



## Comparative Analysis Of Perturb & Observe And INC MPPT For A 5KW PV System Using Buck-Boost Converter

Manjappa N<sup>1</sup>, Dr. Madhusudhana J<sup>2</sup>

<sup>1</sup>PhD.Scholar, Department of Electrical Engineering, UVCE, K.R.Circle, Bengaluru, India

<sup>2</sup>Associate Professor, Department of Electrical Engineering, UVCE, K.R.Circle, Bengaluru, India

**Abstract**— Maximum power point tracking techniques are used in solar photo voltaic system to maximize PV array output power. Different techniques are proposed for implementing the MPPT. In this study, a Buck-Boost converter operating on a 5KW PV system has been designed. The designed circuit is analyzed using two MPPT techniques, viz, P&O and INC algorithm and simulation studies are made using MATLAB/SIMULINK software. The obtained results are presented in the result section and the results are compared to verify the effectiveness of the techniques considered.

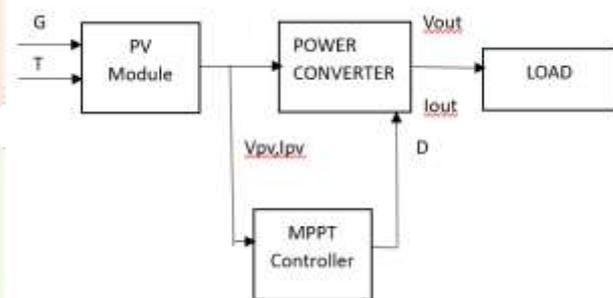
**Key Words** : DC-DC Converter, MPPT Controller, PV system

### I. INTRODUCTION

As the conventional energy sources are reducing fast and the cost of energy is rising, Renewable energy source become an alternative. Renewable energy source will be gradually more important part of power generation in the new millennium [1-4].

Efficiency of the PV system can be increased by using power electronics devices along with maximum power point controller. The extraction of maximum available power from a photovoltaic module is done by maximum power point controller. The efficiency of the photo voltaic system may be substantially increased by using

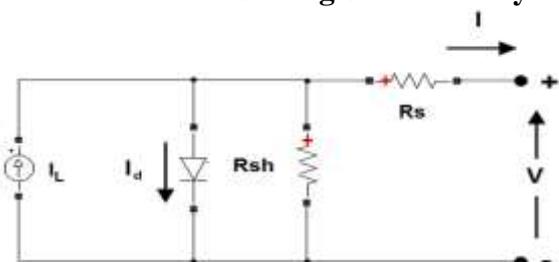
maximum power point tracker. Several algorithm are developed to trace the maximum power point efficiently[5-8].



**Fig 1 : Block diagram of PV array connected to a load through Buck-Boost converter with MPPT controller**

MPPT control algorithm can be implemented by using direct duty cycle control or closed loop control (voltage / control references). The conventional MPPT methods with direct duty cycle control are generally implemented by considering a fixed perturbation with duty cycle based on desired tracking system[9-12].

### 2 Mathematical modeling of a PV array



## Figure 2 : Single diode equivalent circuit of a Solar Cell

The PV array block is a five-parameter model using a current source  $I_L$  (light-generated current), diode saturation current ( $I_0$ ), series resistance  $R_s$ , and shunt resistance  $R_{sh}$  to represent the irradiance- and temperature-dependent I-V characteristics of the modules.

The diode I-V characteristics for a single module are defined by the equations

$$I_d = I_0 \left[ \exp\left(\frac{V_d}{V_T}\right) - 1 \right]$$

$$V_T = \frac{kT}{q} \times n_1 \times N_{cell}$$

Where,

$I_d$  = diode current (A)

$V_d$  = diode voltage (V)

$I_0$  = diode saturation current (A)

$n_1$  = diode ideality factor, a number close to 1.0

$k$  = Boltzmann constant =  $1.3806 \times 10^{-23}$  J.K<sup>-1</sup>

$q$  = electron charge =  $1.6022 \times 10^{-19}$  C

$T$  = cell temperature (K)

$N_{cell}$  = number of cells connected in series in a module

### 3.PV Module

A solar PV module is a collection of solar cells, connected in series. These combinations of solar cells provide higher power than a single solar cell. The PV modules are available in the power ratings range from 3 watts to 300 watts.

