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A comparitive study topologies in grid connected photo volatic system for effiecient behaviour and harmonic reduction

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Abstract: Solar PV has emerged as one of the most promising renewable sources for bulk power generation. The increase in demand variability created by intermittent sources such as photovoltaic (PV) presents new challenges to increase system flexibility. In this paper a suitable model for PV system including maximum power point tracking (MPPT), boost converters and transformer less inverters to get maximum efficiency and good quality of power is presented. A detailed comparison study is conducted for different combinations of MPPTs, converters and inverters under uniform irradiation and partial shading effects. Time domain simulations are provided in order to demonstrate the proposed model of PV system and to evaluate the efficiency of the model. All simulations are carried out in MATLAB.

Keyword: Maximum power point tracking (MPPT)Average boost converter, Average inverter,Switching boost converter, Switching inverter

1. INTRODUCTION

The power consumption is increasing world wide to meet this demand we are generating power by conventional and non conventional energy sources .In non conventional energy sources PV is mostly used across world to generate the power to meet the power demand across world. Generating power through PV and integrating with the grid. The main drawback for not using PV panel is the efficiency of solar cell is very less and losses in power electronic interface while connecting with the grid. And one more drawback is quality of power due to partial shading. Where solar thermal panel tolerates shading, but PV modules are highly sensitive to shading . To reduce this effect on PV cell bypassing diodes are applied at module levels in many literatures [9] this can increase losses at the module levels only. However, suitable combinations of power electronic converters are essential to get maximum power even under partial shading conditions. Cost study and impact of technical and environmental factors on the total expense and revenue of grid connected PV system are investigated in [1]. The detailed modeling of PV cell is reported in [2]. In paper [3] examination of the voltage characteristics of a distribution system under high-density connection, and suitable voltage regulation method for high-density PV connections, using reactive power proportional to global irradiance is proposed. This paper [5] aims to investigate and emphasize the importance of the grid-connected PV system regarding the intermittent nature of renewable generation, and the characterization of PV generation with regard to grid code compliance. The dynamic response of a PV generation system to rapid change in irradiation is investigated in [6].

The modeling of switching inverter is done in [7]**.** A incremental conduction algorithm with fuzzy controller is proposed to get maximum power point (MPP) in the PV system under rapidly varying atmospheric and partial shading conditions [8].

The paper is organized as follows; Section 2 presents the mathematical modeling of PV system. Different configurations of power electronic interface grid connected PV system given in Section 3. The results and discussions are summarized of simulations are discussed in section 4. The conclusions are in section V.

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2. PV EQUIVALENT CIRCUIT

Fig 1 shows the equivalent circuit of PV cell with single diode here R_s represents the series resistance. Inside each cell in the connection between cells and the internal losses. The series resistance will vary with the temperature. The current through R_{sh} represents leakage current in the PV cell.

Figure 2 represents electrical characteristics of the cell. The charecterstics of PV cell are represented through their P-V and I-V curves. I-V curve is represented first and then PV curve, then how these vary with the change of radiation, temperature, diode quality factor, resistance across diode, and coupling of more cells either connected in series or in parallel. I_{sc} is short circuited current and v_{oc} is open circuit voltage. At these two points the power will be zero. The power generated from PV panel is dependent on resistance connected across it.

The PV curve we will get as multiplication of current and voltage.

$$I = I_{pv} - I_o * \left[\exp\left(\frac{V + I * R_s}{A * V_T} \right) - 1 \right] - \left(\frac{V + I * R_s}{R_{sh}} \right) \tag{1}$$

$$I_D = I_o \left[\exp\left(\frac{V}{A v_t} \right) - 1 \right] \tag{2}$$

$$P_{max} = v_{max} * i_{max} \tag{3}$$

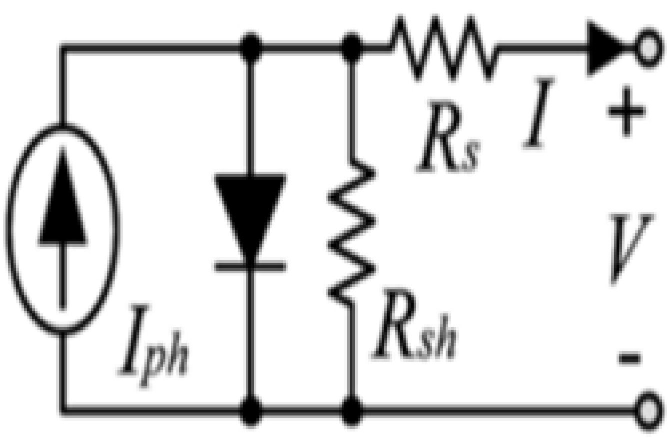


Figure 1: Equivalent circuit of PV cell

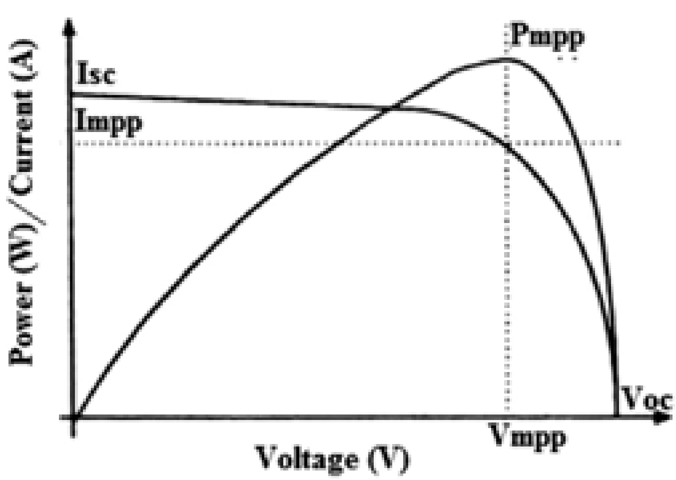


Figure 2: Current vs voltage and power vs voltage characteristic of a PV cell

Grid connected PV panel with power electronic interface

Many methods are available interfacing PV system with utility grid. In this paper, a power electronic interface using boost converter and inverter are proposed with maximum power point tracking (MPPT). This paper presents the design, simulation and implementation of a simple power electronic interface for grid connected PV array using boost converter and inverter. The controller extracts maximum power from the solar array and feeds it to the boost converter switch and then it is send to inverter. The output o inverter is interconnected with single phase utility grid. Fig 3 shows the block diagram of grid connected PV panel.

