MODELING AND SIMULATION OF SOLAR PHOTOVOLTAIC SYSTEM

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ABSTRACT

Solar energy is a vital untapped resource in a tropical country like ours. The main hindrance for the penetration and reach of solar PV systems is their low efficiency and high capital cost.
The efficiency of solar PV is very low. In order to increase the efficiency, Maximum Power Point Tracking (MPPT) techniques are to be undertaken to match the source and load property. These techniques are employed in PV systems to make full utilization of PV array output power. Recently, many MPPT algorithms of PV system have been proposed which depends on solar irradiation and temperature, but perturb and observe (P&O) and Incremental conductance algorithms are basic and most widely used. This project firstly introduces a Mat lab Simulink of photovoltaic array. To achieve the maximum power point tracking the Incremental Conductance method and perturb and observed (P&O) method are used. These two algorithms are employed with PV model along with converter in Mat lab Simulink.Three different converter boost, buck boost and cuk converter are design according to requirement and used. Fewcomparisons such as voltage, current and power output for each different combination have been recorded.

I INTRODUCTION

The Sun-that Power Plant in the Sky-bathes Earth in Ample of Energy to fulfil world's power needs many times over. It doesn't give out CO2 emissions. It won't run out &it's free.

For all practical purposes, renewable resources can be considered to be inexhaustible unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of clean & renewable energy sources. Clean Development Mechanisms (CDMs) are being adopted by the organizations all across the globe.Apart from rapidly decreasing reserves of fossil fuels in the world, another major factor working against is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without harmful effects of pollution unlike their conventional counterparts.

The sunlight reaching the Earth's surface generates six thousand times more than the estimated 15 Terawatts (TW) of power consumed around the globe every year. Thus it may be the most promising energy of the non-conventional energy sources. It's no wonder then, that mankind has long sought to capture and use the power of the sun. The challenge has always been the efficiency of capture and distribution.By leveraging capabilities of the photovoltaic process, as photons of sunlight, comprised of energy particles of different wavelengths hit a photovoltaic cell, their energy is transferred to the electrons which become part of a current in an electrical circuit. Solar panel converts 30-40% of energy incident on it to electrical energy.

Temperature and Irradiation are the major hindrances in exploitation of solar cell efficiency and consequently the need for Algorithm arises for getting the maximum power output from the solar cell. And hence PV power control is one of the burning research fields these days.There are different techniques for MPPT such as Perturb and Observe (hill climbing method),Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage,Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O)and Incremental conductance are most commonly used because of their simple implementation,lesser time to track the MPP and several other economic reasons.

Under abruptly changing weather conditions (irradiance level) as MPP changes continuously,P&O takes it as a change in MPP due to perturbation rather than that of irradiance andsometimes ends up in calculating wrong MPP. However this problem gets avoided inIncremental Conductance method as the algorithm takes two samples of voltage and current tocalculate MPP. However, instead of higher efficiency the complexity of the algorithm is veryhigh compared to the previous one and hence the cost of implementation increases. So we haveto mitigate with a tradeoff between complexity and efficiency.

II MODELLING OF SOLAR PHOTOVOLTAIC SYSTEM

2.1 Solar Photovoltaic (SPV) System

The process of converting light (photons) to electricity (voltage) is called the photovoltaic (PV) effect. A photovoltaic (PV) system directly converts sunlight into electricity. The basic device of a PV system is the photovoltaic (PV) cell.A PV cell typically produces voltage 0.5 volt. In order to increase the voltage cells are connected in series and to increase the current they are connected in parallel. The photovoltaic module is the result of associating a group of PV cells in series and parallel and it represents the conversion unit in this generation system.An array is the result of associating a group of photovoltaic modules in series and parallel.