The parameters of the solar PV modules ( $V_{oc}$ ,  $I_{sc}$ ,  $W_p$ ), mentioned by the manufacturer are measured under some standard conditions of temperature 25 degrees Celsius and solar radiations 1000 (W/m<sup>2</sup>). These test conditions are known as standard test conditions (STC).

Number of modules are listed from main manufacturers, sorted in alphabetical order. The National Renewable energy laboratory (NREL) database includes manufacturer datasheets measured under standard test conditions (STC) (irradiance=1000 W/m<sup>2</sup>, temperature=25 degrees C).

We have used TSMC Solar TS-110C module.

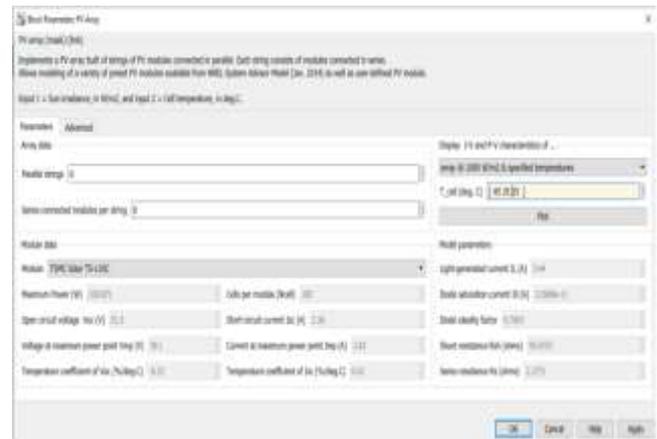


Figure 3: PV Array block parameters

#### Maximum Power (W)

Power obtained at maximum power point ( $V_{mp}$ ,  $I_{mp}$ ).  $P_{max}$  is computed as  $P_{max} = V_{mp} \times I_{mp}$ . The default value is 109.871 W.

#### Cells per module (Ncell)

Number of cells per module.

#### Open circuit voltage Voc (V)

Voltage obtained when array terminals are left open.

#### Short-circuit current Isc (A)

Current obtained when array terminals are short circuited.

#### Voltage at maximum power point Vmp (V)

Voltage at maximum power point.

#### Current at maximum power point Imp (A)

Current at maximum power point.

#### Temperature coefficient of Voc (%/deg.C)

Defines variation of  $V_{oc}$  as a function of temperature.

The open-circuit voltage at temperature T is obtained as

$$V_{ocT} = V_{oc} (1 + \beta_{Voc}(T-25)),$$

where  $V_{oc}$  is the open-circuit voltage at 25 degrees C,  $V_{ocT}$  is the open-circuit voltage at temperature T (in degrees C),  $\beta_{Voc}$  is the temperature coefficient (in %/degrees C), and T is the temperature in degrees C.

#### Temperature coefficient of Isc (%/deg.C)

Defines variation of  $I_{sc}$  as a function of temperature. The short-circuit current at temperature T is obtained as

$$I_{scT} = I_{sc} (1 + \alpha_{Isc}(T-25)),$$

where  $I_{sc}$  is the short-circuit current at 25 degrees C,  $I_{scT}$  is the short-circuit current at

temperature  $T$  (in degrees C),  $\alpha_{Isc}$  is the temperature coefficient (in %/degrees C) and  $T$  is the temperature in degrees C.

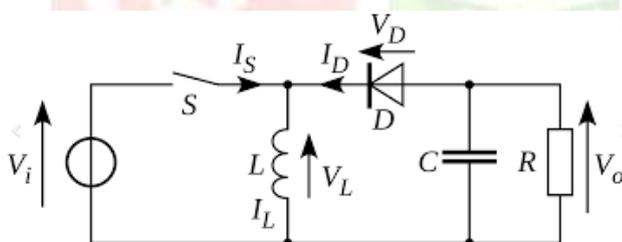
#### 4. DC-DC Converters

To implement MPPT, a PV array is operated in configuration with DC-DC converter. DC-DC converter is the heart of the MPPT hardware. It interfaces the PV source and the DC-AC inverter. The converter must be carefully chosen as the efficiency of the entire system depends on the performance of the converter. Also, the PV voltage can be stepped up for grid connected systems.