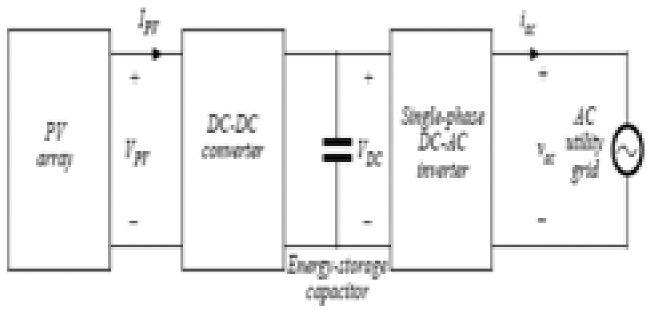


Figure 3: Block diagram of grid connected PV panel

Functions of the power electronics converter

Operate PV array at the maximum power point (MPP) under all conditions

- Generate AC output current in phase with the AC utility grid voltage
- Achieve power conversion efficiency close to 100%

3.1. Maximum power point tracking algorithms

Solar irradiation that incident on the PV cells has a different charecterstics depending on the latitude, orientation of the solar field, the season and hour of the day. During the day time, a shadow may be cast on the cell that may be foreseen, as in the case of a building near the solar field or unforeseeable as those

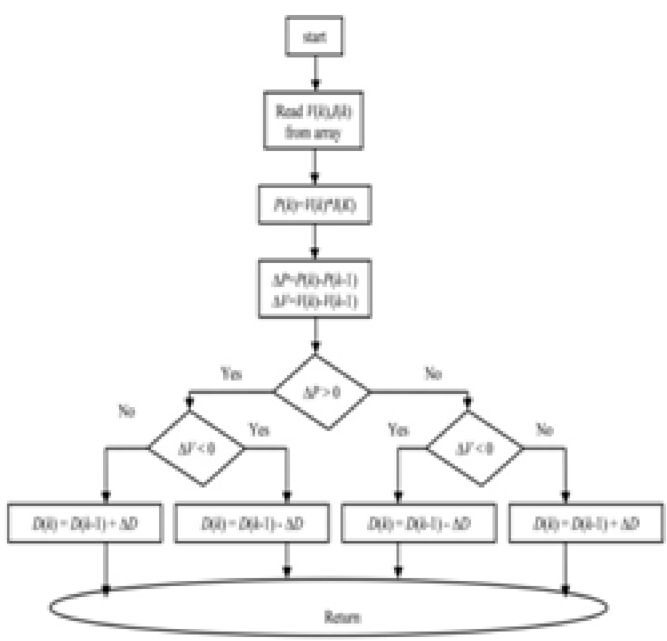


Figure 4: Perturb and observe flowchart

created by clouds. Also the energy produced by each photovoltaic cell depends on the irradiation and temperature. From these considerations, there is necessity to identify maximum power point instant by instant that particular point on the V-l characteristic of the PV generator at which there is the maximum amount of power transfer to the grid occurs. Each PV cell has an individual operating point where it can provide the highest electrical power at maximum power point (MPP). The tracking of maximum power point of the PV panel under intermittent atmospheric condition and partial shading condition get complex due to the presence of multiple local maximum for each panel. So it is nessasary to use an effective MPPT algorithm to track MPP. Different MPPT algorithms are available among those simplest methods for MPPT is perturbation and observation (P&O), and incremental conductance.

Perturb and Observe (P&O)

The flowchart in figure 4shows for the Perturb and Observe MPPT algorithm in which the controller is to compare every time with the previously available power with present power if present power is greater means the duty cycle will increase. Otherwise it will reduce by small value. However, this algorithm may not work properly or oscillate near the maximum power point (MPP) under sudden atmospheric changes or with the partial shading. The incremental conductance method can track changing irradiance conditions with higher accuracy than P&O.