2.2 Equivalent Circuit of PV Cell

The equivalent circuit, which describes the static behaviour of the solar cell, is commonly composed of a current source, a pn junction diode and a shunt resistor (Rsh) in parallel along with a series resistor (Rs). The current source models electron injection from light. Rs is the total Ohmic resistance of the solar cell, which is essentially the bulk resistance. Smaller Rs values equate to increased solar cell efficiencies. Rsh accounts for stray currents, such as recombination currents and leakage currents around the edge of devices. In this case a larger Rsh value equates to increased solar cell efficiency, since it means that the stray currents are reduced.

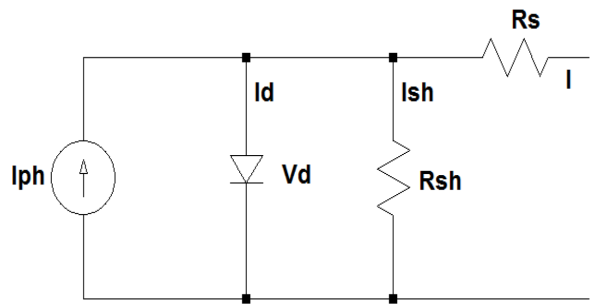


Figure 1 Single Diode Equivalent Circuit of Solar Cell.

III I-V AND PV CHARACTERISTICS

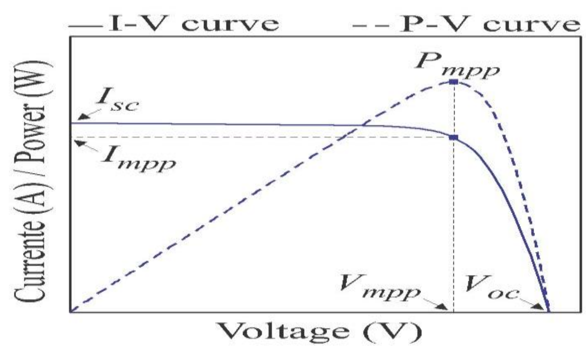


Figure 2: IV and PV Characteristics of a Solar Cell.

The I-V and P-V characteristics are shown in fig. where Vmpp indicates voltage at Maximum power point and Impp indicates the current at maximum power point. The ratio of power at maximum power point and product of open circuit voltage and current is called Fill factor which decide the quality of cell. Generally fill factor lies 0.5 to 0.8.

IV CONVERTER DESIGN AND SIMULATION

4.1 Designing of Converters

DC/DC converters are used in applications where an average output voltage is required, which can be higher or lower than the input voltage. To maximize the power output of the PV system, a high-efficiency, low-cost DC/DC converter with an appropriate maximum power point tracking (MPPT) algorithm is commonly employed to control the terminal voltage of the PV system at optimal values in various solar irradiation conditions.

A dc to dc converter which interface between load and module, serve the purpose of transferring maximum power from PV module to the load. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power as shown in Fig 3.

The aim of this work is to make a comparative of the photovoltaic system performance using the three basic topologies of three different DC-DC converters.

4.2 Boost Converter

A power converter whose dc input voltage is less than the dc output voltage. This means the PV input voltage is less than the battery voltage in the system.

