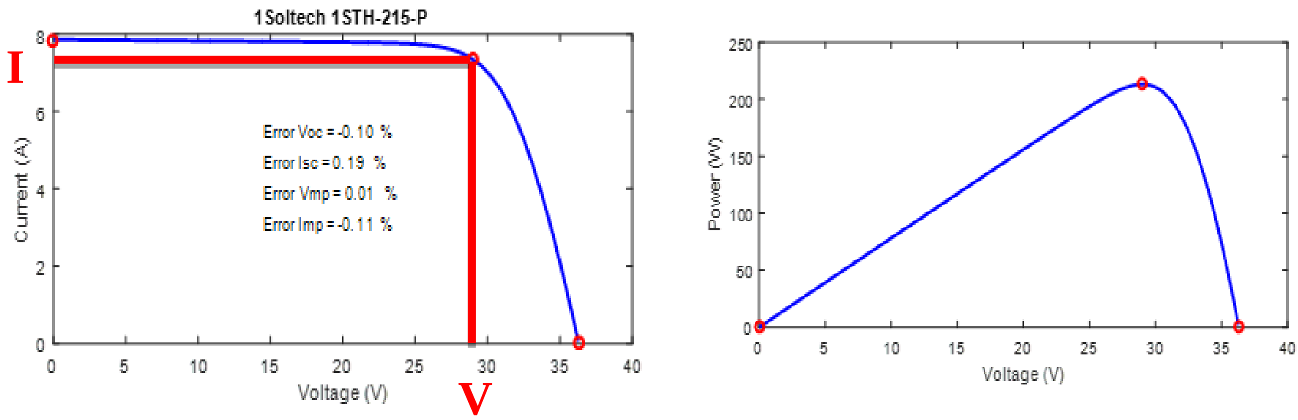


Fig. 5: I-V and P-V characteristics curve of the PV array

- From fig. 5, V_{mpp} = 28 Volt, I_{sc} =7.6 A
- As we have used two PV panels in series,
- V_{oc_array} = (28 + 28) = 56 Volt , I_{sc_array} =7.6A
- P_{MPP_arry} = (56 X 15.2) = 425.6 W

If the proposed algorithm works, then you should have achieved around 425.6 W at the output (for any value of connected load) at rated solar irradiance (1000 W/m^2) and temperature (25^{0}C)

At first, simulate the PV array without MPPT algorithm and find out the power delivered to the load.