Incremental conductance

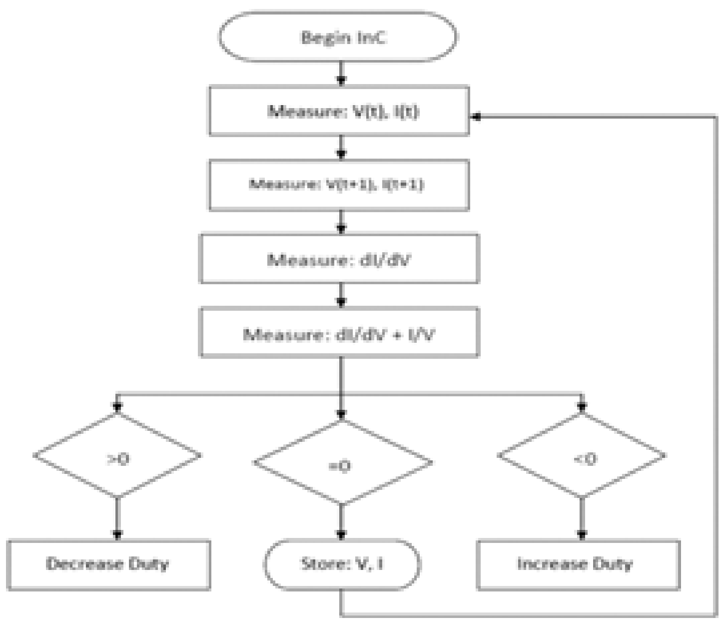


Figure 5: Incrimental conductance algorithm

$$dI/dV = -I/V \text{ at MPP} \tag{4}$$

$$dI/dV > -I/V \text{ left of MPP} \tag{5}$$

$$dI/dV < -I/V \text{ right of MPP} \tag{6}$$

In the incremental conductance algortham, the controller checks with incremental changes in PV array conductance with respect to current and voltage to predict the effect of a voltage change. This method needs more caluculations in the system, but can points correctly with changing conditions more quicky than the Perturb and Observe method (P&O). Like the P&O algorithm, this algoritham also produces oscillations in power at output but comparatively less then P&O. This method uses the incremental conductance (dI/dV) of the photovoltaic array to calulate the sign of the change in power with respect to voltage (dP/dV).

The incremental conductance method tracks the maximum power point by comparing incremental conductance to the actual conductance. When both are the same ($I / V = I_Ä / V_Ä$), the output voltage is the MPP voltage. The algorithm maintains this voltage and current until the irradiation changes if it changes the process will repeate.

3.2. Boost converter

DC-DC converter in figure 3 shows boost converter. The voltage generated from PV panel can be improved to grid level voltage. The boost converter can be modeled in two ways Average model, and Switching model.

Average boost converter

In this paper the average boost converter is modeled using duty cycle as $\frac{V_{out}}{V_{in}}$. The duty cycle is inversely proportional to output voltage (V_{out}). For example V_{out} is more means duty cycle will reduce to keep output put voltage within prescribed limits. The input current from the MPPT, the voltage is taken from solar panel. Ideal boost DC-DC converter works as an ideal DC transformer with an electronically adjustable step-up ratio.

Switching boost converter

In this model the controlling done by switch position. this will control the charging and discharging of capacitor and mode figure 6 shows the circuit diagram of switching boost converter. The control for switch will come from MPPT the voltage is taken from solar panel.

Inductor voltage and capacitor current when the switch is in position 1

$$V_L = V_S \tag{7}$$

$$I_c = -V/R \tag{8}$$

Inductor voltage and capacitor current when the switch is in position 2

$$V_L = V_S - V \tag{9}$$

$$i_c = i_L - V/R \tag{10}$$

Where,

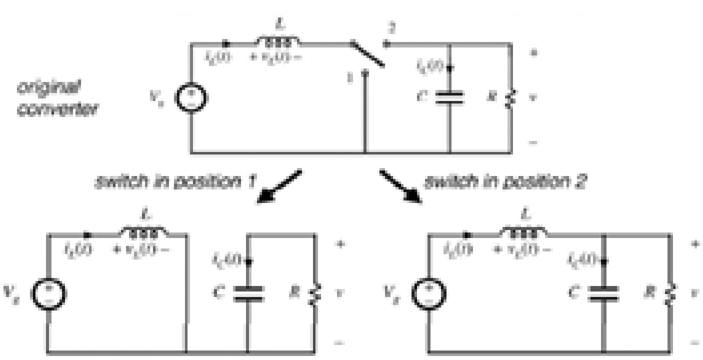


Figure 6: Switching model boost converter

V_s = supply voltage

V_L = inductor voltage

i_L = inductor current

i_c = capacitor current

v = load voltage.

3.3. Inverter

Switching inverter

The voltage from boost converter is DC. The voltage should invert to AC to integrate with the utility grid. The inverter for integration can be modeled in two ways switching inverter and average inverter. Switching inverter For switching pulse we are comparing duty cycle and triangular wave the intersection points will control the switching pulse at switching or high frequency the pulse will change the switch position. Figure 7 shows the circuit diagram of switching inverter.

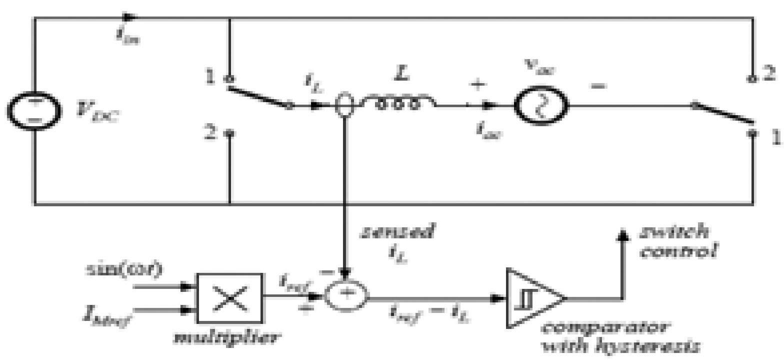


Figure 7: Circuit diagram of switching inverter

Position 1

$$V_L = V_{dc} - V_{ac} \quad (11)$$

$$i_L = i_{ac} \quad (12)$$

$$i_{in} = i_L \quad (13)$$

Position 2

$$V_L = - V_{dc} - V_{ac} \quad (14)$$

$$i_L = i_{ac} \quad (15)$$

$$i_{in} = - i_L \quad (16)$$

To overcome the disadvantages with switching inverter like ripple content in output, switching losses, switching delay, EMI interference, discontinuous and more data points to describe wave average inverter is adaptable.

Average inverter

For the average inverter the control value (duty cycle) for controlled current source is continuous and it is taken from the grid. Average inverter is considered as an ideal amplifier in many cases. I_{ac}=Duty cycle*I_{dc}. Figure 8 shows the block diagram of average inverter.