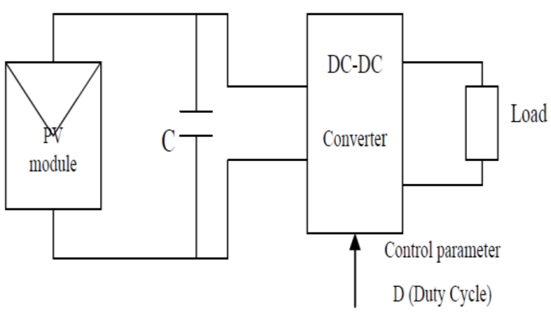


Fig.3 PV Module with dc-dc Converter

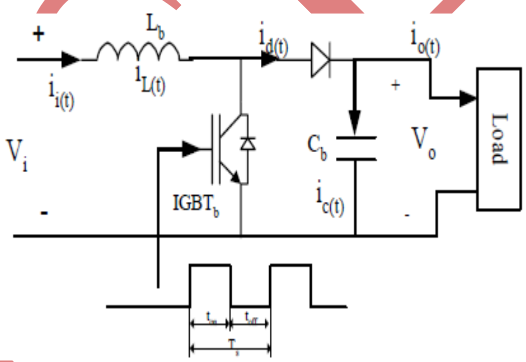


Fig.4 Circuit Diagram Of Boost Converter

4.3 Mode of Operation

4.3.1 The First Time Interval: The transistor is in ON state and diode is OFF

In this time period the inductance L stores energy. The load current is assured by the output capacitor as shown in Fig 5.

4.3.2 The Second Time Period: The Transistor is OFF and Diode is ON

In the moment when the transistor switch in OFF state, the voltage across the inductor will change the polarity and diode will switch in ON state. The energy stored in the inductor will supply the load as shown in Fig 6.

4.3.3 The Third Operation Mode: The Both Transistor and Diode are OFF

If the inductor current becomes zero before ending the diode ON period, both the transistor and the diode will be OFF. Due to the diode current becomes zero, the diode will naturally close, and the output capacitor will discharge on the load. This operation regime is called discontinuous current mode as shown in Fig 7.

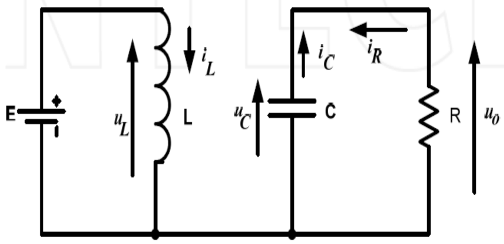


Fig 5 When Switch is ON and Diode is OFF

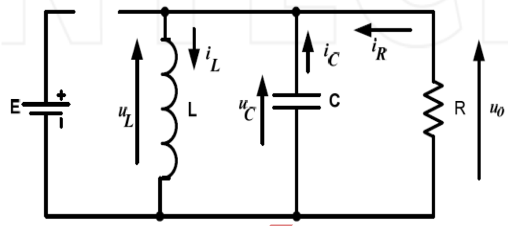


Fig 6 When Switch is OFF and Diode ON

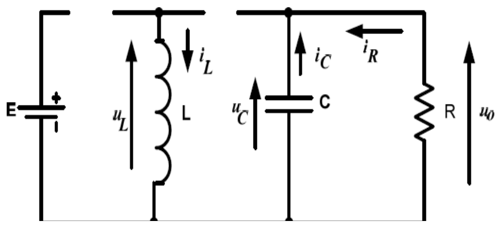


Fig 7 When Switch and Diode Both OFF

V SIMULATION OF SPV SYSTEM

TABLE 1 Parameters of the KC200GT Solar Array at 25 ◦C,1000W/m2.

Parameter	Value	Parameter	Value
Imp	7.61	Ns	54
Vmp	26.3 V	I0,n	9.825 · 10−8 A
Pmax	200.143	Ipv	8.214 A
Isc	8.21 A	a	1.3
Voc	32.9 V	Rp	415.405 ohm
Kv	-0.1230 V/K	Rs	0.221 ohm
Ki	0.0032 A/K		

The photovoltaic array can be simulated with an equivalentcircuit model based on the photovoltaic model of Fig. 8.

Fig 9. shows a circuit model using one current source(Im) and two resistors (Rs and Rp). This circuit can beimplemented with any circuit simulator. The value of themodel current Im is calculated by the computational blockthat has V , I, I0 and Ipv as inputs. I0 is obtained from(4) or (6) and Ivp is obtained from (3). This computational block may be implemented with any circuit simulator able to evaluate math functions.

