MPPT OF PV MODULE BY VARIOUS METHODS

Shailesh Subhash Gujar
Department of Electrical Engineering, V.I.T Nagpur,
R.T.M.N. University Nagpur, India

ABSTRACT

Energy crisis is now days a biggest problem facing by each country. Solar energy is renewable but it has some limitations .The implementation of solar panel and all other things related with it are very costlier. A common person cannot afford its utility. The demand of electrical power is unlimited as population is increasing day by day. Therefore there must be a such system which will provide efficiency. Hence a maximum power extracting technique should be used so that the above problem with solar energy can be avoided. This paper shows different topologies for dc to dc converter for tracking maximum power with efficiency.

Keywords: *MPPT, perturb and observe algorithm, incremental conductance, PV module.*

I. INTRODUCTION

Sun is the ultimate source of energy. Every source of energy on the earth is because of sun directly or indirectly. The Sun emits 3.8 x 10^33 ergs/sec or 3.8 x 10^26 watts of power, an amount of energy each second equal to 3.8 x 10^26 joules. In one hour, or 3600 seconds, it produces 1.4 x 10^31 Joules of energy or 3.8 x 10^23 kilowatt-hours. Since E = mc^2, in 1 hour it loses (1.37 x 10^37 ergs)/(9 x 10^20) = 1.5 x 10^16 grams or 15 billion metric tons of mass. It's been doing this for about 4.5 billion years! This large amount of energy must be utilized for power generation. Solar cells playas an important role in absorbing energy. There are broadly two types of solar cells amorphous silicon cell and crystalline silicon cell. In this paper amorphous silicon cell is used. To extract maximum power from the solar cell irrespective of the atmospheric condition dc to dc converter can be used which convert variable dc output into fixed dc output.

II. PHOTOVOLTAIC SYSTEMS

Electrons and the ‘holes’ they leave behind are, respectively, negative and positive charge carriers, which usually appear in pairs within solid matter. Semiconductors are used to produce solar cells, and the characteristics of the semiconductor material make it easy for incoming photons of sunlight to release electrons from the electron hole binding. Leaving the holes behind them, the released electrons can move freely within the solid.
However, these movements have no clear direction; to make use of the electricity, it is necessary to collect electrons. The semiconductor material is therefore polluted with ‘impure’ atoms. Two different kinds of atom produce an n-type and a p-type region inside the semiconductor, and these two neighbouring regions generate an electrical field (see Figure 1). This field can then collect electrons, and draws free electrons released by the photons to the n-type region. The holes move in the opposite direction, into the p-type region. However, not all of the energy from the sunlight can generate free electrons. There are several reasons for this. Part of the sunlight is reflected at the surface of the solar cell, or passes through the cell. In some cases, electrons and holes recombine before arriving at the n-type and p-type regions (figure 1 shows these processes in a photovoltaic (PV) cell.). Furthermore, if the energy of the photon is too low – which is the case with light at long wavelengths, such as infrared

– it is not sufficient to release the electron. On the other hand, if the photon energy is too high, only a part of its energy is needed to release the electron, and the rest converts to heat.