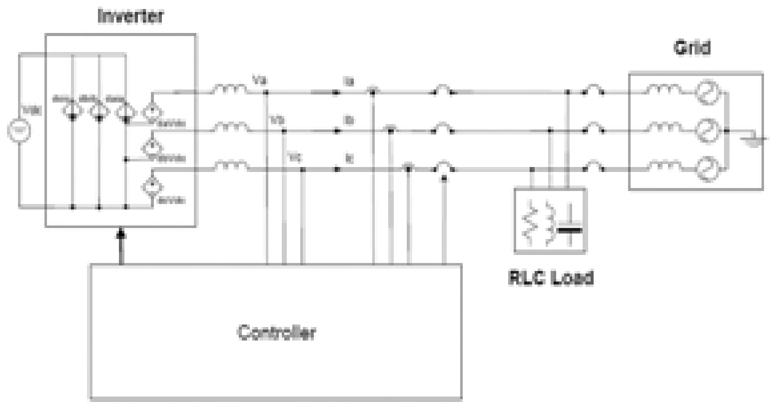


Figure 8: Circuit diagram of average inverter with load and grid

Worst prospective in average inverter: the current that is coming to the inverter is sin wave then we cannot take average inverter as simple amplifier as a relation between inputs to the output.

4. SIMULATION RESULTS

For single phase grid PV panel of 500W is connected to 1000W grid to supply a load of 1500W. For 500W power 36cells are in one module like this 6 modules are connected in series to get 108.6V and 4.7A current. For three phase grid connected PV panel the PV panel of 10KW is connected to three phase grid of 15KWto supply a load of 25KW.

The results of MPPT, boost converter, and inverter is checked with single phase grid connected PV panel of 500W. The best combination is used for three phase grid connected PV panel. The simulation is carried out in MATLAB/SIMULINK 2014b with processing speed of 1.9GHz.

Grid connected PV system with power electronic interface

Figure 9 shows the simulation diagram of grid connected PV system with power electronic interface along MPPT algorithm.

4.1. Comparison between two proposed MPPTs

In this paper comparison between two MPPT algorithms, perturb and observe and incremental conductance algorithm in order to get maximum power point. Figure 11 and figure 13 Shows the power of PV panel

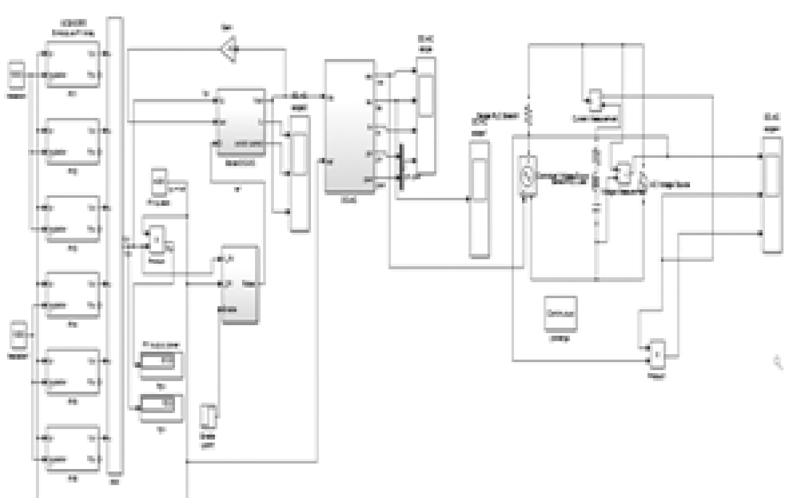


Figure 9: Simulation diagram of grid connected PV system with power electronic interface

under uniform and partial shaded conditions. Similarly figure 10 and figure 12 shows the current output for PV panel with perturb and observe and incremental conductance methods under uniform irradiation and partial shaded conditions. From the results we can conclude that incremental conductance MPPT algorithm will track maximum power pointwith less disturbance.

Comparison between perturb and observe and incremental conductance in order to get maximum power point