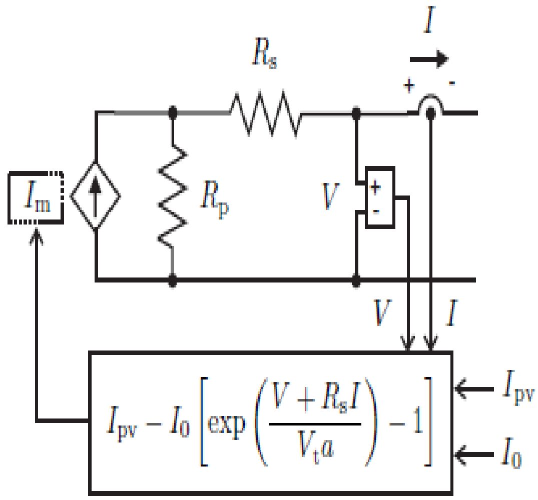


Figure 8 Photovoltaic array model circuit with a controlled current source, equivalent resistors and the equation ofthe model current (Im).

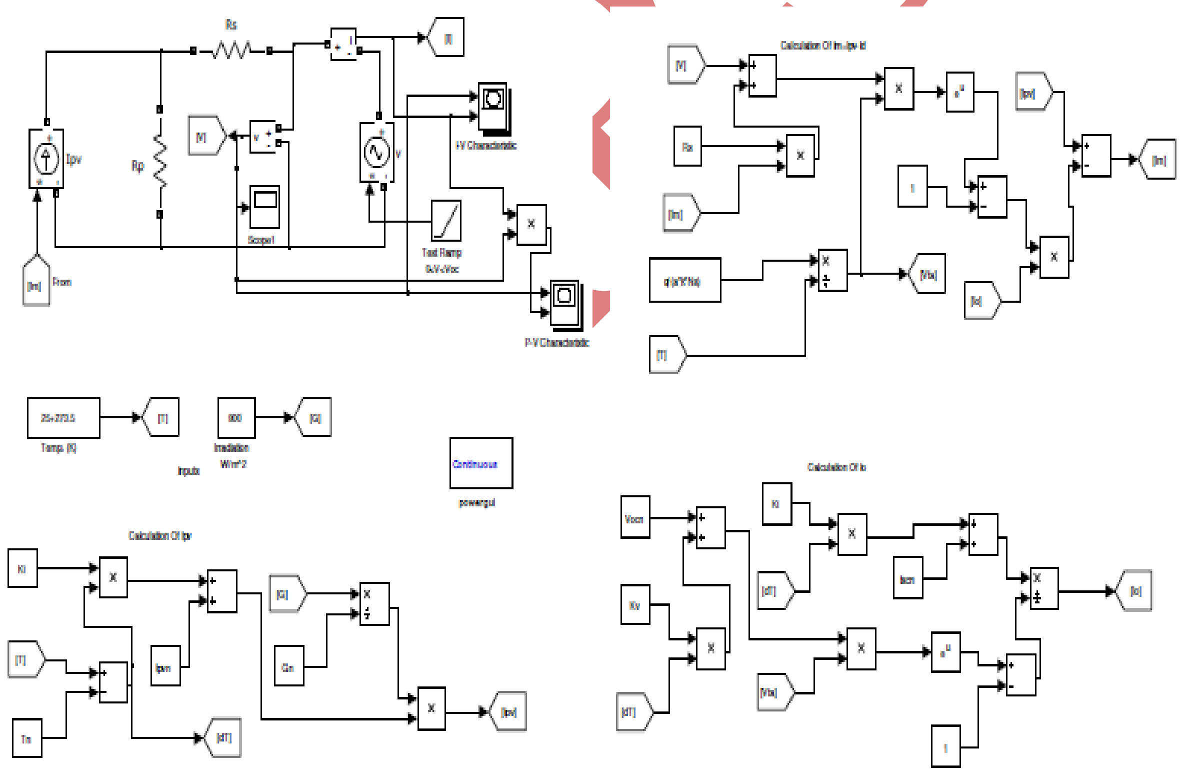
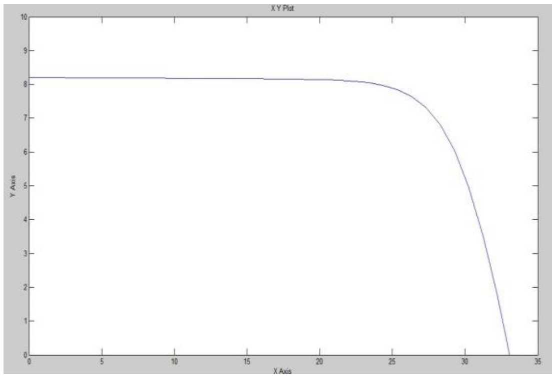


