

# Design, Coding and Simulation of MPPT on DC-DC Buck and DC-DC Boost Converters

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**Abstract:** *Solar PV Arrays have come out as a very easily implementable mode of renewable energy generation. But the major drawback with Solar PV Array is their efficiency and reliability. There are various ways to improve the efficiency of a PV Array. A very optimal solution to improve the efficiency and reliability is by implementing Maximum Power Point Tracing (MPPT) techniques to the Solar PV Array system. There are numerous techniques available to implement MPPT such as Perturb and Observe (P&O) and Incremental Conductance (IC). In this paper, we will design, implement and analyse Perturb and Observe technique to DC-DC Buck and DC-DC Boost Converter and study its effects at different levels of irradiance and compare the results with the maximum power that a particular PV system can produce. The simulations are done using MATLAB/Simulink and code for MPPT is written using MATLAB.*

**Keywords:** PV Array, MPPT, Perturb and Observe, Solar Energy, MATLAB/Simulink.

## I. INTRODUCTION

There are a huge number of ways to produce or generate renewable energy, but one of the most widely used ways is generating electricity through solar PV arrays. This energy can be stored in batteries for later use. But, solar PV arrays have some major drawbacks, namely, their efficiency and reliability. The quantity that influences these parameters is temperature and solar irradiation. The power produced by any PV module depends on the strength of the sunlight that the PV module receives i.e. irradiance and also the temperature of the surroundings of the PV module.

One of the most effective solutions to negate the drawbacks of using solar PV arrays is implementing MPPT (Maximum Power Point Tracing). There are a number of techniques available to implement MPPT. Two of the most used MPPTs are Incremental Conductance (IC) and Perturb and Observe (P&O) algorithm. In the following discussions we will be designing and implementing P&O technique, so as to control the duty cycle of the DC-DC converters to operate at maximum power point. Then, this power can be stored to battery. The result obtained by this technique is optimum.

The objective of this project is to use the Perturb and Observe MPPT algorithm to get the most optimum outputs from a particular Solar Power Generating and Battery Charging Module with DC-DC Buck and DC-DC Boost Converter. MPPT is implemented in MATLAB/Simulink. With the analysis that we will do, we will get to know about the best DC-DC Converter that can be used with P & O MPPT algorithm.

## II. METHADODOGY

Initially, we study the maximum possible output power delivered by a PV module of a 100KW rating at different irradiance levels. The specifications of the solar PV module are shown in Table 1.

**Table 1:** PV Module Specifications

S. No.	Parameter	Value
1	Parallel strings	47
2	Series-connected modules per string	10
3	Series-connected modules per string	60
4	Short-circuit current $I_{sc}$	7.84A
5	Open circuit voltage $V_{oc}$	36.3V
6	Voltage at maximum power point $V_{mp}$	29V
7	Current at maximum power point $I_{mp}$	7.35A

8	Temperature coefficient of Voc	-0.36099%/deg.C
9	Temperature coefficient of Isc	0.102%/deg.C

Fig. 1 shows the maximum powers at irradiance levels of  $1\text{KW}/\text{m}^2$ ,  $500\text{W}/\text{m}^2$  and  $100\text{W}/\text{m}^2$  at a temperature of  $25^\circ\text{C}$ .

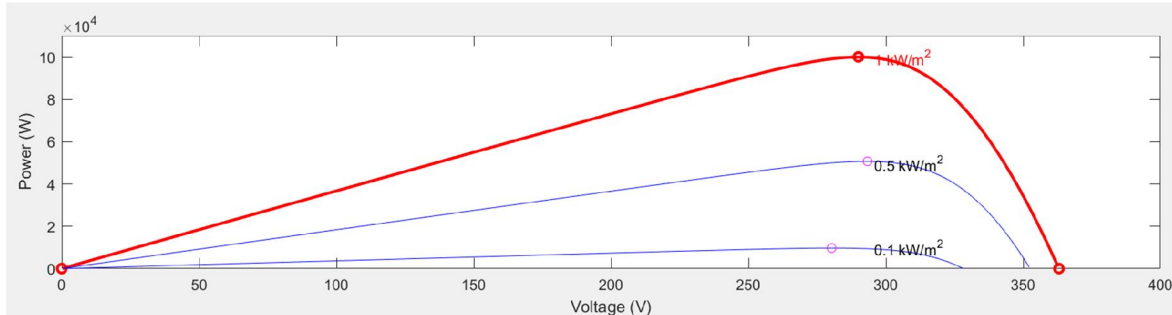


Fig. 1 Irradiance levels of  $1\text{KW}/\text{m}^2$ ,  $500\text{W}/\text{m}^2$  and  $100\text{W}/\text{m}^2$  at a temperature of  $25^\circ\text{C}$ .