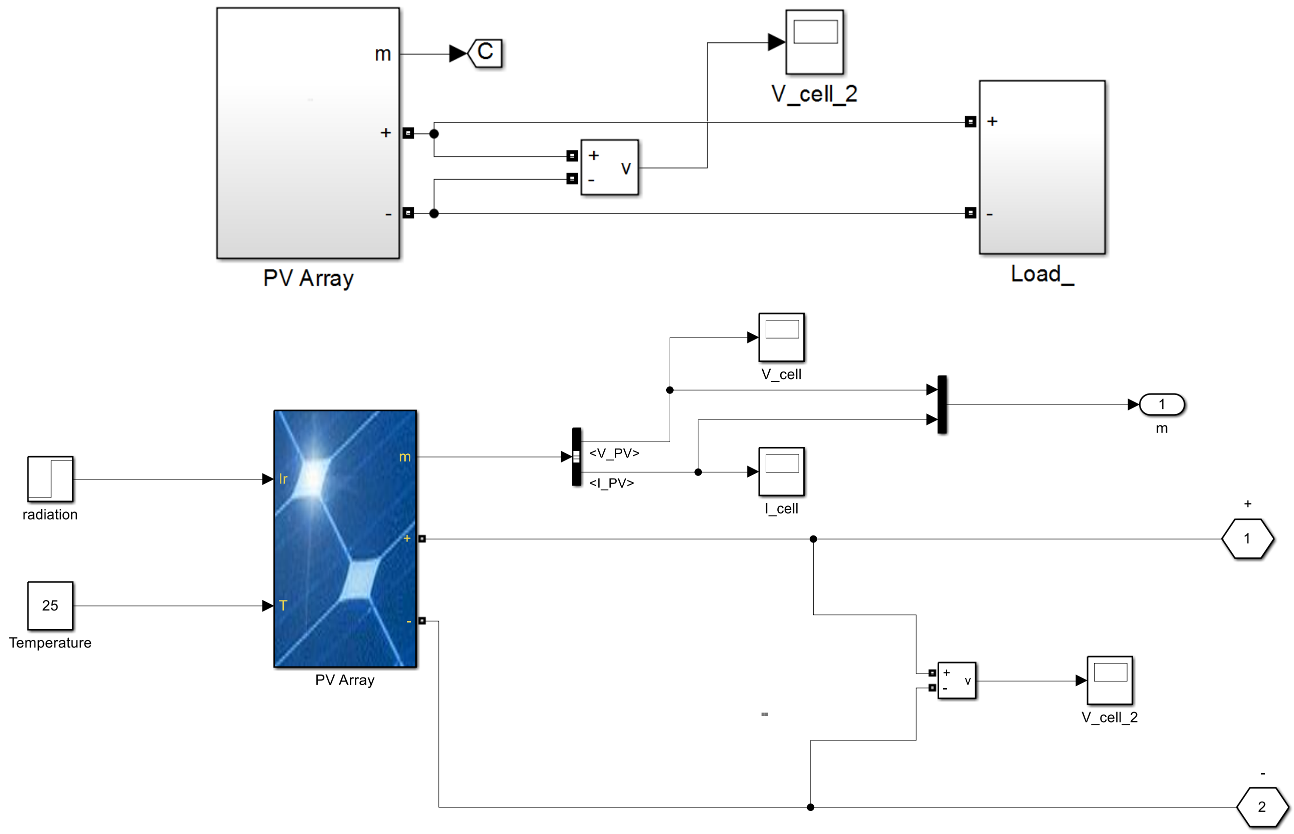


Fig. 6: MATLAB Simulink Circuit for PV array without MPPT
[Solar Irradiance 1000 W/m^2, 25 ºC Temp and 60Ω resistive load]

But the power delivered to the load is only 84.4 W as shown in fig. 7 which is far below than the calculated maximum power (425.6 W).

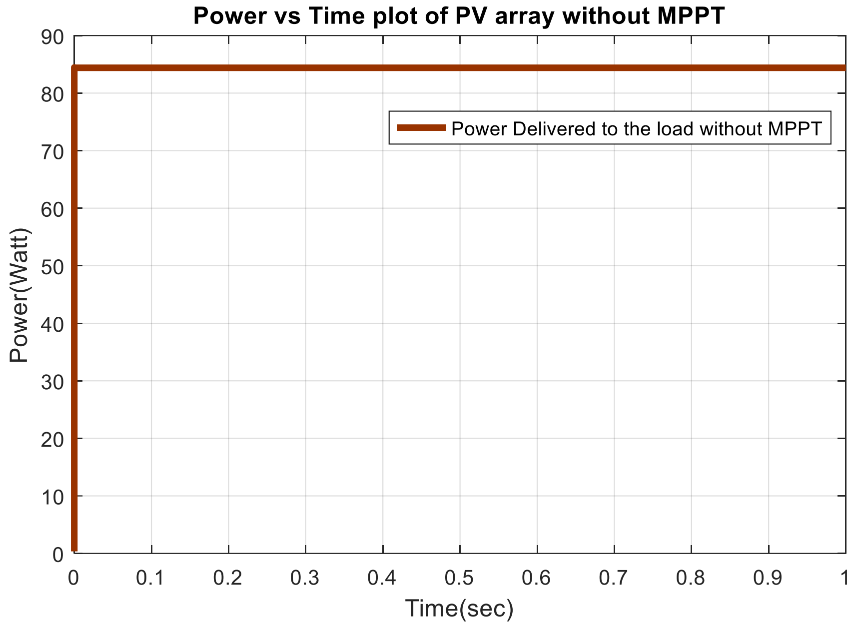


Fig. 7: Power delivered to the load from the PV array without using MPPT

Now simulate the same PV array with constant voltage based MPPT algorithm which is shown in fig. 8. The simulated MPPT algorithm and Buck Boost Converter circuit is also shown in fig. 9 and 10 respectively.