Figure 9 Photovoltaic circuit model built withMATLAB/SIMULINK.

VI RESULTS

6.1 Simulation of IV and PV curve of solar array.



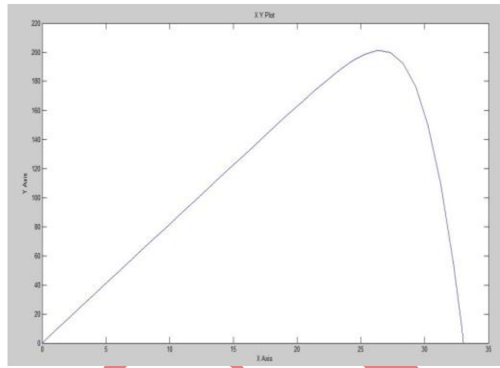


Figure 10 IV characteristics of solar array. at 1000 W/square m

Figure 11 PV characteristics of solar array at 1000 W/square m.

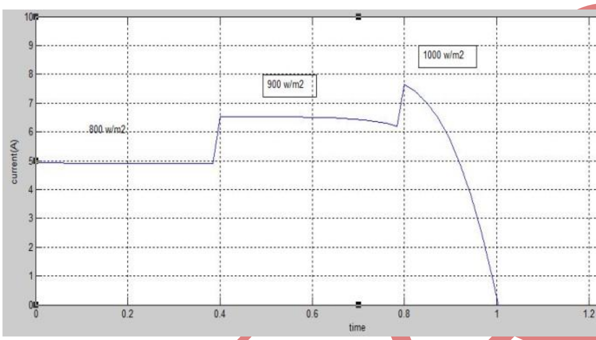
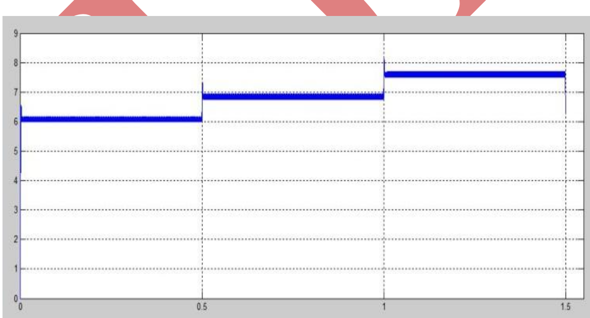


Figure 12 Variation in current with change in irradiation.

6.2 Simulation result of MPPT model with boost converter with IC Algorithm:



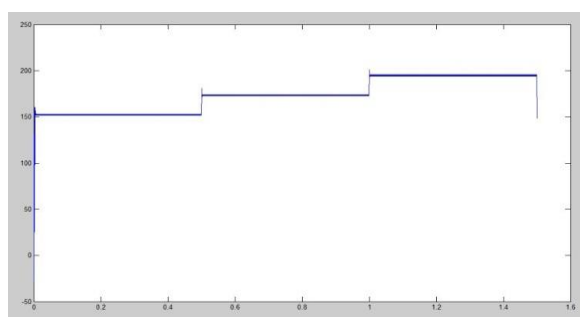
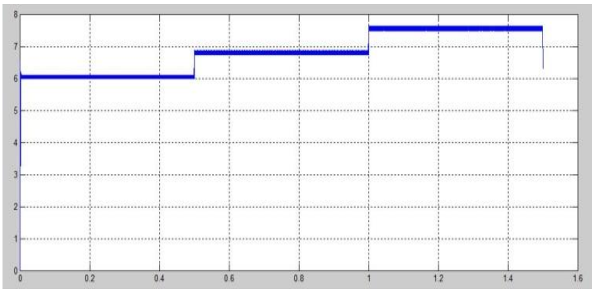


Figure 13 Waveform of current at different. irradiation using boost converter.

