

## Photovoltaic System Equipped Interleaved Boost Converter for Maximum Power Tracking Technique

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### ABSTRACT

*Due to depletion of natural resources, the demand for new and clean energy sources is increasing. And what can be better than solar power as an alternative power source which is free and available abundant. The only hurdle in this energy source is that it is not efficient due to obvious reasons that maximum power cannot be extracted and other switching & transmission losses. This paper deals with the solution to extract maximum power output from the solar PV module using P&O methodology and transform this power with implementation of interleaved boost converters and hence to meet the requirement of generation and effectively transmit power up to its utility in more efficient manner. Use of interleaved boost converter and its design and integration with P&O algorithm is something new and challenging for the application.*

**Keywords—Photo Voltaic; Maximum Power Point Tracking; Interleaved boost converter; Renewable energy.**

### NOMENCLATURE

RSH- Shunt Resistance of PV Cell

RS- Series Resistance of PV Cell

I<sub>0</sub>- Diode Saturation Current

I- Output Current

U/V- Output Voltage

IPV- PV Cell Current

STC- Standard Test Conditions

K- Temperature coefficient of Short Circuit Current

A- Constant of Ideality

L- Inductor

R- Resistor

C- Capacitor

D- Diode

S- Thyristor Switch

PG- Pulse Width Modulator

Isc- PV Short Circuit Current

G- Radiation

## I. INTRODUCTION

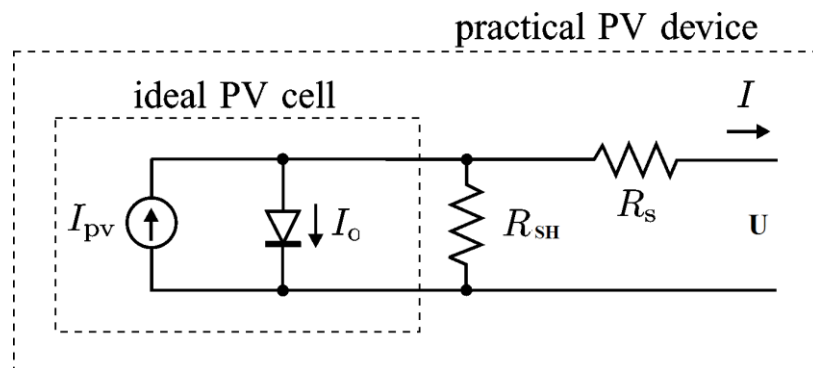
The sun is a natural power source that will keep available for more than 4.5 billion years. Solar power (photovoltaic) systems are a sustainable way to convert the energy of the sun radiation into electricity. By proper tracking the sun's direction the efficiency can be increased by 40-45%.

Further to reduce the losses in switching and transmission, effective use of modern available thyristor devices needs to be employed to convert and voltage and transmit power along the way to its utility.

In the event, necessary storage options should also be available which can feed the power in absence of solar power specially during night time and will be charged back during day time and continue to operate in float mode.

## II. MATLAB SIMULATION OF INDIVIDUAL MODULES

### A. PV Module- Working, Matlab Simulation & Results



**Fig. 1. Equivalent Circuit of Photovoltaic Cell**

Fig 1 shows the equivalent circuit for photovoltaic cell, the output voltage can be derived using following equation (1),

$$U = R_{SH} I_{PV} - (R_{SH} + R_S) I - R_{SH} I_o \left[ \exp\left(\frac{U + IR_S}{AU_T}\right) - 1 \right], \quad (1)$$

First, we will start with the simulation of photovoltaic Module to derive the values required for equation (1). As shown in fig 2, PV module consists of photovoltaic cell and a bypass diode connected in parallel to it on the rear side of the panel. Further the photovoltaic module consists of three main blocks- The Photo Current Block, The Parasitic Elements Block and The Diode Current Block. These three blocks can be seen in fig 3.