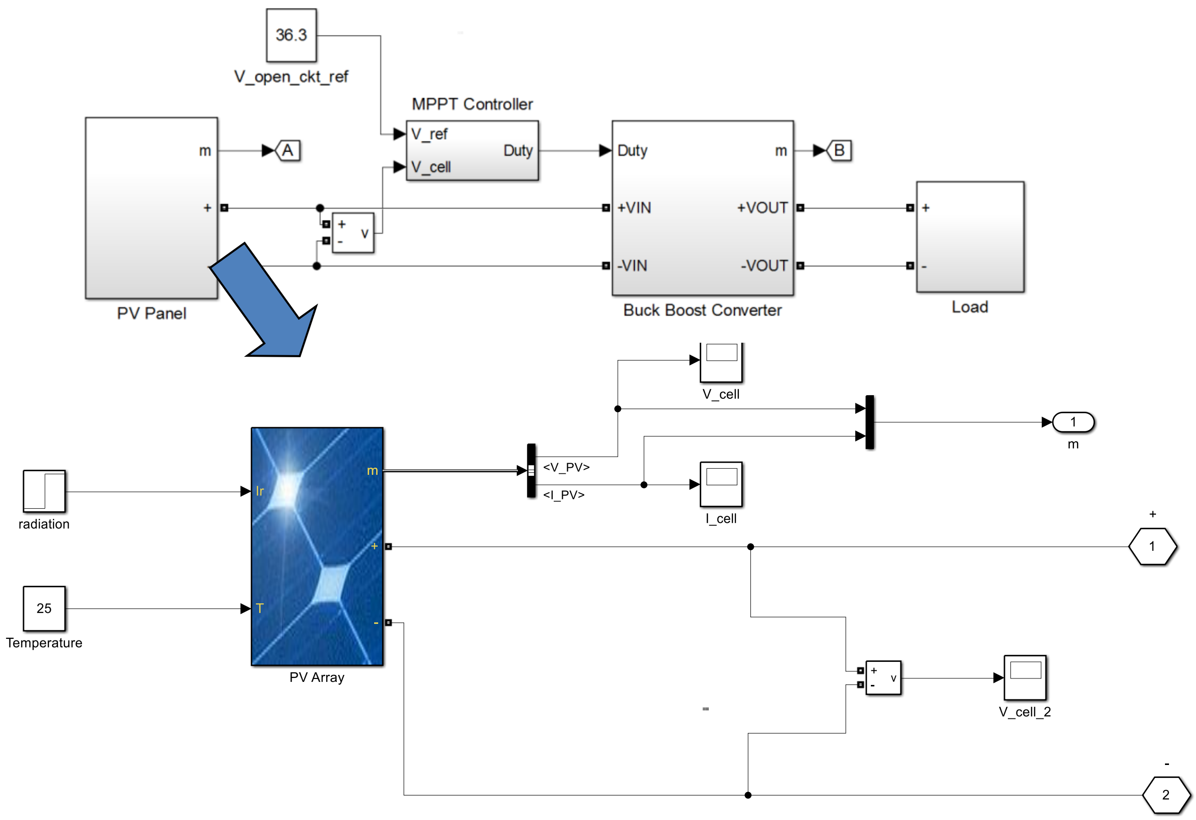


Fig. 8: MATLAB Simulink Circuit for PV array with Constant Voltage based MPPT [Solar Irradiance 1000 W/m^2, 25 ^{o}C Temp and 60Ω resistive load]