Figure 14 Waveform of the power at different irradiation using boost converter.

6.3 Simulation result of MPPT model with boost converter with PO Algorithm:



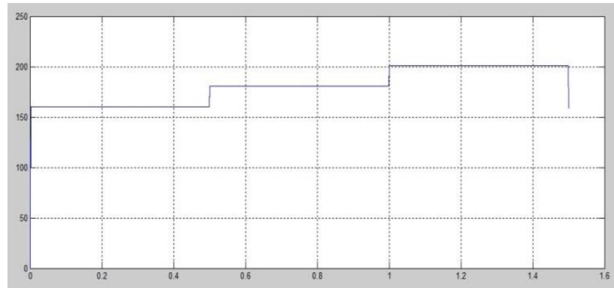
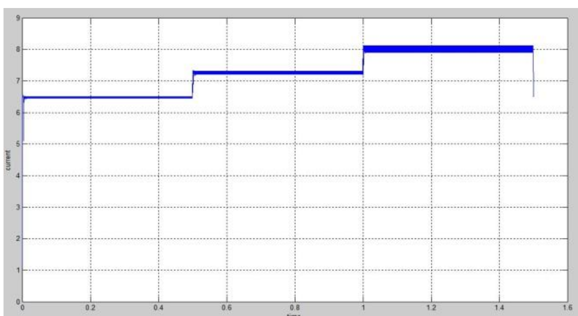


Figure 15 Waveform of current at different irradiation using boost converter.

Figure 16 Waveform of the power at different irradiation with boost converter.

6.4 Simulation result of MPPT model with buck boost converter with IC Algorithm:



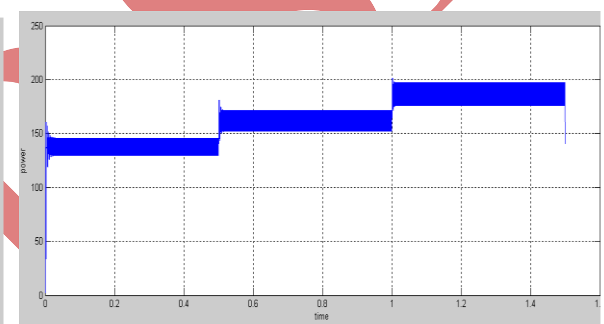
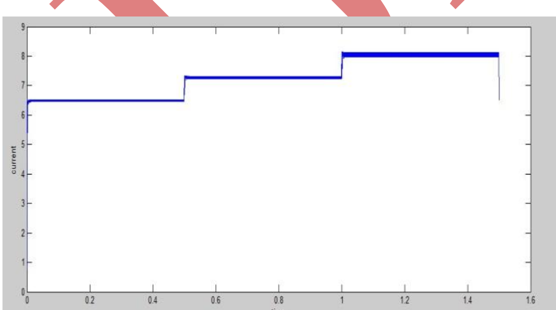


Figure 17 Waveform of current at different irradiation with buck boost converter.

Figure 18 Waveform of the power at different irradiation with buck boost converter.