4.2. Comparison between switching boost converter and averaged boost converter

Boost converter output in uniform irradiation

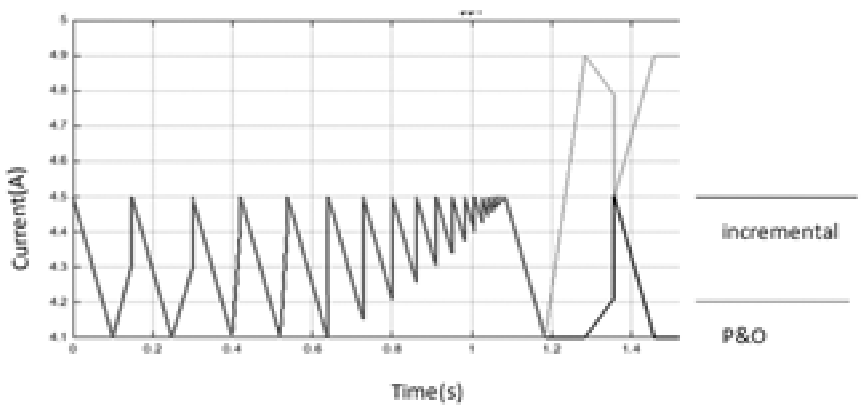


Figure 10: Current with P&O and incremental conductance

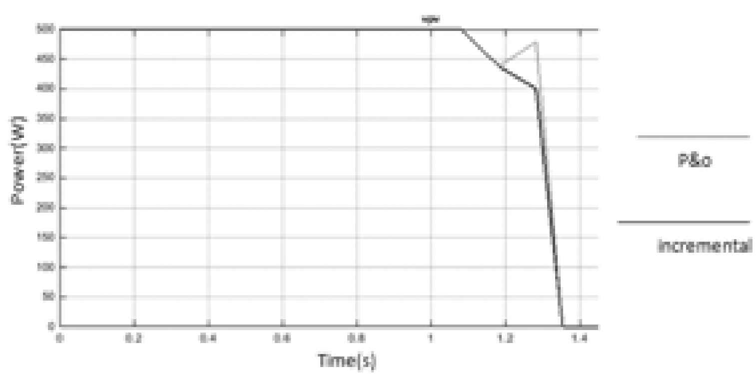


Figure 11: Power with P&O and incremental conductance

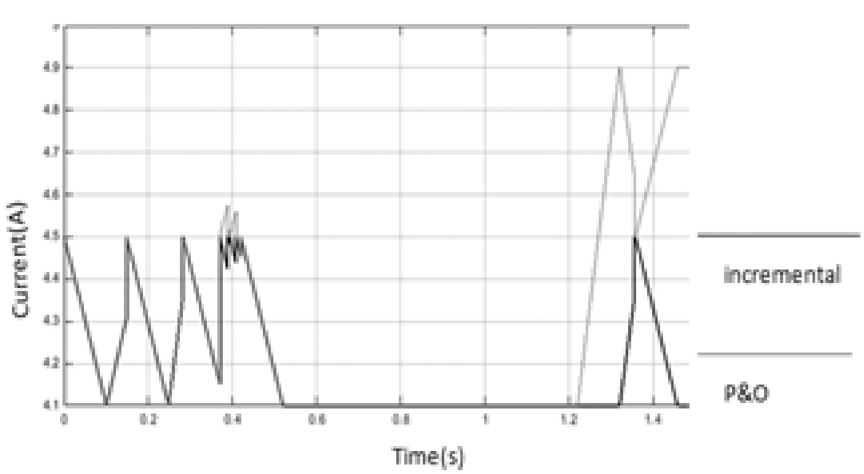


Figure12: Current with P&O and incremental conductance MPPT

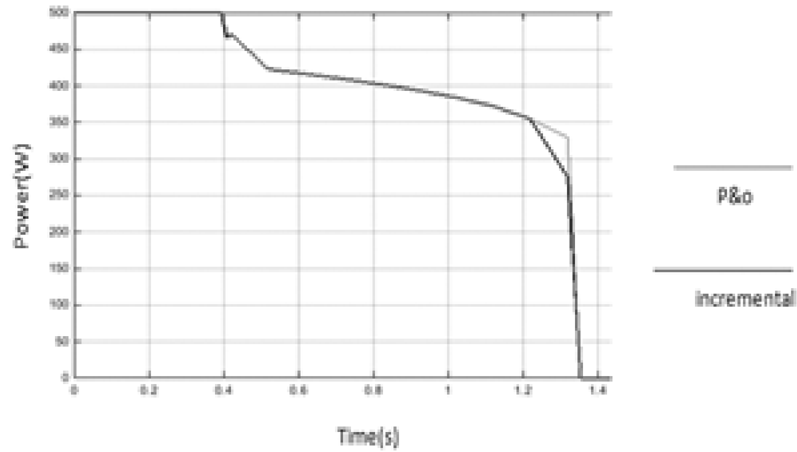
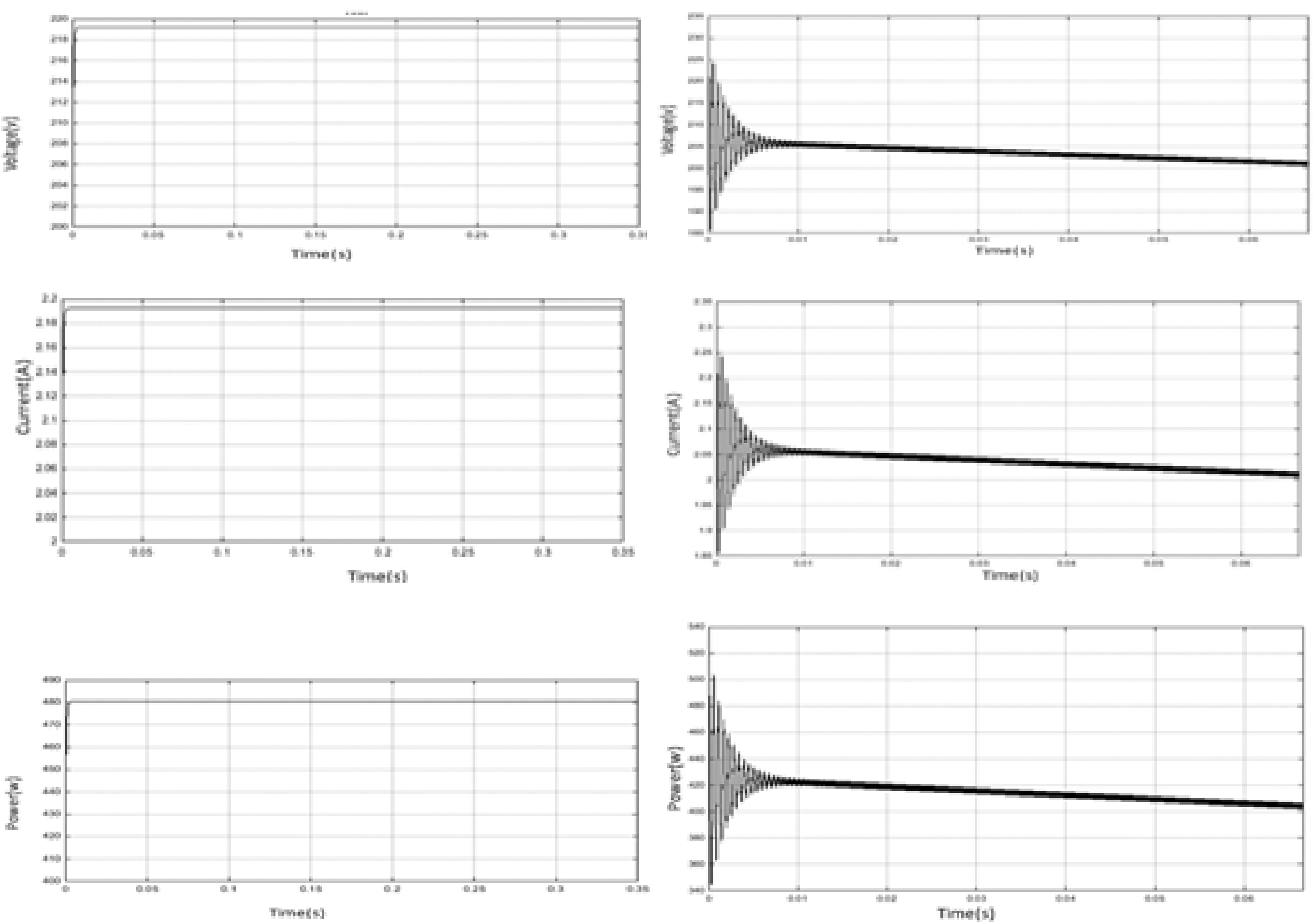