In the Fig. 6, we can see that the maximum attainable power at  $25^\circ\text{C}$ . For  $1\text{kW}/\text{m}^2$  irradiance, we can get a maximum power of  $100.18\text{kW}$ . For  $0.5\text{kW}/\text{m}^2$  irradiance, we can get a maximum power of  $50.754\text{kW}$ . For  $0.1\text{kW}/\text{m}^2$  irradiance, we can get a maximum power of  $9.72\text{kW}$ . These will be the values that we will aim to achieve with the help of our algorithm using both the converters.

### 2.1 Perturb and Observe Technique

In P&O MPPT technique, a minor perturbation is introduced to cause the power variation of the PV module. The PV output power is periodically measured and compared with the previous power. The flowchart in Fig. 2 gives a better idea of the P&O technique.

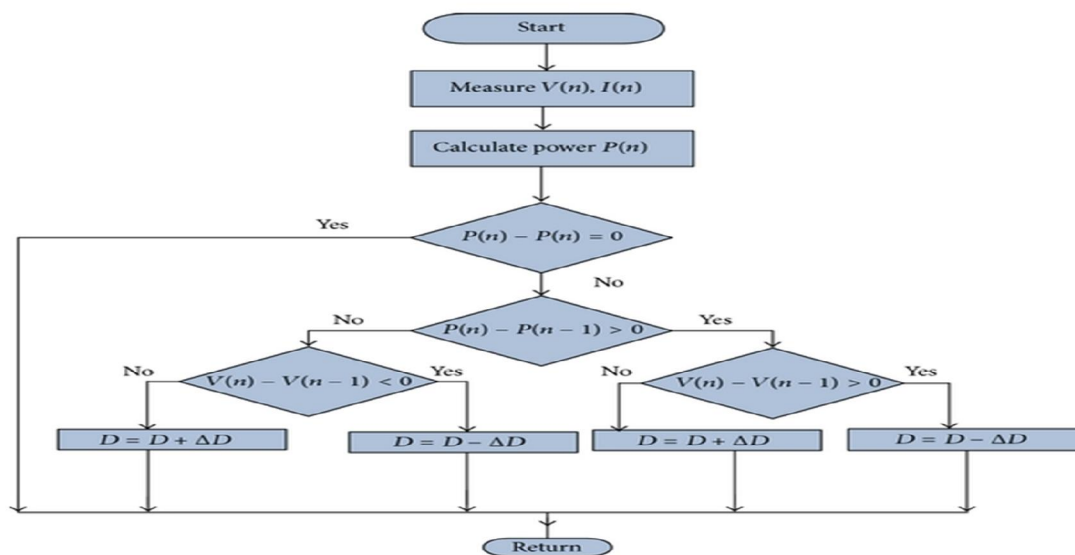


Fig. 2 Flowchart for P&O Technique

### 2.2 Code and Approach

In this research, SIMULINK and MATLAB are used for both the MPPT coding and simulation section for both the converters. The code for the P&O MPPT algorithm is as follows:

```
function D = DutyCycle(V,I)
```

```
Dmax = 0.95;
```

```
Dmin = 0;
```

```
Dinit = 0.95;
```