DC to DC buck converter is a converter in which DC voltages are stepped down to the desired level by high-frequency switching of semiconductor switches such as MOSFET or IGBTs. This type of converter is also called a step-down converter.

DC to DC boost converter is a converter in which DC voltages are stepped up to the desired level by high-frequency switching of semiconductor switches such as MOSFET or IGBTs. This type of converter is also called a step-up converter.

#### 5. Buck-Boost Converter



**Figure 4 : Buck-Boost Converter**

Buck –Boost converter is a “DC to DC converter which either steps up or steps down the input voltage level “. The step up or step down input voltage level depends on the duty ratio or duty cycle is the ratio of output to the input voltage in the circuit . Buck-Boost converter provides regulated DC output.

When it is in buck mode , the output voltage is less than the input applied voltage . In this mode the output current is more than the input current . However the output current is equal to the input power . When it is in boost mode, the output voltage obtained is more than the input applied voltage.

In this mode the output current is less than input current . However, output power is equal to the input power . To operate the Buck – Boost converter, the switches will operate simultaneously . When switches are closed ,inductor get discharged and give supply to the load . The inductor in circuit doesn't need certain variations. The capacitor across the load provides a regulated DC output.

#### 6. Maximum power point tracking

Maximum Power Point Tracking (MPPT) techniques are very significant, as one can improve the efficiency of the PV model through them. There are many methods of MPPT, such as the Perturbation and Observation (P&O), the incremental conductance, the Fractional Open-Circuit Voltage, the Fractional Short-Circuit Current, the fuzzy logic control and the Ripple Correlation Control. All the above vary in complexity, cost, popularity, convergence speed, hardware requirements and efficiency levels. In this section, we examine Perturbation and Observation (P&O) and Incremental Conductance algorithm.

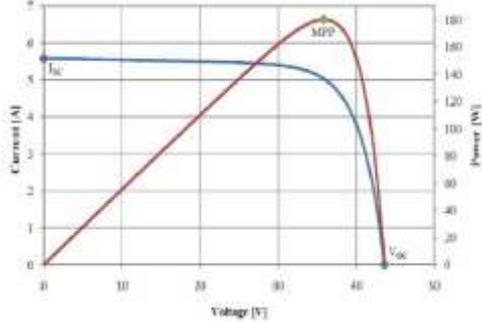
#### 7. Hill-climbing techniques

Both P&O and InCond algorithms are based on the "hill-climbing" principle, which consists of moving the operation point of the PV array in the direction in which power increase. Hill-climbing techniques are the most popular MPPT methods due to their ease of implementation and good performance when the irradiation is constant . The advantages of both methods are the simplicity and low computational power they need.

#### 8. Perturb and Observe algorithm.

The P&O algorithm is also called "hill-climbing", but both names refer to the same algorithm depending on how it is implemented. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O a perturbation in the operating voltage of the DC link between the PV array and the power converter. In the case of the Hill-climbing, perturbing the duty cycle of the power converter implies modifying the voltage of

the DC link between the PV array and the power converter, so both names refer to the same technique.



**Fig5 : PV panel characteristic curves**

From above Fig it shows that the slope of the curve is zero at the maximum power point (MPP), positive on the left side of the MPP (increasing power region) and negative on the right side of the MPP (decreasing power region). Therefore, the algorithm is repeated and oscillated until the MPP is reached.

The oscillation can be minimized by reducing the step-size of the perturbation, but this slows down the process reaching the MPP.