6.5 Simulation result of MPPT model with buck boost converter with PO Algorithm:



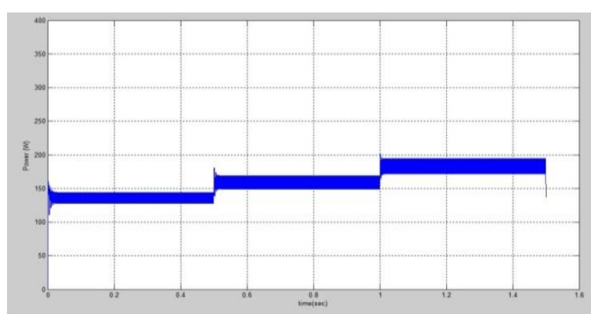


Figure 19 Waveform of current at different irradiation with buck boost converter.

Figure 20 Waveform of the power at different irradiation with buck boost converter.

6.6 Simulation result of MPPT model with CuK converter with IC Algorithm:

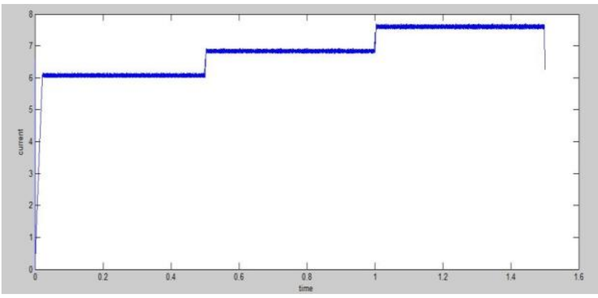


Figure 21 Waveform of current at different irradiation with Cuk converter.

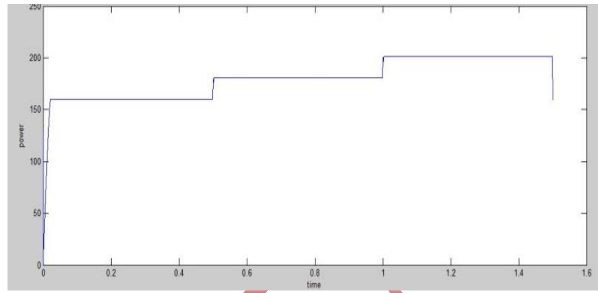


Figure 22 Waveform of the power at different irradiation with buck boost converter.

6.7 Simulation result of MPPT model with CuK converter with PO Algorithm:

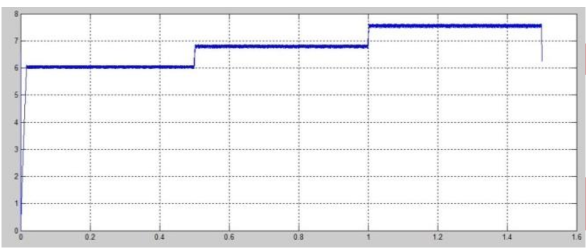


Figure 23 Waveform of current at different irradiation with Cuk converter.

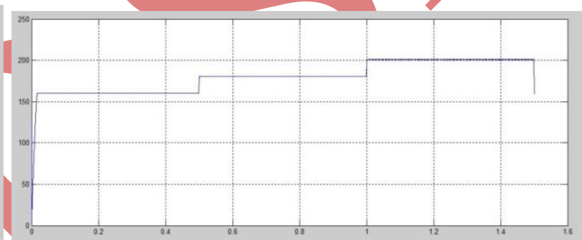


Figure 24 Waveform of the power at different irradiation with buck boost converter.

6.8 Output voltage across the load

a) With boost converter

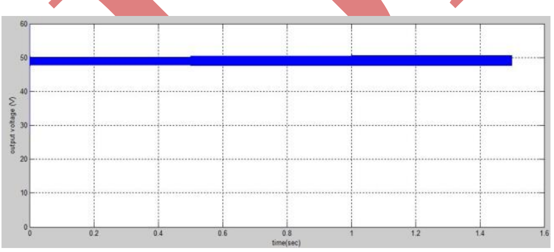


Figure 25 Waveform of the Voltage at output with boost converter.