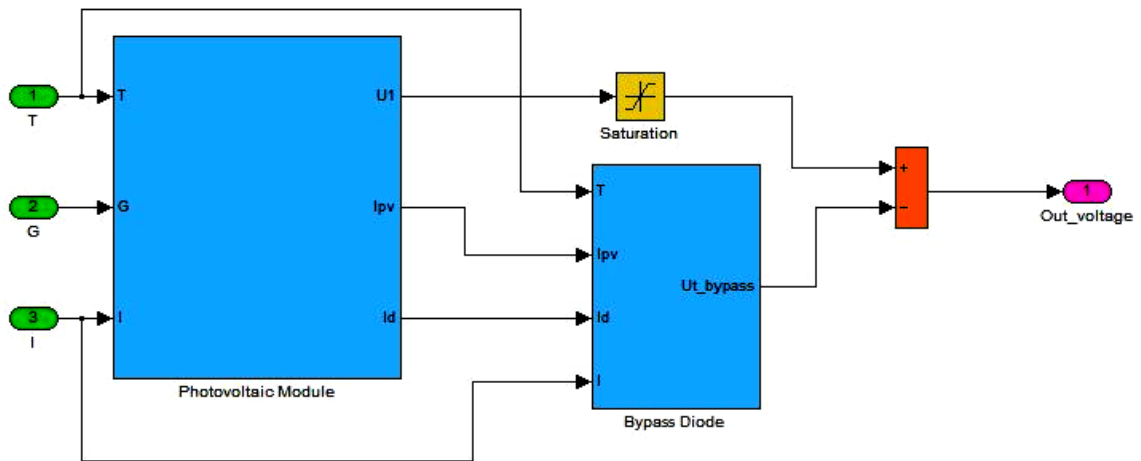


Fig. 2. Simulink models of photovoltaic module and bypass diode

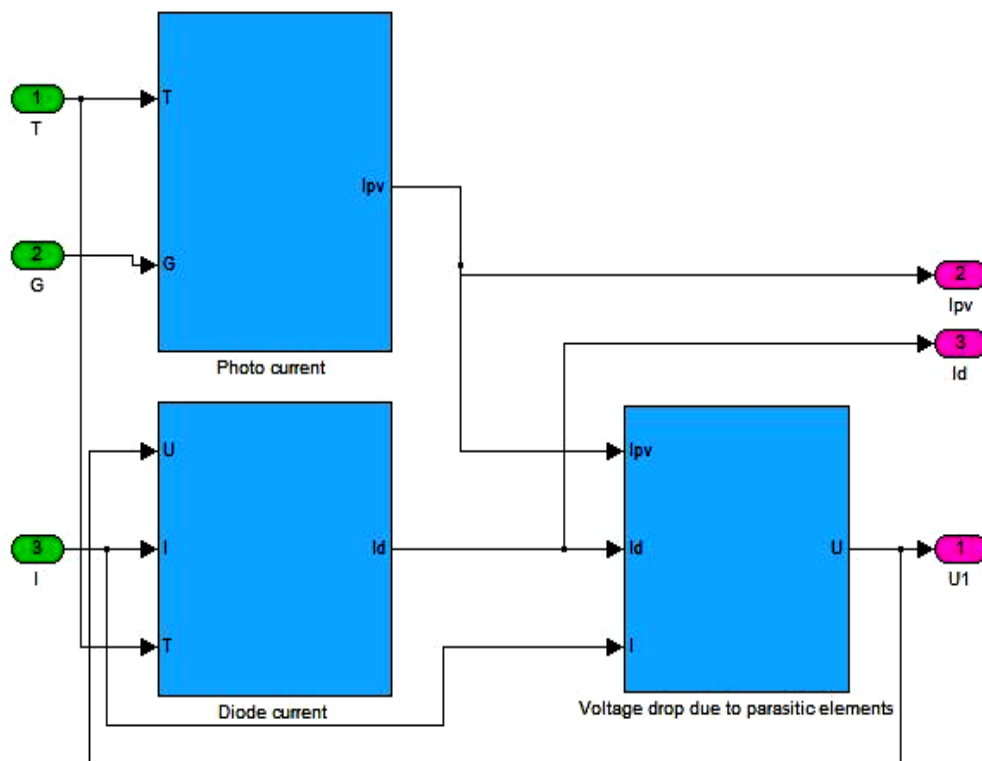


Fig. 3. The Simulink model of photovoltaic module Block

The above fig 3 is nothing but the mathematical model of equation (1). Further we need to derive the unknown values of the equation (1) has various unknown factors which we need to derive. We start with finding out IPV. Equation (2) is used to derive this value,

$$I_{PV} = (I_{PV,STC} + K_I \Delta T) \frac{G}{G_{STC}}, \quad (2)$$

Again in equation (2), value of  $I_{PV,STC}$  is unknown which can be found out by below equation (3)

$$I_{PV,STC} = \frac{R_{SH} + R_S}{R_{SH}} I_{SC,STC}, \quad (3)$$

Hence, we achieve value for first block which is Photo Current. Now next we need to find value for Diode Current  $I_d$  which can be derived by equation (4)

$$I_d = I_o \left[ \exp\left(\frac{U + IR_S}{AU_T}\right) - 1 \right]. \quad (4)$$