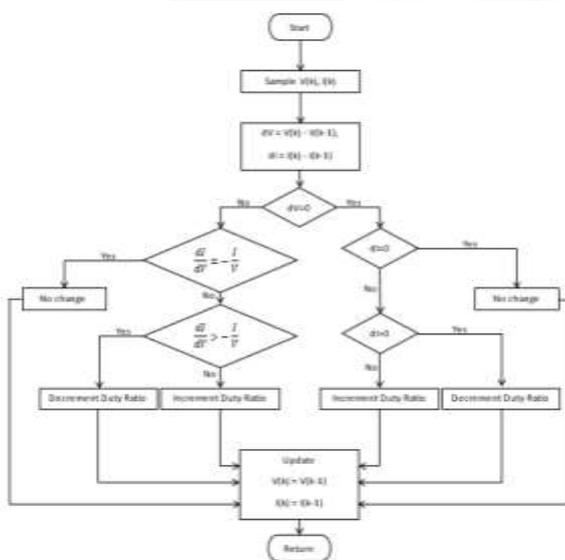
The control variable of the P&O algorithm is the Duty cycle ( $D$ ). The algorithm aims to extract maximum power in solar panel by varying the duty cycle in step-size until the optimal operating point is reached. To do this, there are three possible actions that can be performed; either  $D$  stays the same,  $D$  is increased, or  $D$  is reduced. A ‘Switch’ block is used to implement the required ‘if’ cases. First, the algorithm checks

until the condition is no longer true and the operating voltage is higher than  $V_{MPP}$  it subtracts  $\Delta D$  from the duty cycle. In the conventional P&O MPPT developed, the step size  $\Delta D$  is fixed for all input voltages. These changes are then applied to the PWM Generator which controls the switching of the converter. The fixed step size is set as 0.01

**9. Incremental conductance algorithm :**

The time complexity of the perturb & observe algorithm is much less but on reaching very close to the MPP it does not stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm . However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPPT.

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by INC method . The INC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between  $dl/dV$  and  $-I/V$  This relationship is derived from the fact that  $dP/dV$  is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP.



**Fig6 : Flowchart of P&O algorithm**

if  $\Delta P > 0$ . Then it checks if  $\Delta V > 0$ . If the algorithm detects that the operating voltage is lower than  $V_{MPP}$ , it adjusts the duty cycle by adding a fixed value  $\Delta D$  to get a higher voltage. It keeps adjusting



**Capacitor Design**

$$C = \frac{1 - D}{R \left(\frac{\Delta V_o}{V_o}\right) f}$$

$$= \frac{1 - 0.746}{10(0.005)1000} = 5.08 \times 10^{-6} F$$

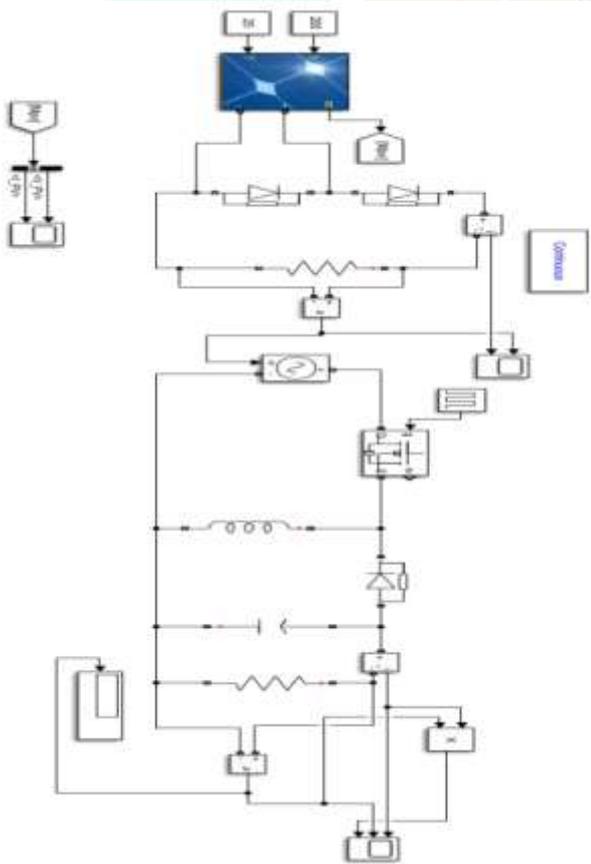
**11. Simulation Circuits and Results**

The simulation is run for one simulation time for 5kW solar array with the above mentioned design values of Buck-Boost converter without MPPT, with P&O, and INC algorithm and output is observed.