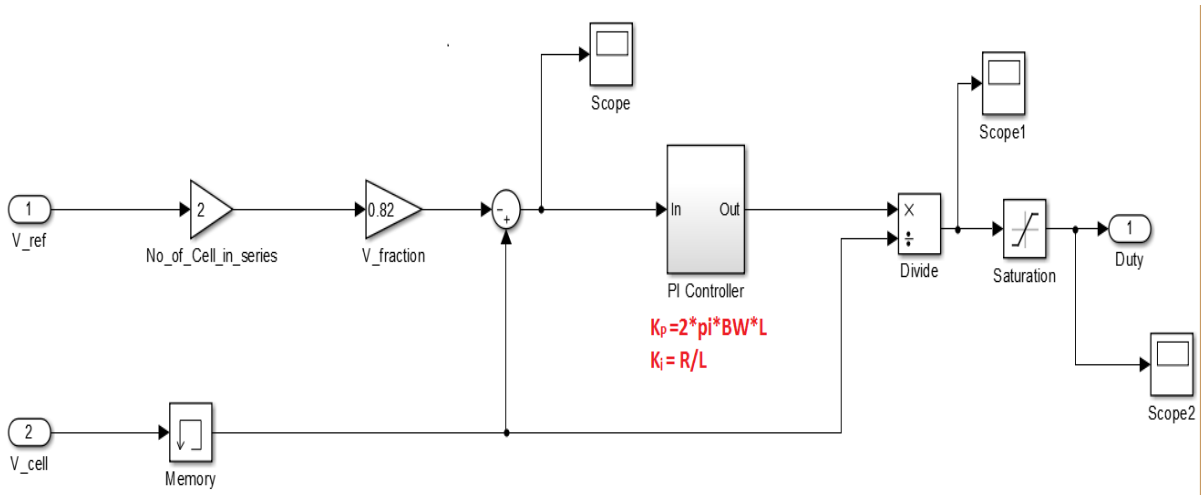


Fig. 9: Constant Voltage based MPPT algorithm

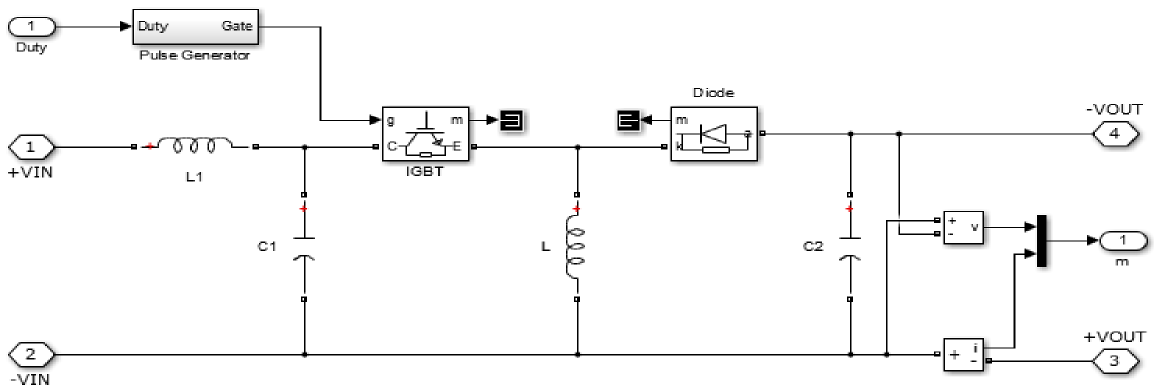


Fig. 10: Buck Boost Converter

From the simulation result it can be find out that, the output power delivered to the load is approximately 400W which is close to the calculated maximum output power (425.6W). Fig. 11 represents the output power delivered to the load using MPPT algorithm.