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DOI 10.48175/IJARSCT-5700

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```

De1D = 0.0001;
persistent Vold Pold Dold;
datatype = 'double';
if isempty(Vold)
    Vold = 0;
    Pold = 0;
    Dold = Dinit;
end
P = V*I
dV = V-Vold;
dP = P-Pold;
if dP ~= 0;
    if dP < 0;
        if dV<0
            D = Dold-De1D;
        else
            D = Dold - De1D;
        end
    else
        if dV < 0
            D = Dold + De1D;
        else
            D = Dold - De1D;
        end
    end
else D = Dold;
end
if D >= Dmax || D < Dmin
    D = Dold;
end
Vold = V;
Pold = P;
Dold = D;

```

### III. DC-DC BUCK CONVERTER

Here, we study the effect of MPPT on a DC-DC Buck Converter. We will first use a conventional Buck Converter with a PV Array. Then, we will use an MPPT algorithm with it. This way, it will be clear how the MPPT will help in attaining maximum power at different irradiances.

#### 3.1 Design Specifications

$$\text{RatedPower} = 100\text{KW}$$

$$V_{in} = 250 - 350\text{V}$$

$$V_o = 120\text{V}$$

$$\frac{V_{oc}}{\text{Module}} = 36.3\text{V}$$

$$\text{CurrentRipple} = 5\%$$

$$\text{VoltageRipple} = 1\%$$

$$f_{sw} = 5\text{Hz}$$

$$\text{OutputCurrent } (I_o) = \frac{\text{RatedPower}}{\text{OutputVoltage } (V_o)}$$

$$\Delta I_L = 5\% \text{ of } I_o = 41.667A$$

$$L = \frac{V_o(V_{in} - V_o)}{\Delta I_L \times f_{sw} \times V_{in}} = 29.95 \times 10^{-3}H$$

$$C = \frac{\Delta I_L}{8 \times f_{sw} \times V_{in}} = 8.68 \times 10^{-6}F$$

### 3.2 Conventional DC-DC Buck Converter

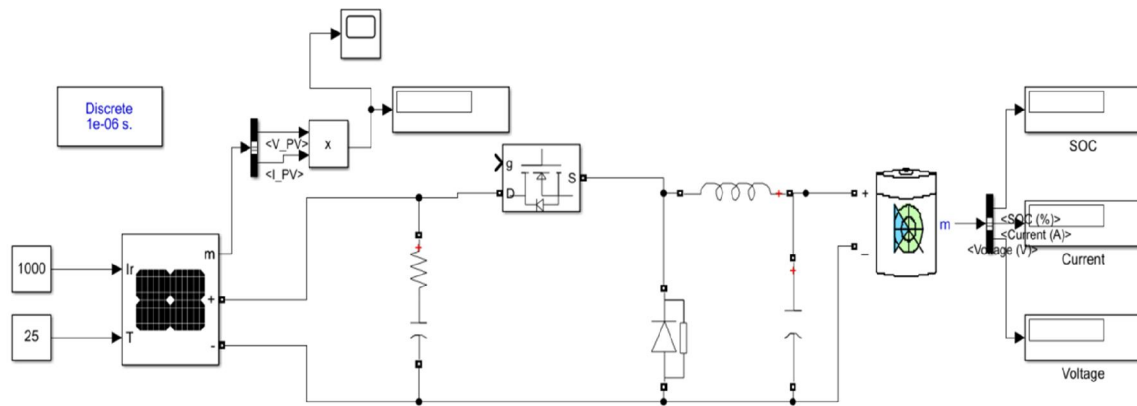


Fig. 3 Conventional DC-DC Buck Converter without MPPT