Figure13: Power with P&O and incremental conductance MPPT

The value of capacitor is $1*10^{-6}$F, the inductor value is 200e-6H and the switching frequency is$200*10^{-6}$ H. Output current, Voltage duty cycle from MPPT as an input and boosted voltage and current as an output. Figure 14 shows the output voltage, current, power of average and switching boost converter respectively.

By observing the graphs of average and switching mode boost converter the disturbance is very less in average boost converter in uniform irradiation.



(a) **(b)**

Figure 14: Voltage, current, power output of a. average boost converter b. switching boost converter

Boost converter in partial shading condition

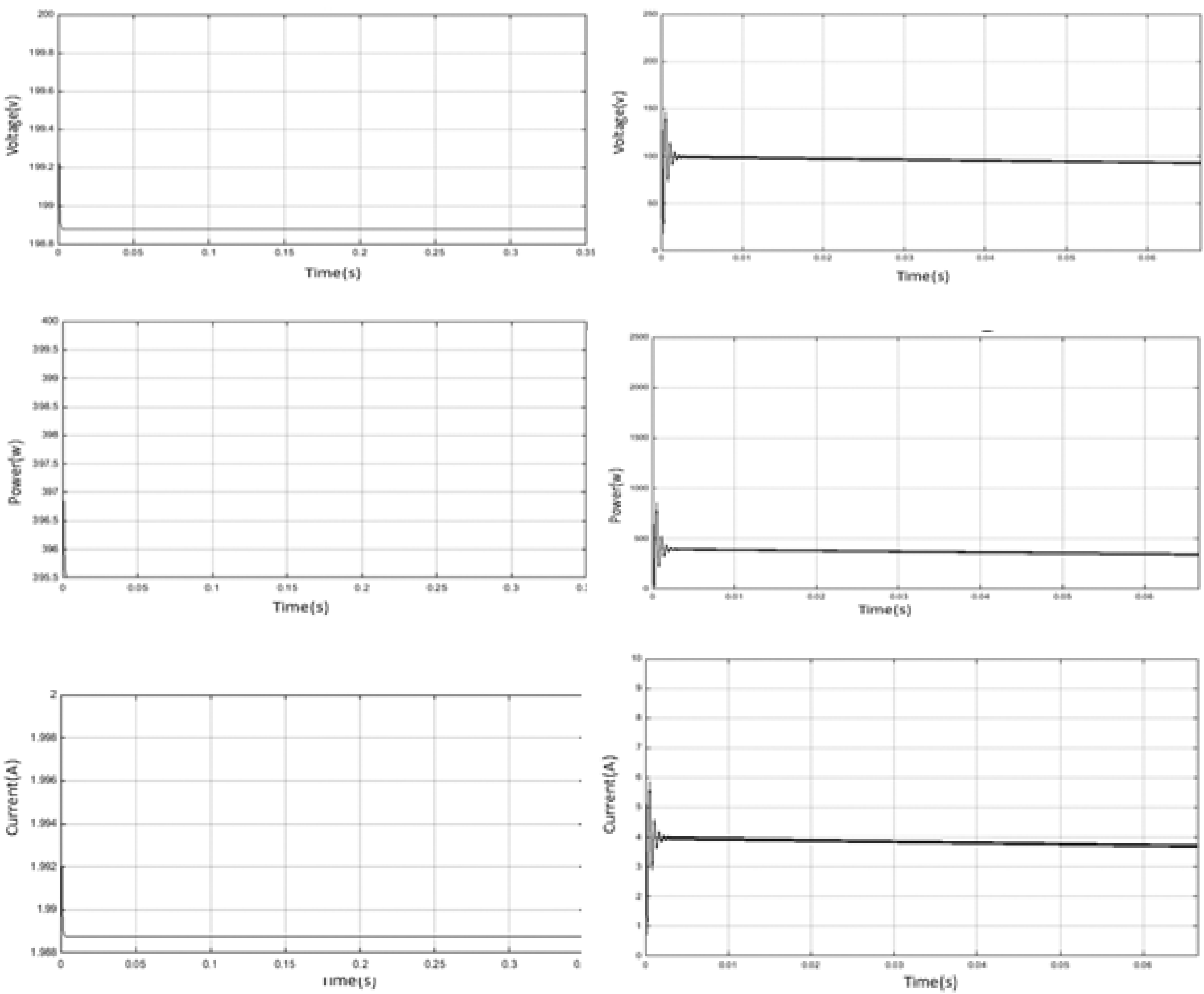
Partial shading means some cells are exposed to 1000w/m^2 and some cells are exposed to 300 w/m^2. Figure 15 shows the voltage, power, current output of average boost converter and switching boost converter respectively.