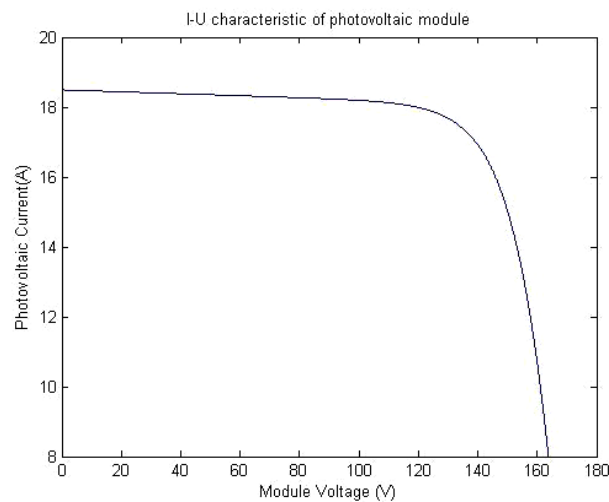
In above equation (4), value of  $I_o$  can be derived by equation (5)

$$I_o = \frac{I_{PV,STC} - (U_{OC,STC} / R_{SH}) + K_T \Delta T}{\exp\left(\frac{U_{OC,STC} + K_U \Delta T}{AU_T}\right) - 1}, \quad (5)$$

Lastly we need equation for bypass diode which is expressed in equation (6)

$$U_{bypass} = U_{T,bypass} A_{bypass} \ln\left(\frac{I + I_d - I_{PV} + I_S}{I_S}\right), \quad (6)$$

Output of this PV Module is shown in fig 4 & 5. Figure 4 shows I-V Characteristics of PV module and figure 5 shows the I-V Characteristics of PV module with maximum power point. These are exactly in line with the standard outputs which are indicated by PV Module manufacturers.



**Fig. 4. I-U Characteristics of PV Module**

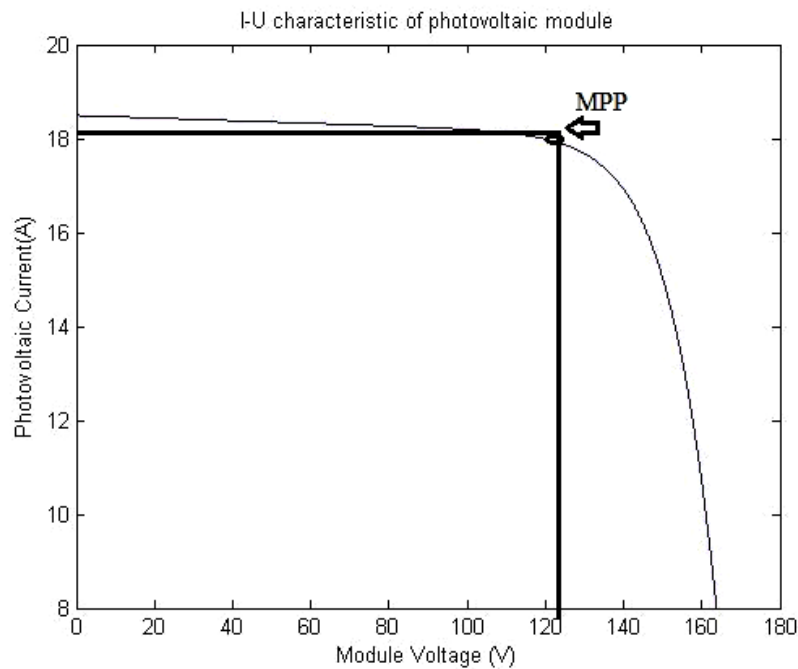


Fig. 5. I-U Characteristics of PV Module with Maximum Power Point

### B. MPPT Module- Working, Matlab Simulation & Results

There are various methods for tracking the maximum power, but Perturb & Observe is the most simple and widely used method.