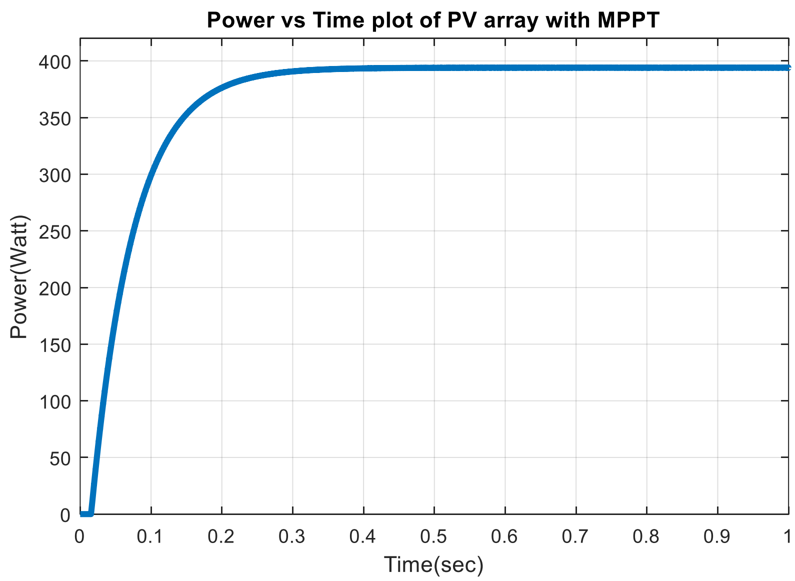
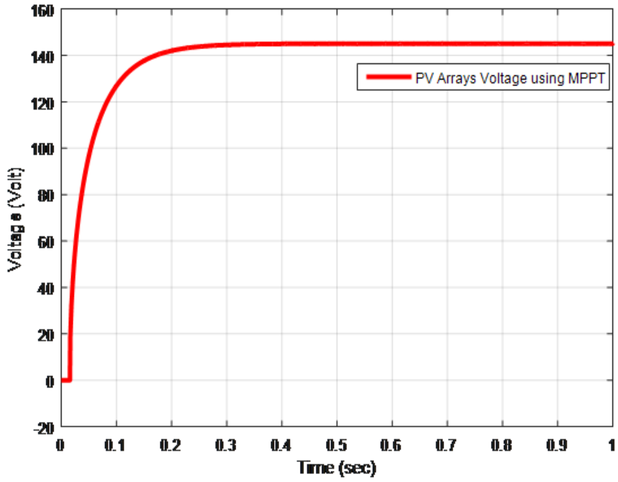
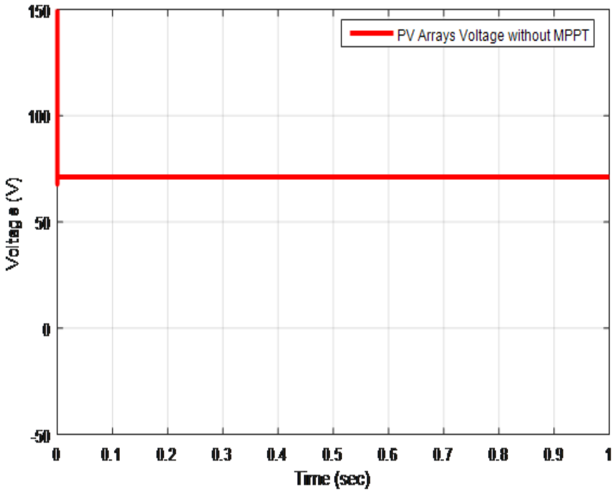


Fig. 11: Power delivered to the load from the PV array with MPPT algorithm

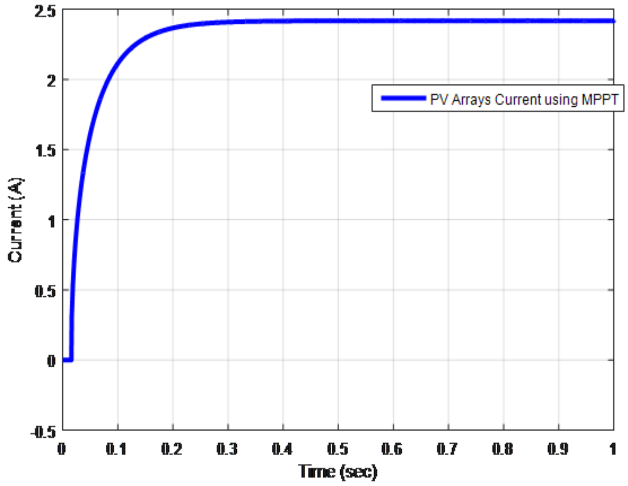
For better understanding, the voltage, current and power of PV array with and without MPPT algorithm can be plotted side by side.

