Modeling and Simulation of Solar Photovoltaic System

Irfan Khan
Student of M.Tech Power System, MTPS-13-29 , Department of Electrical & Electronics Engineering, AL- Falah University, Faridabad, Haryana, India

Ameen Uddin Ahmad
Assistant Professor, Department of Electrical & Electronics Engineering, AL- Falah University, Faridabad, Haryana, India

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. Few comparisons such as voltage, current and power output for each different combination have been recorded**.**

Keywords: Perturb and Observe, Incremental Conductance, Maximum Power Point Tracking, energy storage system

INTRODUCTION

The Sun-that Power Plant in the Sky-bathes Earth in Ample of Energy to fulfill world's power needs many times over. It doesn't give out CO_2 emissions. It won't run out & its free.

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 and sometimes ends up in calculating wrong MPP. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases. So we have to mitigate with a tradeoff between complexity and efficiency.

1. MODELING OF SOLAR PHOTOVOLTAIC SYSTEM

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.

Equivalent Circuit of PV Cell: The equivalent circuit, which describes the static behavior 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). Thecurrent 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.
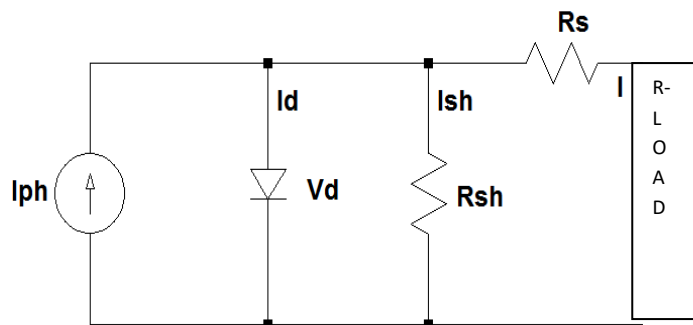

Fig. 1 Single diode Equivalent circuit of solar cell

2. CONVERTER DESIGN AND SIMULATION
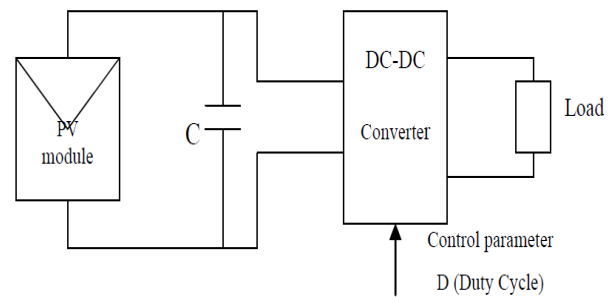
Designing of Converters

Fig.-2 PV module with dc-dc converter

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.

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. This are discussed below:

1. **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.
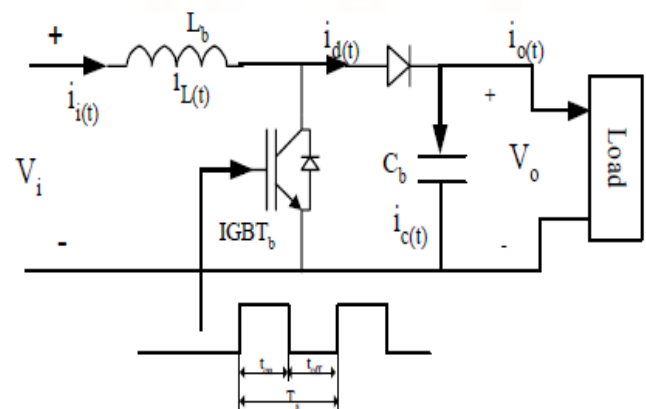

Fig.3 circuit diagram of Boost converter

2. **Buck-Boost Converter:** This is a combination of buck converter and a boost converter. Here, the output voltage can be increased or decreased with

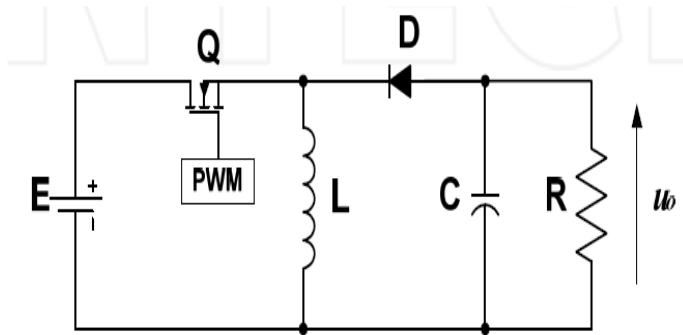respect to the input voltage by varying the duty cycle.