In this method, the algorithm stores the initial values of voltage, current & power values and perturbs to next level and compares the stored values with new values, if the difference is positive it perturbs to next level, if the difference is negative, it perturbs back. On reaching maximum point, it oscillates back & forth at that point and achieved the maximum power point. Fig 6 shows the flowchart for P&O algorithm.

Output of PV Module is input to MPPT Module, it can be seen from the figure 8 the output are as desired,

$$V_{out} = 124.9V$$

$$I_{out} = 18.47A$$

$$P_{out} = V_{out} \times I_{out} = 124.9V \times 18.47A = 2308 W$$

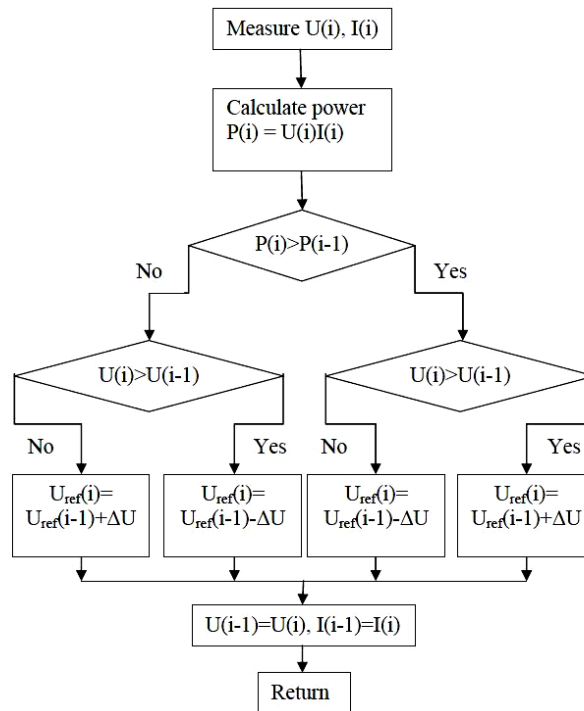


Fig. 6. Flow Chart for P&O Method

This flowchart is used in modeling of P&O algorithm in Matlab. Fig 7 shown the detailed Matlab Model and Fig 8 shows the results derived from this model.