From the figure14 and figure 15 it is clear that disturbance content is less in switching boost converter but the efficiency is more in switching boost converter even in partial shaded conditions. The voltage is boosted to 230V.

4.3. Comparison between two inverter models

Switching model: For switching pulse compare a constant value and triangular wave the inter section points will control the switching pulse at switching or high frequency. The RMS voltage of ac source is 120V along with current controller series resistance is 0.8OHM inductor value is 20*10^{-6} H. figure 16a shows the output current, voltage, power respectively.

Average model: The switching network can be represented by controlled voltage and current sources with averaged switching duty cycle. The inputs are duty cycle, AC current and DC voltage outputs are AC



(a) (b)

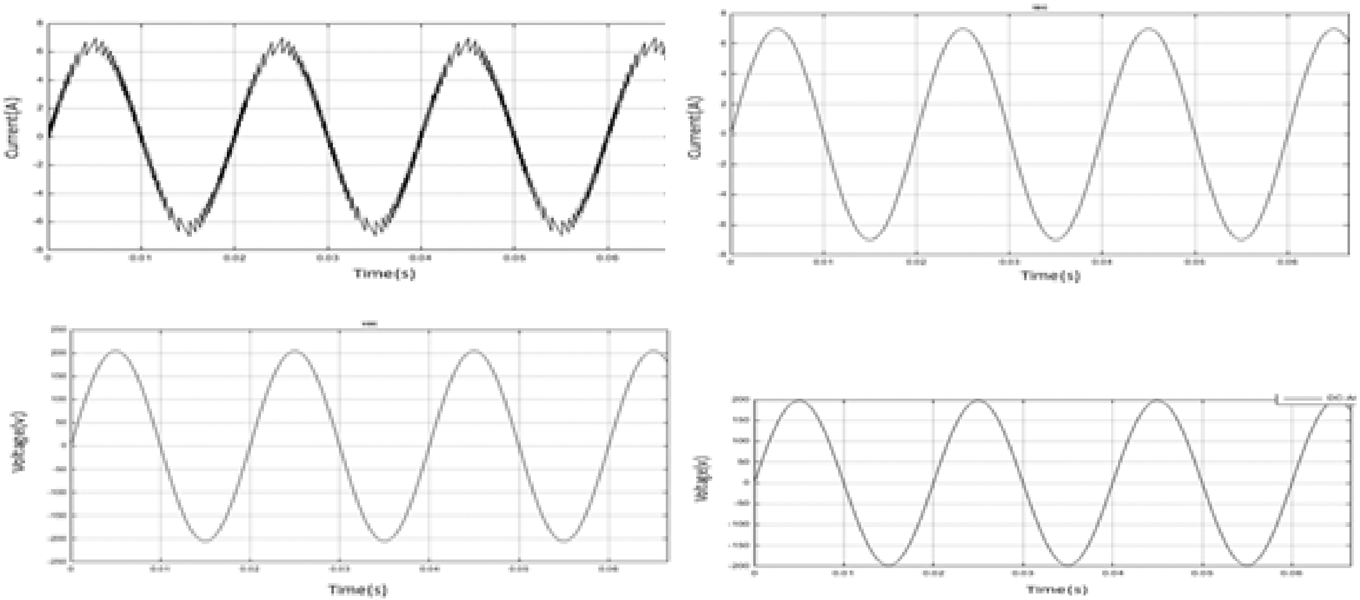
Figure15: Output voltage, power, current of a. average boost converter b.switching boost converter under partialshading conditions

current and voltage. The duty cycle should be limited between 0 and 1. Otherwise energy conversion equation is not satisfied. Inverter is considered as a linear amplifier. Figure 16b shows the output current, voltage, power respectively.

By seeing graphs we are able to know harmonic content is very less in average inverter compared to switching inverter.