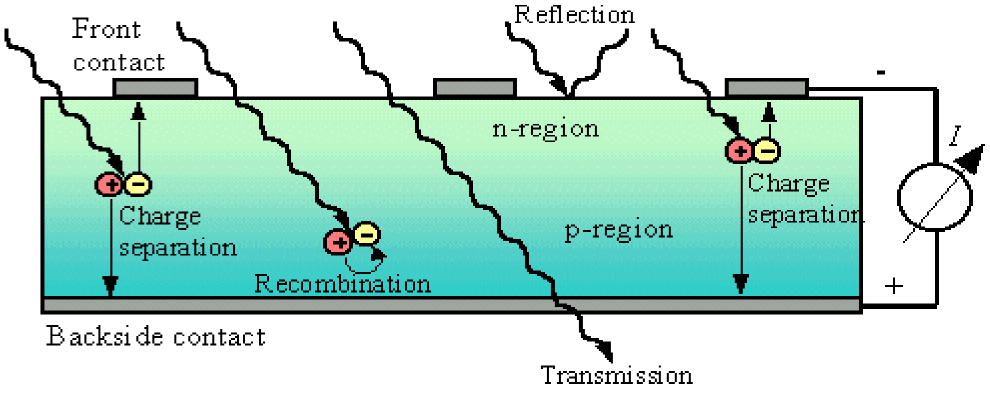

Figure 1. Photovoltaic system

Silicon material is extensively used for the photovoltaic cells because it is comparatively cheap and available in the ample amount. To understand the basic working of the PV cell we shall first discuss the atomic structure of the silicon material. In silicon material there are 4 valence electrons are present which is balance once and ready to combine with another material to form the co-Valente bond. If the same type of semiconductor material is attached to each other then there will be stability form between them and hence this stability doesn't allow the flow of current. Hence there is need to make it imbalance with the different impurities. Therefore two kind of impurity allowed in the silicon material i.e. trivalent (Boron) and pentavalent impurity (Phosphorus). Since in the last shell of boron contain 3 electrons and in phosphorus contain 5 electrons in tis outer most shell. Because of which there is perfectly acceptor and donor relation can form between these materials. The silicon material with trivalent i PV array consist of PV module and PV module made of several PV cells. Let's have light on each of these elements one by one. In the PV technology there are two kind of ways one is crystalline silicon pv cell and another is thin film pv cell. Since there are significant developments in the PV cell manufacturing technology since past years. Solar cells are P-N junction diodes which are made up of semiconductor materials like silicon. However semiconductor material with abrupt amount of tri-valent and pentavalent impurities helps in the manufacturing of P-N junction diode along with barriers of odd potential levels. As the sun ray's falls on the P-N junction diode electricity get produced. Hence these above analysis can be replicated in software i.e. matlab through one diode modelling and two diode modelling methods.

2.1. Solar Cell Modeling

The characteristics of solar cell "current versus voltage" under the environmental conditions (irradiation and temperature) is depicted with the help of equivalent circuit of one diode model or equivalent circuit of two diode model which contains the current source, one or two diodes, shunt resistors, a series resistor in load branch. The PV module is the interface which converts light into electricity. Modeling this device, necessarily requires taking weather data (irradiance and temperature) as input variables. The output can be current, voltage, power or other. However, trace the characteristics I(V) or P(V) needs of these three variables. Any change in the entries immediately implies changes in outputs. That is why, it is important to use an accurate model for the PV module. This paper presents a detailed modeling of the effect of irradiance and temperature on the parameters of the PV module. The chosen model is the single diode model with both series and parallel resistors for greater accuracy. The detailed modeling is then simulated step by step using MATLAB/Simulink software due to its frequent use and its effectiveness.

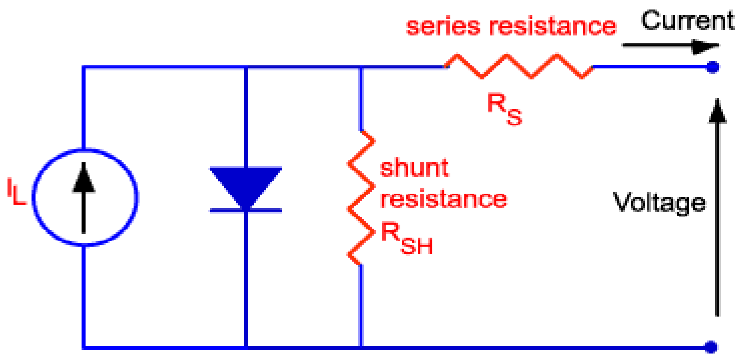

Figure 2. Equivalent circuit of PV cell representing one diode model

Figure 2 shows the equivalent circuit of one diode model whereas fig 2 shows equivalent circuit if two diode model. From these two figure we can say that there are four unknown parameters of one diode model i.e isc, id, rsh, rs and in two diode model we have six unknown parameters i.e isc, is1, is2, Rsh, Rs.

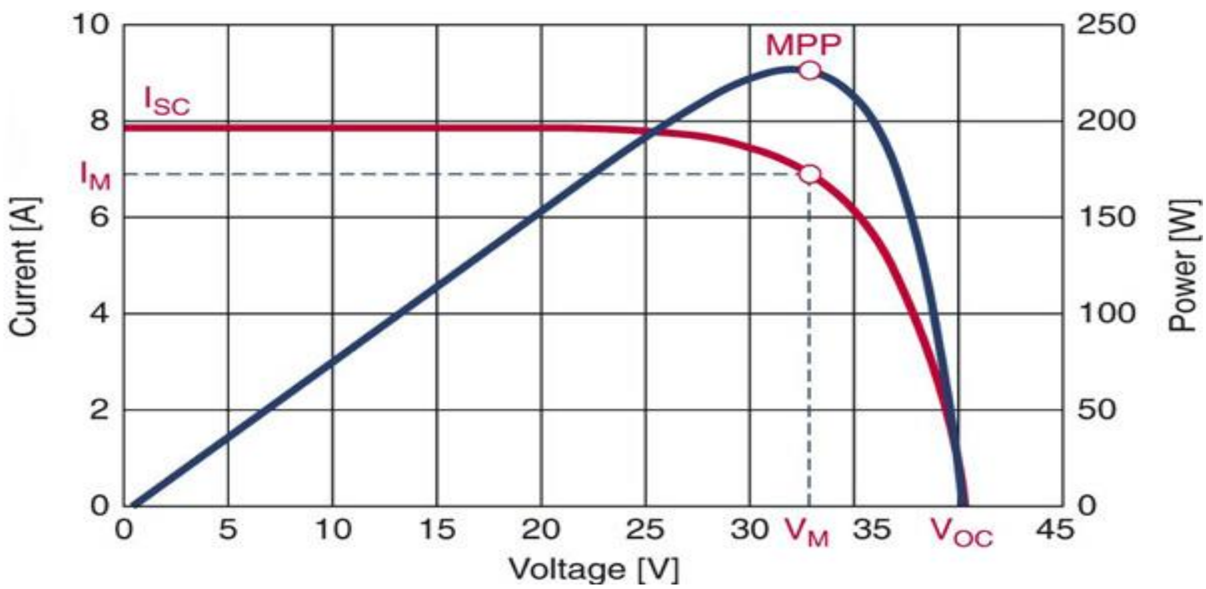

Figure 3 Graph of current and power versus voltage for a typical solar cell, showing the maximum power point and the cell's current curve.