### 3.3 DC-DC Buck Converter with MPPT

In order to apply the P&O algorithm, we will change the duty cycle of the converter by supplying appropriate gate pulses to the MOSFET. This way we will be able to get the maximum possible power. Fig. 4 shows the schematic for the application of MPPT on the Buck Converter shown in Fig. 3.

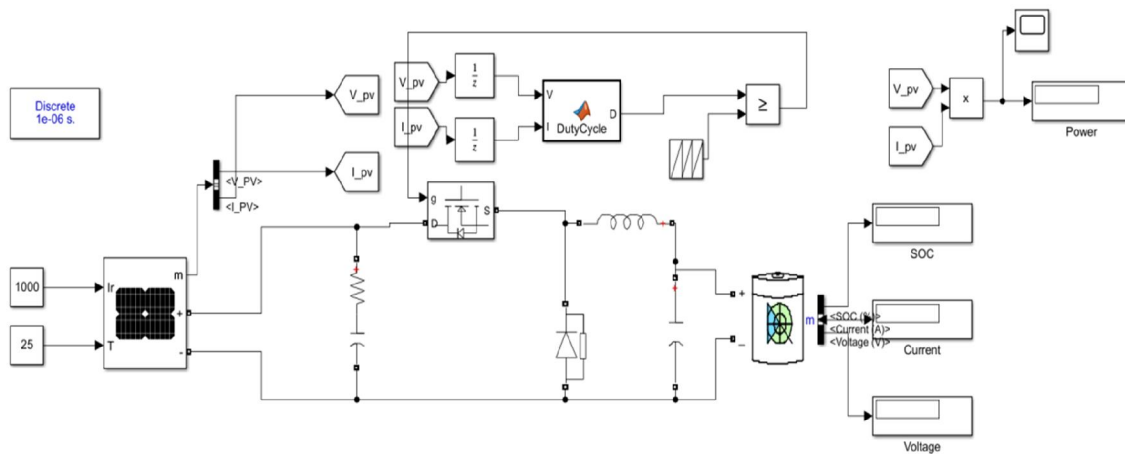


Fig. 4 DC-DC Buck Converter with MPPT

### 3.4 Results

Fig. 5 below shows that the MPPs were obtained at 4 different irradiance levels of 1Kw/m2, 0.5Kw/m2, 0.3Kw/m2 and 0.1Kw/m2 with respect to the Buck Converter configuration. These MPPs correspond with the values of maximum power which we got from the PV plot of the PV array. This way, we know that our MPPT algorithm and the simulations work successfully.

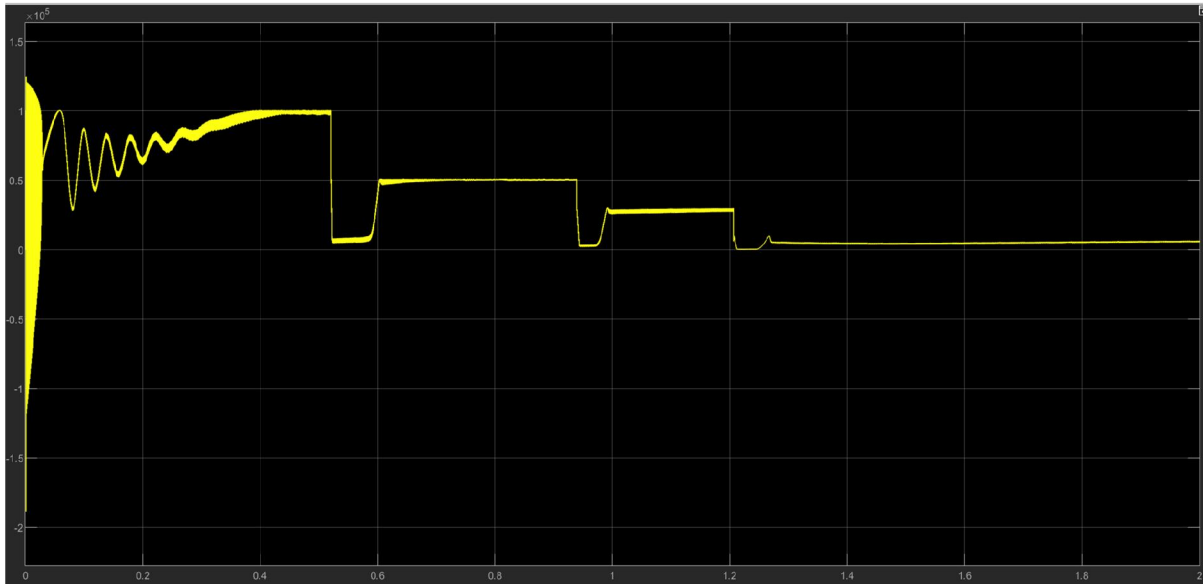


Fig. 5 Output Power at different irradiance levels with MPPT

#### IV. DC-DC BOOST CONVERTER

Here, we Study the effect of MPPT on a DC-DC Boost Converter. We will first use a conventional Boost Converter with a PV Array. Then, we will use an MPPT algorithm with it. This way, it will be clear how the MPPT will help in attaining maximum power at different irradiances.

##### 4.1 Design Specifications

$$\text{RatedPower} = 100\text{KW}$$

$$V_{in} = 250 - 350\text{V}$$

$$V_o = 600\text{V}$$

$$\text{CurrentRipple} = 5\%$$

$$\text{VoltageRipple} = 1\%$$

$$f_{sw} = 5\text{Hz}$$

$$\text{InputCurrent } (I_{in}) = \frac{100\text{KW}}{250\text{V}} = 400\text{A}$$

$$\text{OutputCurrent } (I_o) = \frac{100\text{KW}}{600\text{V}} = 166\text{V}$$

$$\Delta I_L = 5\% \text{ of } 400 = 20\text{A}$$

$$\Delta V_L = 1\% \text{ of } 600 = 6\text{V}$$

$$L = \frac{V_{in}(V_o - V_{in})}{\Delta I_L \times f_{sw} \times V_o} = 0.00145 \text{ H}$$