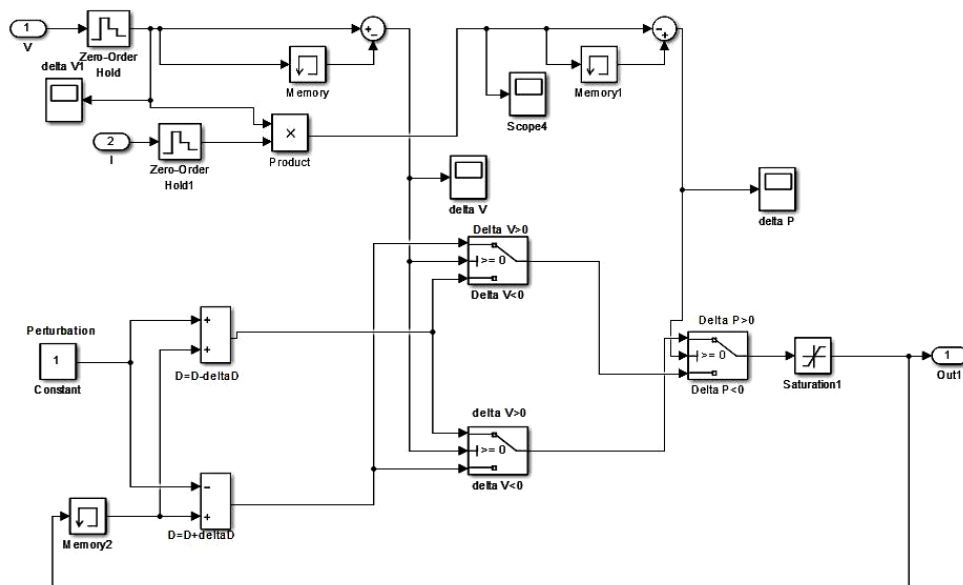
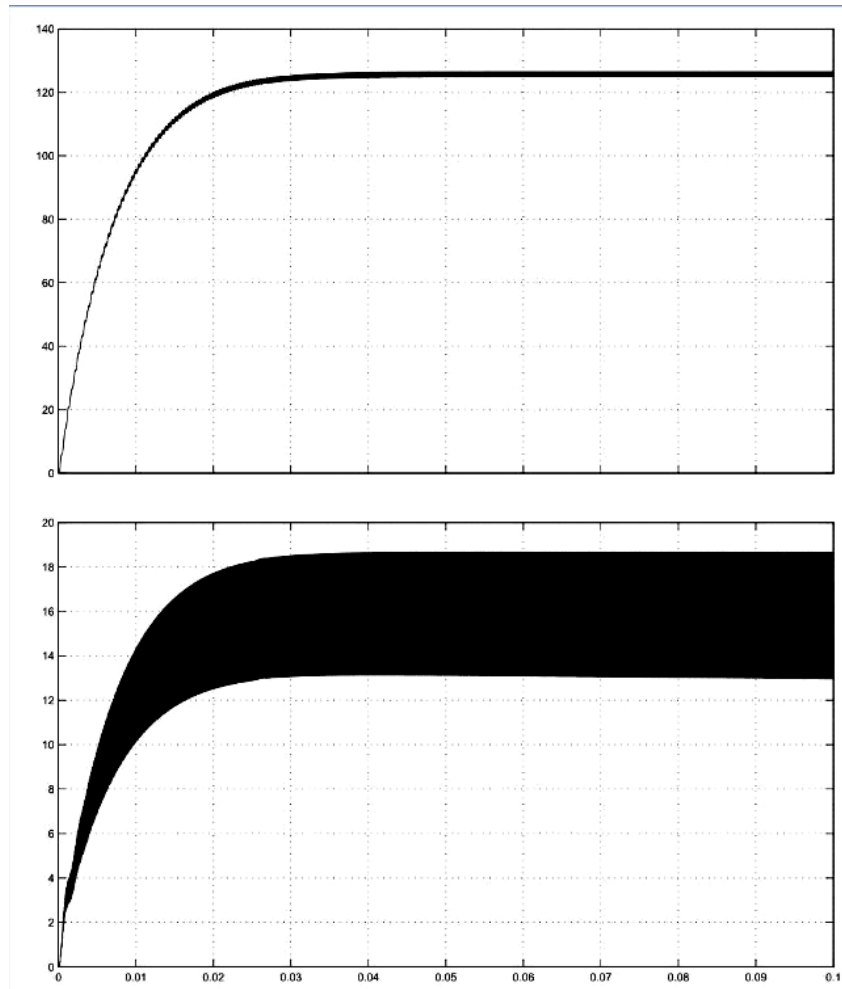


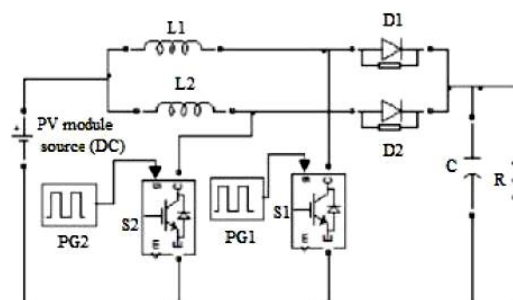
Fig. 7. Matlab Simulation for P&O Method



**Fig. 8. Output Voltage, Current & Power of P&O Module**

**C. IBC Module- Working, Matlab Simulation & Results**

IBC means Interleaved Boost Converter. Commonly used Boost converter has its own limitations on capacity, cost, size, etc. and so they cannot be used for handling heavy voltages. IBC is nothing but the boost converters connected in parallel, we can connect two, three, four converters as required by the system to boost the voltage and handle the current. Fig 9 shows the two stages IBC for easy understanding. In same line we can have multi stage converters also.



**Fig. 9. Circuit Diagram for two phase IBC**

From fig 9 we can see that the IBC has thyristor switch S1 & S2. The control of these two switches is nothing but the operating sequence of this module.

In Mode-1 ( $0 \leq t < t_1$ ), the switch 'S1' is turned on, the current across the inductor L1 rises linearly. At the same time, the switch 'S2' in the second phase is turned off & the energy stored in the inductor L2 is sourced to the load through the output diode D2. In this time interval, the diode D1 in the first phase is in reverse bias condition. The rate of change of  $i_{L2}$  is approximately given in equation (7)