b) With Buck boost converter

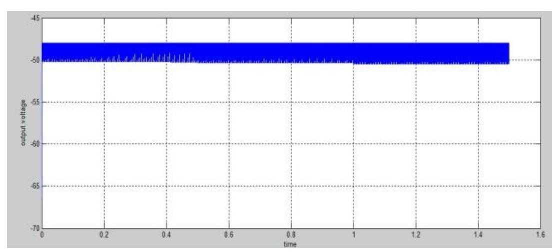


Figure 26 Waveform of the Voltage at output with buck boost converter.

c) With Cuk converter

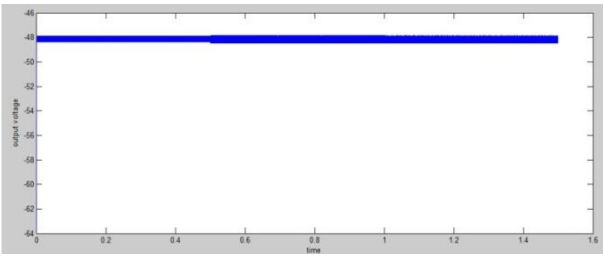


Figure 27 waveform of the Voltage at output with Cuk converter.

VII DISCUSSION

In this project, we have gone through the Solar Cell Equations and its Simulation. Along with this, we also incorporated the study of various MPPT Algorithms for maximum power output from the solar cell module or panel.From the various algorithms, we have implemented the Incremental Conductance Algorithm in Matlab Simulink. We have compared the output from the Solar Cell incorporating MPPT Algorithm with the output without MPPT incorporation.

Through solar array, we are getting the MPP current of around 7.61A while the MPP voltage is around 26.3V. The maximum power output we are getting from solar array alone is around 200W. To get this constant output voltage, we have implemented the MPPT Algorithms with different converters like dc-dc Boost, Buck-Boost and Cuk Converter.Employing Boost converter, the results of MPP current and power are almost same in both the algorithms. There is minor variation with the actual value of MPP current and maximum power from actual value. However there are reduced ripples upon implementation of P&O algorithm.

Employing Buck-Boost Converter, however the values of MPP current and maximum power are good but the ripples in the output voltage is much increased which are completely undesirable.Finally with Cuk Converter, the results are good and the ripples are much reduced. However, the value of MPP current and maximum power are almost equal and the output voltage across the load almost equal to the desirable.

And from converters, the best results are obtained from Cuk Converter since the output voltage is much closer to the actual. The output voltage of cuk converter is around 48V with inverted polarity whereas the required output is also 48V. In the end, the IC MPPT Algorithm used model with Cuk Converter has better results than P&O MPPT Algorithm used model. So we would suggest using IC Algorithm for Maximum Power Point Tracking of solar photovoltaic system and cuk converter for maintain output voltage constant. The value of MPP circuit current is around 7.6A while the value of maximum power is 200W.

Tracking Efficiencies Observed:

For Irradiation of 1000W per square m

With Boost Converter:

IC Algorithm = 96.53%; P&O Algorithm = 99.0%

With Buck-Boost Converter:

IC Algorithm = 95.54%; P&O Algorithm = 95.54%

With Cuk Converter:

IC Algorithm = 99.50%; P&O Algorithm = 99.0%

CONCLUSION

1. There is higher number of applications of SPV system like space applications, providing electricity to remote areas etc.
2. Simulation of solar cell gives us a in depth idea of solar cell and the origin of its characteristics.
3. MPPT increases the efficiency of SPV system with tracking efficiencies ranging from 80%-99%.
4. Reaching a stable, true MPP at steady state instead of oscillating around this point would further improve the system's efficiency and increase reliability.
5. Thus, implementing the Incremental Conductance Algorithm is a good choice.
6. Through simulation we can see that the system completes the maximum power point tracking successfully despite of fluctuations. When the external environment changes suddenly the system can track the maximum power point quickly. Although there is little deviation in the results, the overall trends and forms are practical.

FUTURE WORK

In future, we would like to develop two different working model of Solar Photovoltaic system employing these algorithms practically using Cuk Converter.

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