Fig. 4 Circuit Diagram of Buck-Boost Converter

3. **Cuk converter:**
   CuK converter is actually the cascade combination of a boost and a buck converter. The capacitor C1 acts as a primary means to store and transfer the power from input to output. The voltage vc1 is always greater than either input or output voltage. The average output to input relations are similar to that of a buck-boost converter circuit.
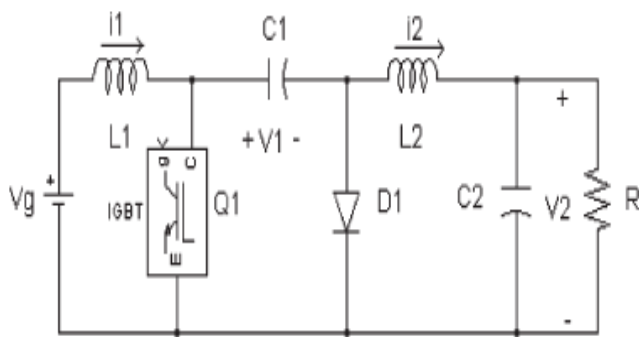
Fig. 5 Circuit representation of CuK converter

4. SIMULATION OF SPV SYSTEM

Simulation of Solar Array: Following shows the equivalent circuit of the ideal photovoltaic cell. The basic equation from the theory of semiconductors that mathematically describes theI-V characteristic of the ideal photovoltaic cell is:

$$I = I_{pv,cell} - I_{0,cell} \underbrace{\left[\exp\left(\frac{qV}{akT} \right) - 1 \right]}_{I_d} \quad (1)$$

where Ipv, cell is the current generated by the incident light(it is directly proportional to the Sun irradiation), Id is the Shockley diode equation, I0,cell [A] is the reverse saturation or leakage current of the diode [A],

q is the electron charge [$1.60217646 \cdot 10{-}19$C], k is the Boltzmann constant[$1.3806503 \cdot 10{-}23$J/K], T [K] is the temperature of the p-n junction, and a is the diode ideality constant.

Parameter	Value	Parameter	Value
Imp	7.61	Ns	54
Vmp	26.3 V	I0,n	$9.825 \cdot 10{-}8$ 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		

Table-1- Parameters of the KC200GT solararray at 25 ◦C,1000W/m2.

5. RESULT AND DISCUSSION

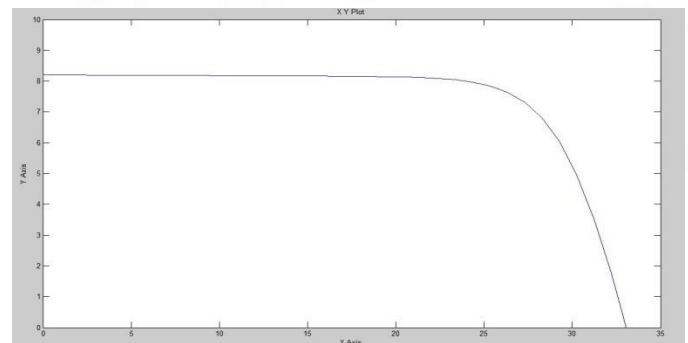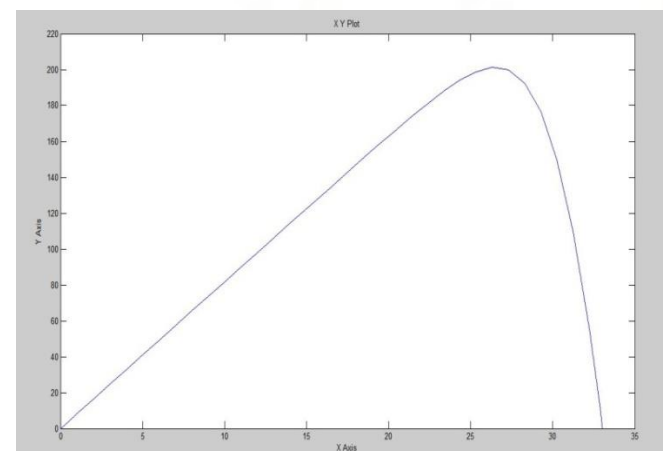4.1. Result: Simulation of IV and PV curve of solar array:

Fig 6: characteristics of solar array at 1000 W/square m

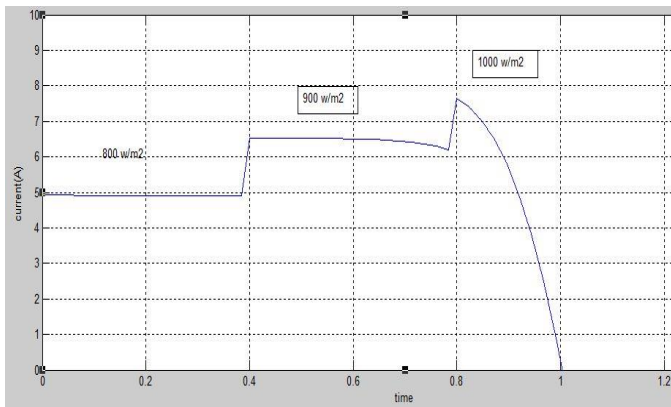Fig. 7   PV characteristics of solar array at 1000 W/square m.

Fig 8:   Variation in current with change in irradiation.

4.2   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.

5.   CONCLUSIONS

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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