$$C = \frac{I_o(V_o - V_{in})}{f_{sw} \times V_o \times \Delta V_L} = 3227 \times 10^{-6}\text{F}$$

**4.2 Conventional DC-DC Boost Converter**

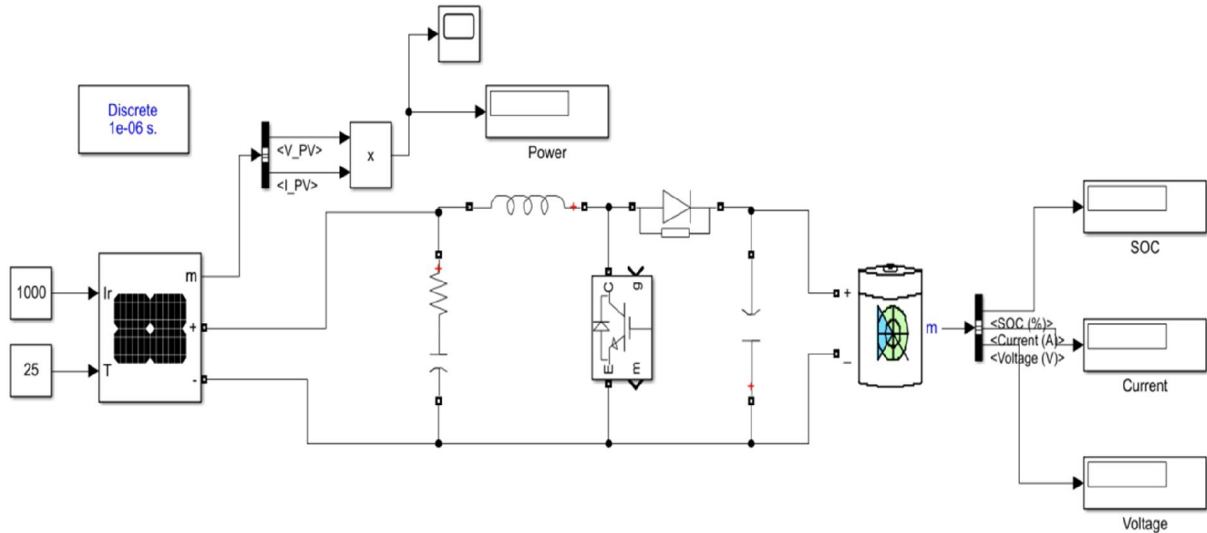


Fig. 6 Conventional DC-DC Boost Converter without MPPT

**4.3 DC-DC Boost Converter with MPPT**

In order to apply the P&O algorithm, we will change the duty cycle of the converter by supplying appropriate gate pulses to the MOSFET. This way we will be able to get the maximum possible power. Fig. 7 shows the schematic for the application of MPPT on the Buck Converter shown in Fig. 6.

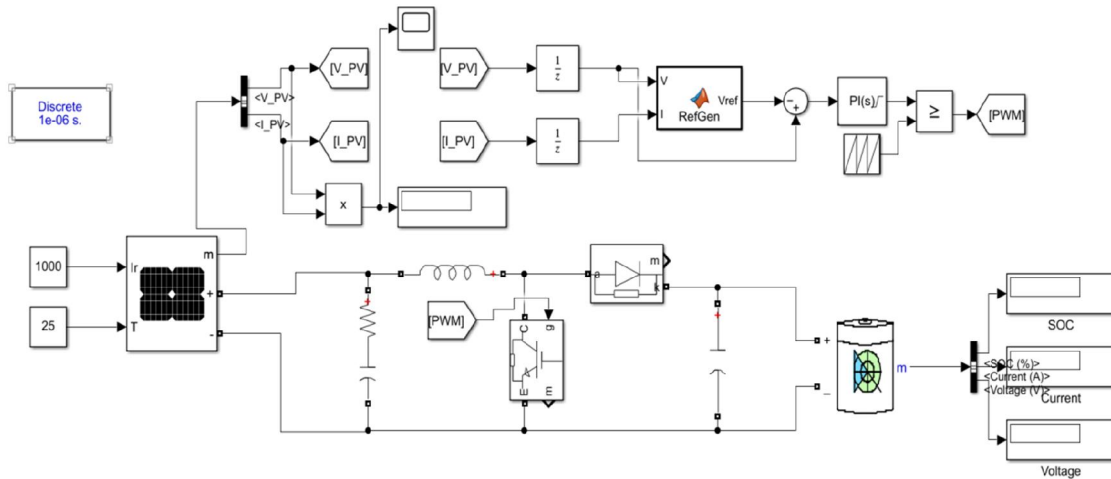


Fig. 7 DC-DC Boost Converter with MPPT

**4.4 Results**

Fig. 8 below shows that the MPPs were obtained at 4 different irradiance levels of 1kW/m<sup>2</sup>, 0.5kW/m<sup>2</sup>, 0.3kW/m<sup>2</sup> and 0.1kW/m<sup>2</sup>, with respect to a Buck Converter configuration. These MPPs correspond with the values of maximum power which we got from the PV plot of the PV array. This way, we know that our MPPT algorithm and the simulations work successfully.

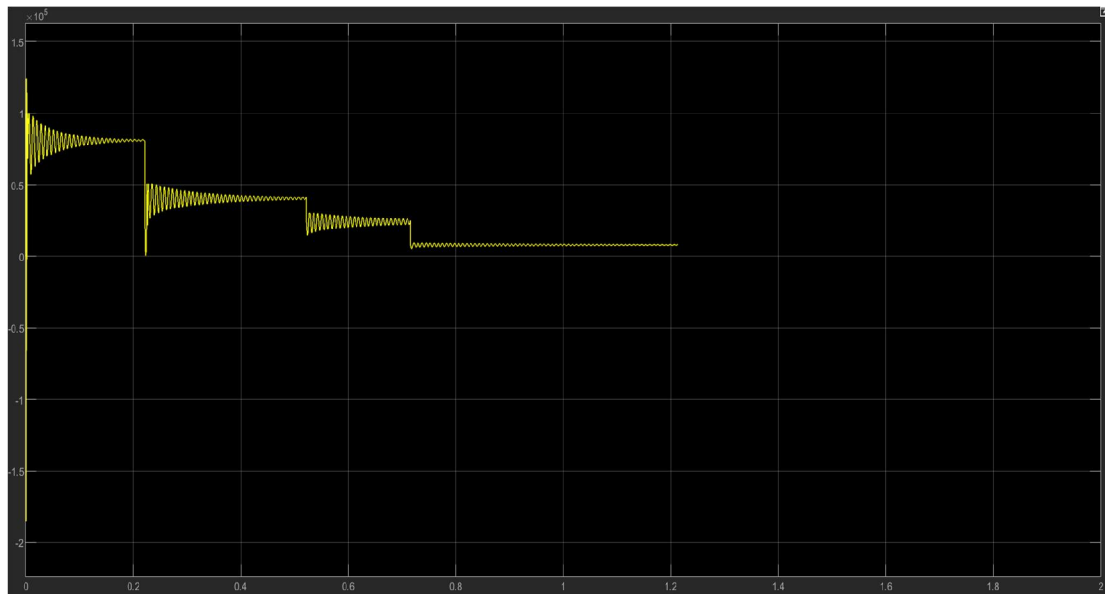


Fig. 8 Output Power at different irradiance levels with MPPT

## V. CONCLUSION

### 5.1 Realistic Constraints

MPPT with DC-DC Converters is already an on-ground performing technique. The only realistic constraint with the simulations is the fast changing irradiance and temperature level. Even though we change the irradiances to prove the effectiveness of the MPPT algorithm, we cannot simulate the ever rapidly changing irradiance and temperature levels.

### 5.2 Alternatives and Tradeoffs

Instead of using MPPT algorithm only, it could be combined with other AI based algorithms to increase its efficiency but this could end up making the project more complex due to the combination of AI algorithms such as GA or PSO. MPPT could also be implemented on Buck-Boost converter instead of Buck and Boost converter. The IC MPPT algorithm can also be analyzed with different converters

### 5.3 Cost Analysis

The project is based on MATLAB Simulink so currently no high cost is required to make the project. But from Literature review and previous hardware projects, we found out that DC-DC boost converter has lower current rating for power switches and gate drivers but the DC-DC buck converter requires high-side power switches driver which are more difficult to work with and more expensive.

### 5.4 Results from the Simulation

From the power-time curve at different irradiance levels of Buck Converter, we see that even though the curve smoothens after reaching MPP, the response is very sluggish. While, in the Boost Converter, The response time to find the MPP at different irradiance level is very low. Even though the curve doesn't saturate fast enough, it comes to a straight time after some time.

### 5.5 Future Scope of the Work

Implementation of Buck-Boost converter can help us study more aspects of MPPT. We can analyze the increase and decrease of PV modules and their effect on the final MPPT in all 3 dc-dc converters. Introduction of AI techniques can help optimize entire process all at once. ANN models can help in simulations of Buck and Boost converters. Optimization techniques like PSO, GA and GWO can help as well.

### 5.6 Summary

From the simulations, we observed that even though Boost Converter responds better to irradiance changes with respect to the P-t curve, the Boost Converter responds a lot more quickly than the Buck Converter.

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