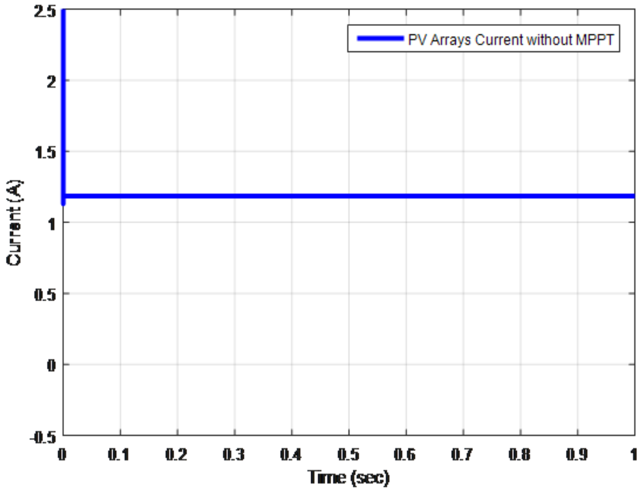




(a) (b)

Fig. 12: PV Arrays output voltage (a) using MPPT (b) without MPPT (Solar Irradiance 1000 W/m^2 and Temp. 25^{0}C, Load = 60Ω)





(a) (b)

Fig. 13: PV Arrays output current (a) using MPPT (b) without MPPT (Solar Irradiance 1000 W/m^2 and Temp. 25^{0}C, Load = 60Ω)

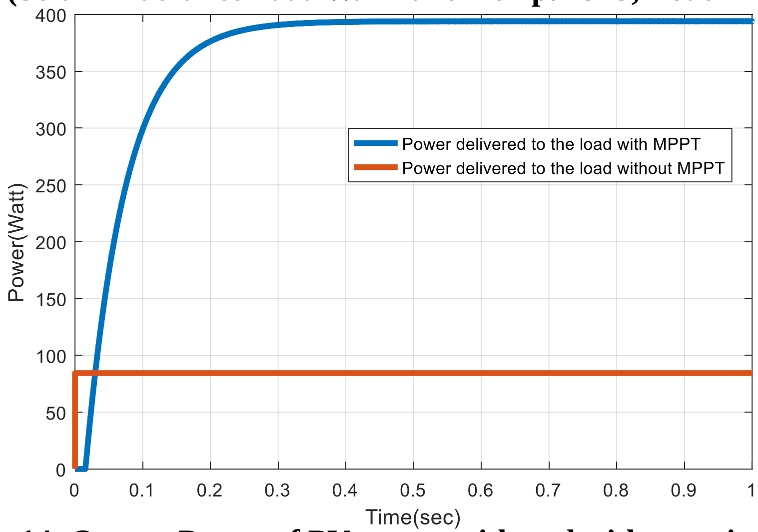


Fig. 14: Output Power of PV arrays with and without using MPPT (Solar Irradiance 1000 W/m^2 and Temp. 25^{0}C, Load = 60Ω)

Questions for report writing:

1. To understand the effect of solar irradiance, change the solar irradiance from 1000 W/m^2 to 1350 W/m^2 and in same axis plot the power delivered to the load for both cases. Explain your result.
2. To understand the effect of temperature, change the temperature from 25^oC to 45^oC and plot the power delivered to the load, voltage and current for both cases. Explain your result.
3. For the simulated PV array, the calculated maximum power is 425.6 W and the obtained output power from simulation is 400 W. Why there is a small deviation of output power?
4. Simulate the perturb & observe or incremental conductance algorithm for the same PV array.

Discussion:

Discuss your simulation (perturb & observe or incremental conductance) and compare your result with constant voltage based algorithm.

Reference(s):

[1] Gilbert M. Masters, "Renewable and Efficient Electric Power System," Wiley, 2004
[2] Kalogirou, Soteris A. Solar energy engineering: processes and systems. Academic Press, 2009.