**Five kw**

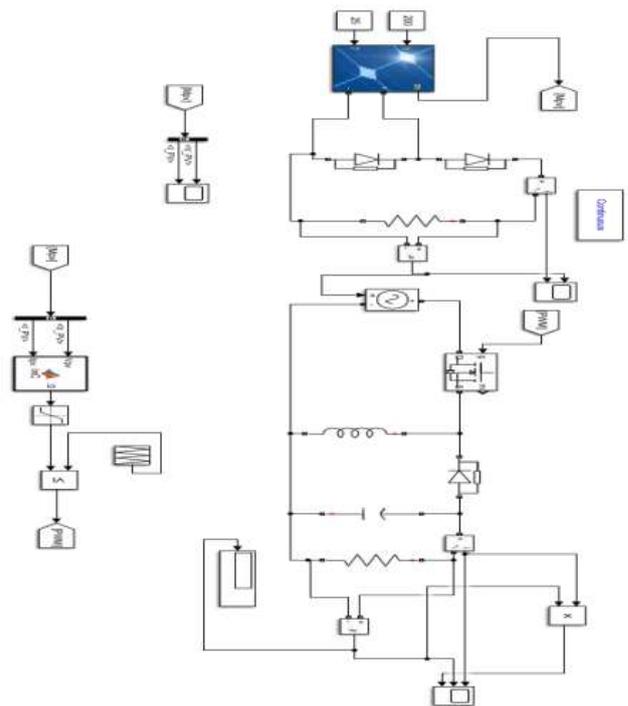
**Buck - Boost Simulation [BOOST]**

**a) Without MPPT**



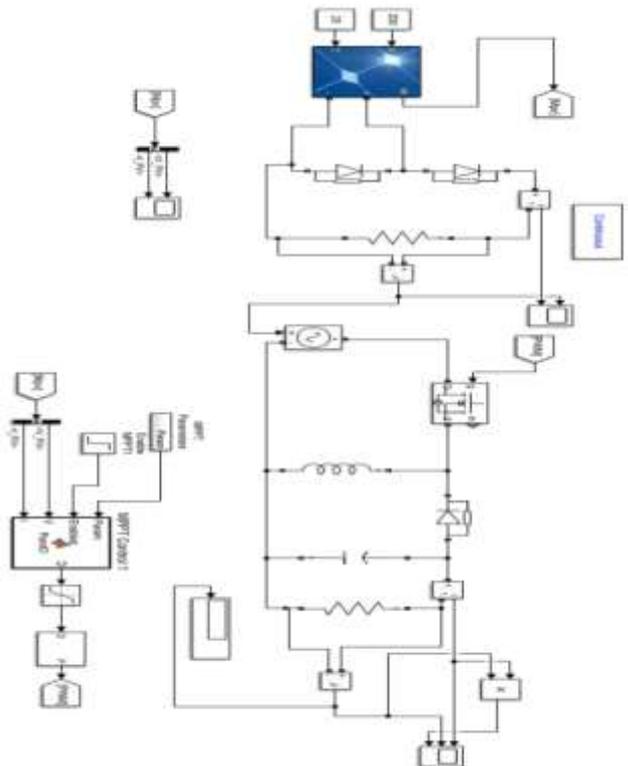
**Fig8 : Simulation diagram of PV system with Buck-Boost converter without MPPT –Boost operation**

**b) With INC MPPT**



**Fig9 : Simulation diagram of PV system with Buck-Boost converter with INC –Boost operation**

**c) With P&O MPPT**



**Fig10 : Simulation diagram of PV system with Buck-Boost converter with P&O –Boost operation**

5kw Buck-Boost Simulation [BUCK]