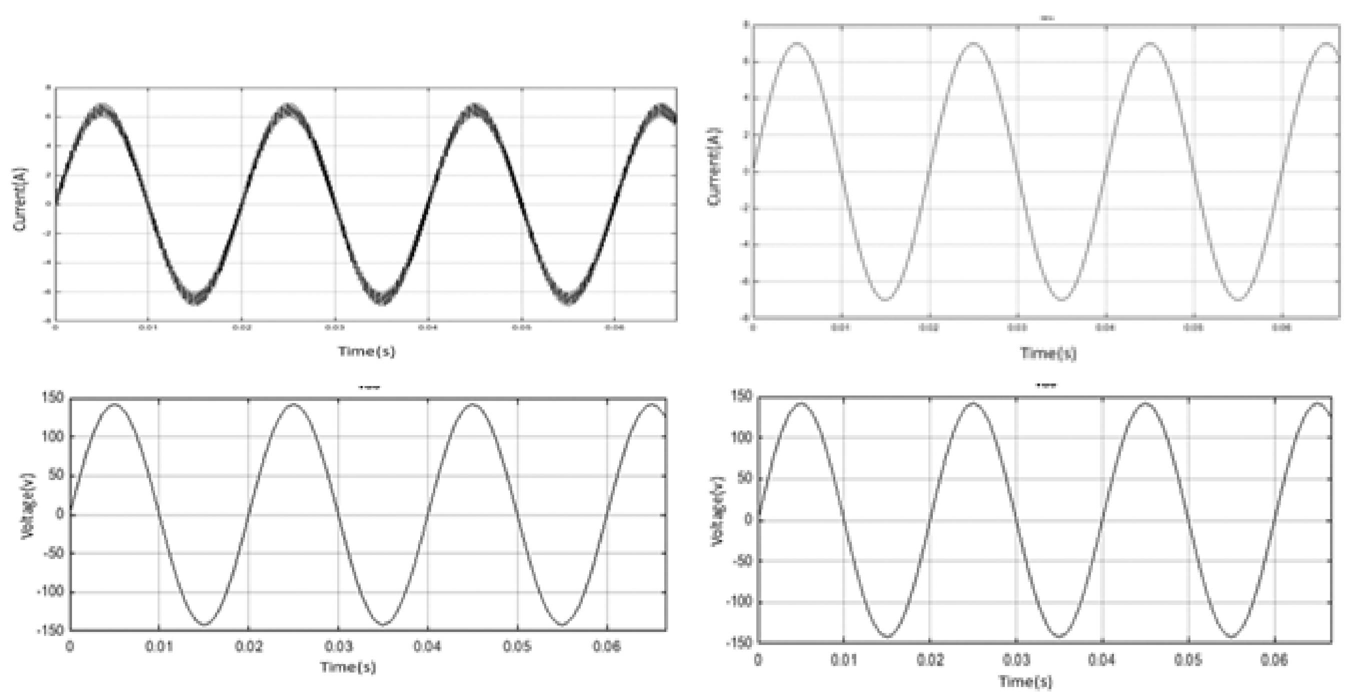
Inverter output with partial shading

After the result from figure 16 and figure 17 it is clear that total harmonic distortion is very less in average inverter compared with switching mode inverter even in partial shading condition.



(a) **(b)**

Figure 16: Current, voltage, power of a. switching inverter b. average inverter



(a) **(b)**

Figure17: Output current, power, voltage of a. Switching inverter b. Average inverter in partial shading condition

4.4. output of inverter connected to utility grid

Three phase grid connected PV panel

Tthe PV panel is of 10KW is integrated with three phase grid of 15KW is supplied to 25KW load figure 19 shows the output voltage of three phase load.

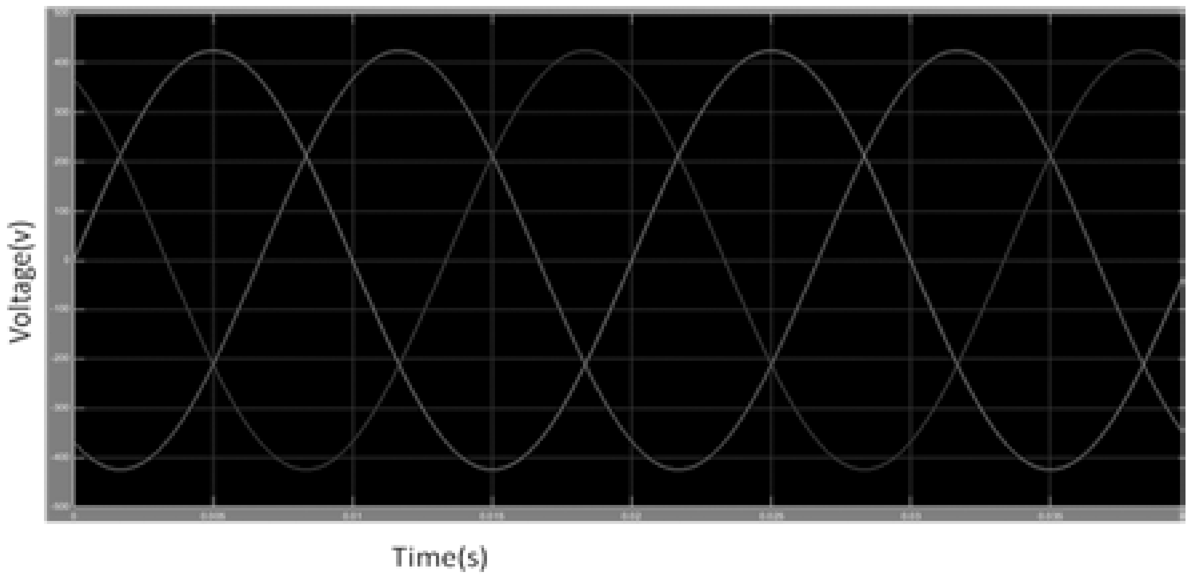


Figure 18: Voltage of three phase load

Table 1
Comparisons of different combinations of MPPT and power electronic interface:

	efficiency	*Total harmonic distortion*	*Simulation time*
Average booster and average inverter	94	0.18	Fast
Average booster and switching inverter	96.2	7.95	moderate
Switching booster and average inverter	96	0.37	Moderate
Switching booster and switching inverter	99	7.79	slow
Switching booster and switching inverter with passive filters	93	5.17	slow

5. CONCLUSIONS

Comparison between PandO and incremental conductance algorithms concluded that the incremental conductance mppt algorithm will result fast tracking and with less harmonics. Comparison between switching boost converter and average boost converter found that harmonic content and simulation time is less in average model with uniform irradiance and it is more with partial shading, but efficiency is less in average model switching booster is selected with reasonable disturbance. Comparison between average and switching inverter by seeing the graphs of two inverter harmonics are very less in average model when compared to switching inverter with passive filter. The efficiency is also high compared to switching inverter with passive filter.

The combination of incremental conductance, switching boost converter, and average inverter made better combination compared to other combination. The harmonic distortion is very less compared to traditional methods even in partial shading conditions.

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