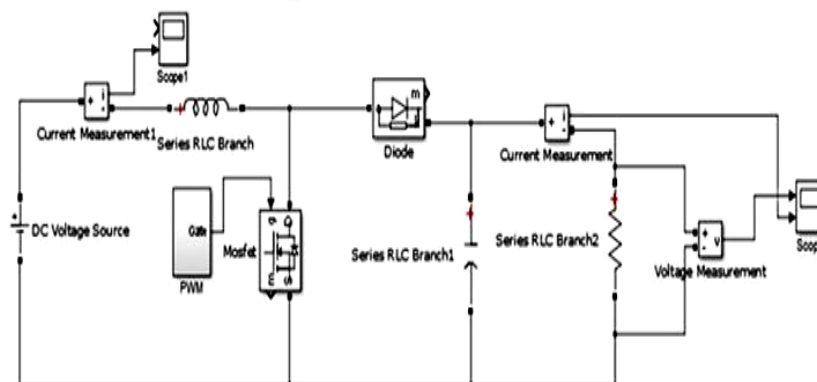
$$\frac{di_{L2}}{dt} = -\frac{V_0}{L_1 + L_2} \quad (7)$$

In Mode-2 ( $t_1 \leq t < t_2$ ), the switch 'S2' is turned on, the current across the inductor L2 rises linearly. At the same time, the switch 'S1' in the first phase is turned off & the energy stored in the inductor L1 is transferred to the load through the output diode D1. In this time interval, the diode D2 in the second phase is in reverse bias condition. The rate of change of  $i_{L1}$  is approximately given in equation (8)

$$\frac{di_{L1}}{dt} = -\frac{V_0}{L_1 + L_2} \quad (8)$$

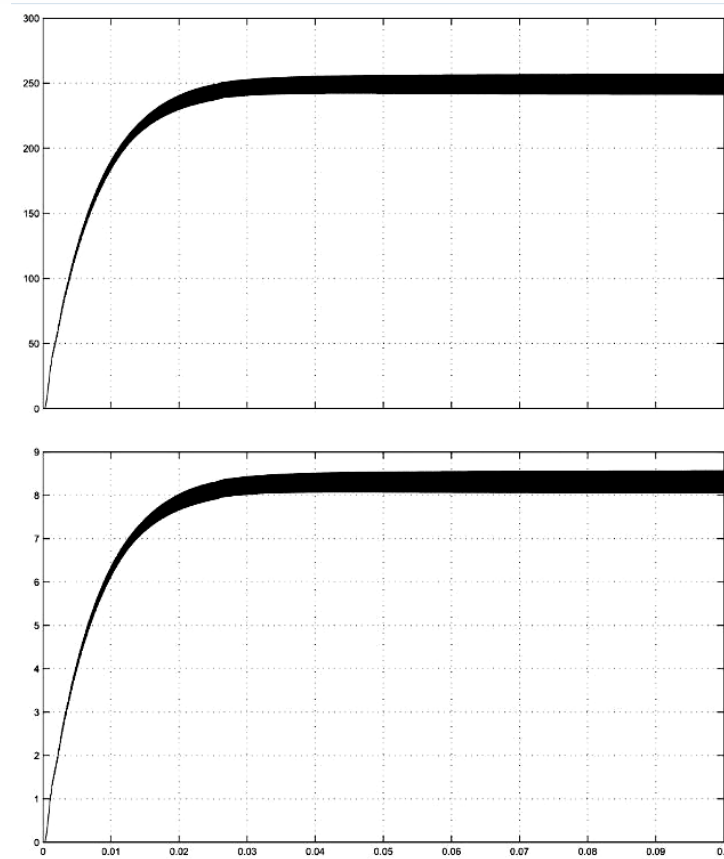
Below is the Matlab model shown in fig 10, for simplicity single stage boost converter is simulated to check if results are as desired, later it can be added with multi stage converter as per system requirement.

Fig 11 shows the results derived from IBC Matlab module. These are in line with the basic requirement and further utilization in complex network.