a) Without MPPT

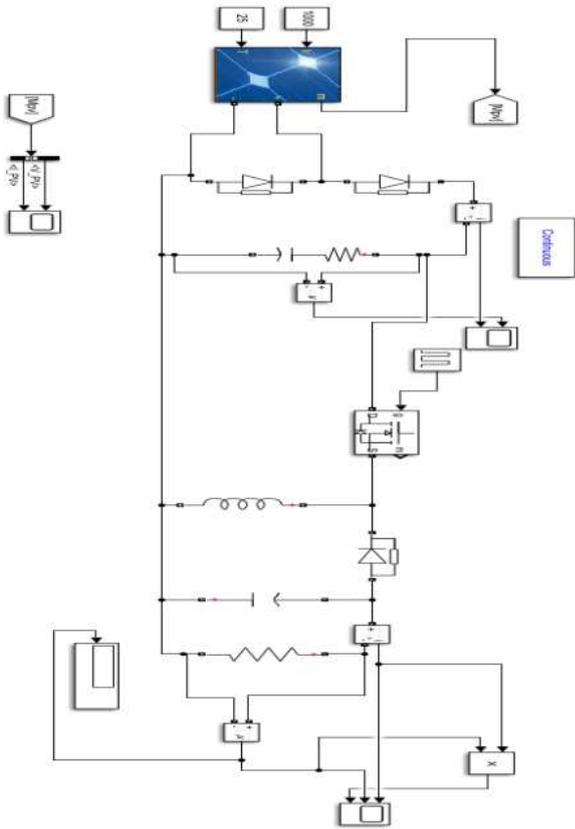


Fig11 : Simulation diagram of PV system with Buck-Boost converter without MPPT –Buck operation

b) With INC MPPT

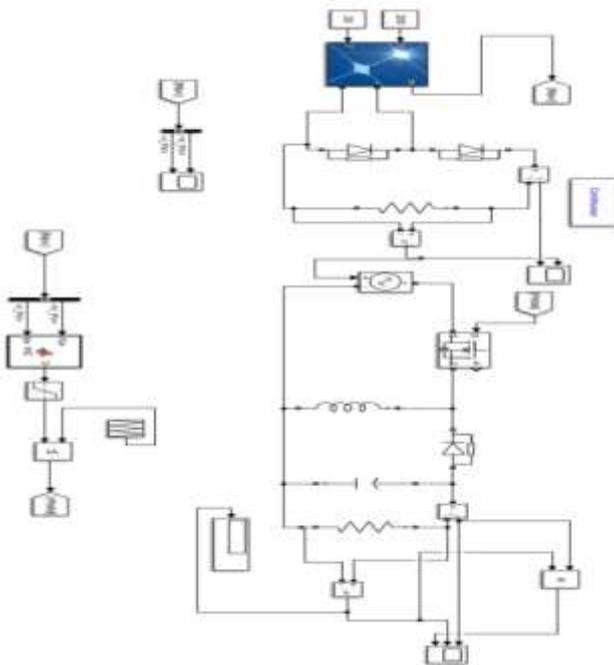


Fig12 : Simulation diagram of PV system with Buck-Boost converter with INC –Buck operation

c) With P&O MPPT

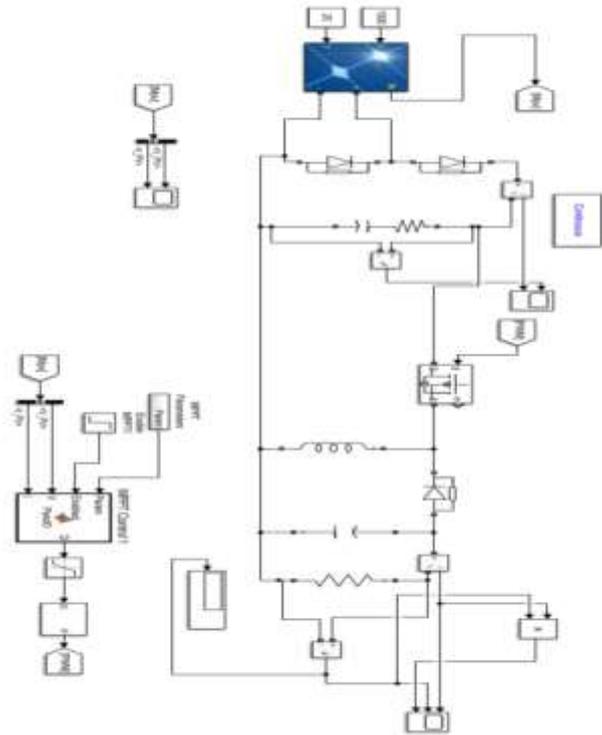


Fig13 : Simulation diagram of PV system with Buck-Boost converter with P&O –Buck operation