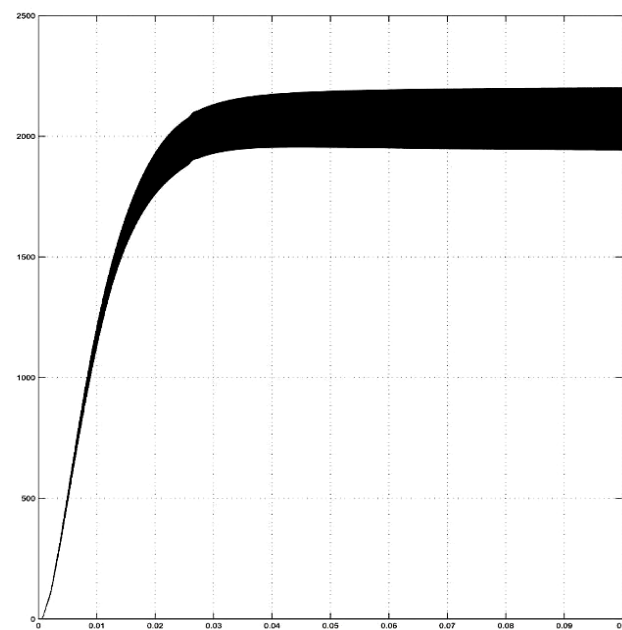


**Fig. 10. Matlab Model for IBC Module**





**Fig. 11. Output Voltage and Current for IBC Module**



**Fig. 12. Output Power for IBC Module**

Output of MPPT Module is input to IBC Module, it can be seen from the figure 12 the output are as desired,

$$V_{out} = 258.8V$$

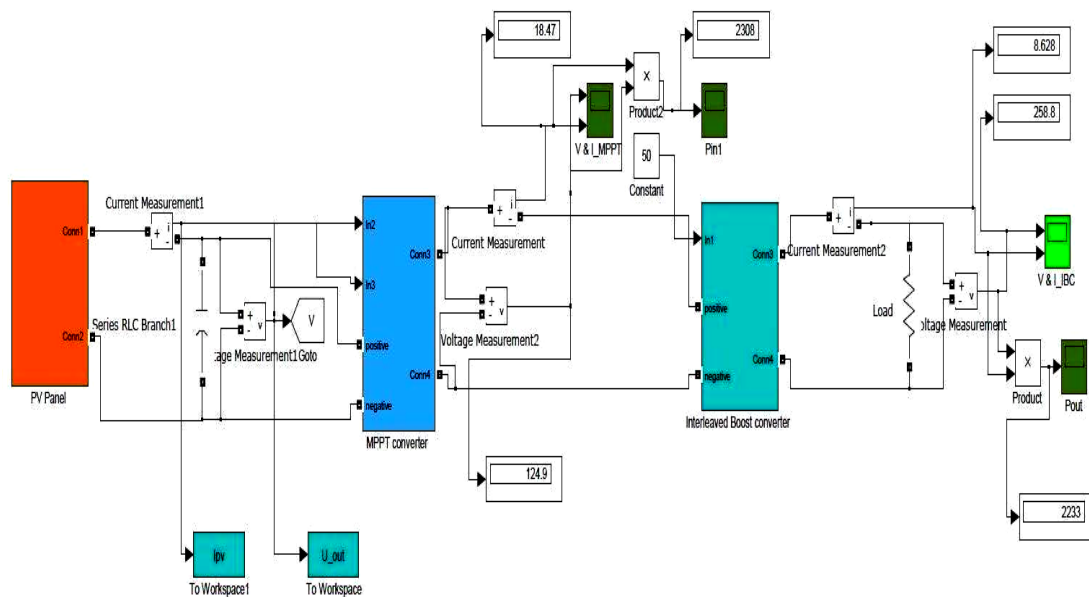
$$I_{out} = 8.62A$$

$$P_{out} = V_{out} \times I_{out} = 258.8V \times 8.62A = 2233W$$

### III. MATLAB SIMULATION OF OVERALL COMPLEX SYSTEM

After achieving the desired results of individual modules, these independent modules are combined to have a complex network to check the working and performance of the network as a complete integrated system.

As shown in figure 13, we have complex network consisting of PV module as the first module, the output of PV module is feed to MPPT system where we have maximum power point tracking. Once we have maximum power, the output of MPPT is feed to interleaved boost converter, where the voltage is increased to the desired utilization voltage. A load is connected in parallel and a battery is connected in parallel in such a way that the power generated by PV is stored in battery and also utilized by load, the battery is in float mode and only discharges and feed the power when we don't have power from the PV module.



**Fig. 13.** Complex System Matlab Model

### IV. CONCLUSION

An efficient approach to design a solar MPPT has been presented in the paper. All individual components like PV cell, MPPT, converters, etc. were simulated and tested separately under different conditions using Matlab Simulink model to conclude that the result obtained are up to expectation. After complete integration to have a system as whole, the results were analyzed in detail and proven that the system works fine with desired results. The results obtained from the simulation were satisfactory and in accordance to the assumptions and literature survey.

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