Results With Output Waveforms

$V_{in} = 372$   
 5kw for Buck operation

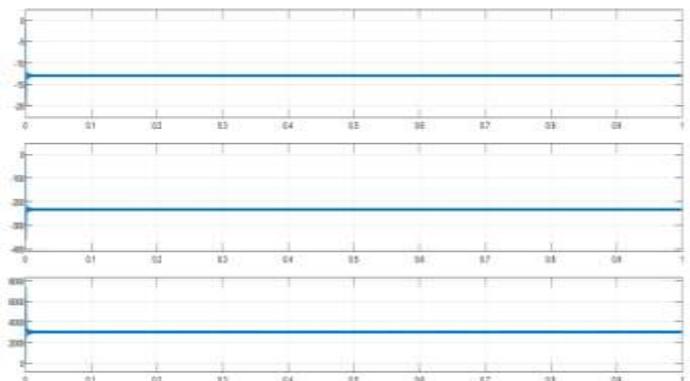
	Without MPPT	With INC	With P&O
$V_o$	-220	-233	-225
$I_o$	-8.33	-14.1	-13.00
$P_o$	1.87	3.3	3.01

$V_{in} = 78$   
 For Boost Operation

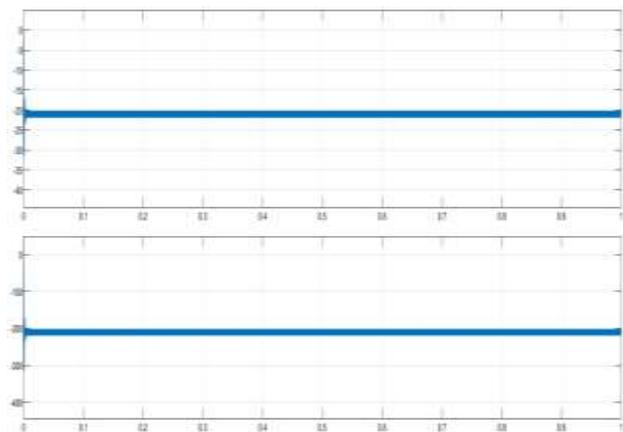
	Without MPPT	With INC	With P&O
$V_o$	-219.5	-239.0	-229.1
$I_o$	-8.5	-13.9	-13.5
$P_o$	1.86	3.32	3.0

12. OUTPUT WAVEFORMS

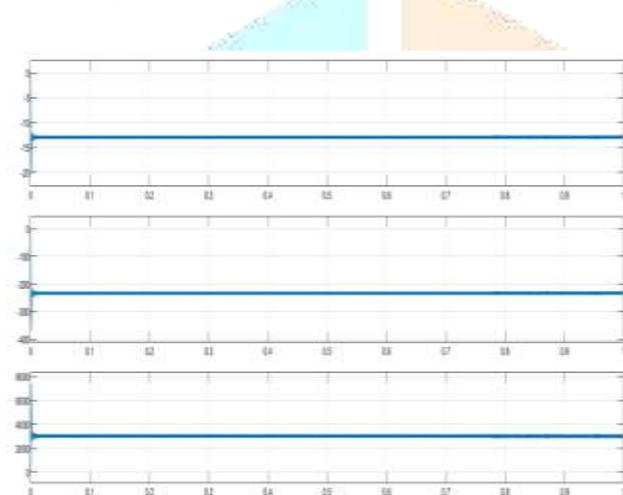
5kw Buck – Boost Converter With INC MPPT - Boost Converter



### 5kw Buck – Boost Converter Without MPPT - Boost Converter



### 5kw Buck – Boost Converter With INC MPPT –Buck Converter



### 5kw Buck – Boost Converter Without MPPT – Buck Converter



### 13. Conclusion

P&O and INC MPPT technique implemented with MATLAB /SIMULIK for simulation . The MPPT methods simulated in this paper is able to improve the efficiency of the PV system This paper also presents simulation based comparative study between Perturb and Observe and incremental conductance (INC) method . From the result it is oserved that with INC MPPT output voltage increased to 239V its more compared to volatge obtained with P&O. Higher O/P obtained with increase in insolation level.

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