The above figure 3 shows i-v and power output charcacteristics of dolar panel. If there is no load connected across the solar panel then the volatge across the terminal of solar panel wiil be v_{oc} i.e. Open circuit volatge which is depend upon the number of solar cell connected in series and parallel but the current will be zero since open circuit voltage therefore ultimate power will be zero. On the other hand if the terminal of solar panel shorted then short circuit current i_{sc} flow but the terminal voltage becoes zero. In both these cases the power drawn from the solar panel is zero. Therefore solar panel must be operated in between thesee two condition so that the maximum power can be drwan from them. The maximumPower point (mpp) is a spot near the knee of the i-v curve, and the voltage and current at the mpp are designated as v_m and i_m. As the load changes the mpp will also change anolng with i-v curve which depend upon irradiation, tempretute, shading etc. Hence it is very much important to draw maximum power at allthe possible time of the solar panel life span since its initial cost is high andthis can be done with the help ofimpedance matching by using different types of dc to dc converter. These are also reffered as smart converter or tracking converter.

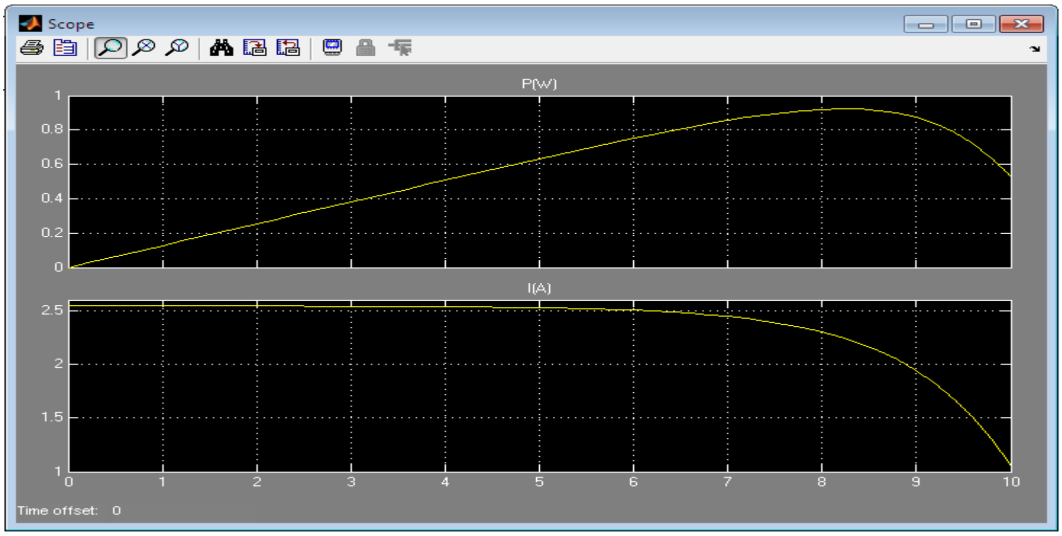

Figure 4: Simulation results of VI characteristics

The following formatting rules must be followed strictly. This (.doc/.docx) document may be used as a template for papers prepared using Microsoft Word. Papers not conforming to these requirements may not be published in the journal.

III. Maximum Power Point Technique

Maximum power point tracking (MPPT or sometimes just PPT is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. Although solar power is mainly covered, the principle applies generally to sources with variable power: for example, optical power transmission and thermo photovoltaics. PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

3.1 MPPT Implementation

When a load is directly connected to the solar panel, the operating point of the panel will rarely be at peak power. The impedance seen by the panel derives the operating point of the solar panel. Thus by varying the impedance seen by the panel, the operating point can be moved towards peak power point. Since panels are DC devices, DC-DC converters must be utilized to transform the impedance of one circuit (source) to the other circuit (load). Changing the duty ratio of the DC-DC converter results in an impedance change as seen by the panel. At a particular impedance (or duty ratio) the operating point will be at the peak power transfer point. The I-V curve of the panel can vary considerably with variation in atmospheric conditions such as radiance and temperature. Therefore it is not feasible to fix the duty ratio with such dynamically changing operating conditions.
MPPT implementations utilize algorithms that frequently sample panel voltages and currents, then adjust the duty ratio as needed. Microcontrollers are employed to implement the algorithms. Modern implementations often utilize larger computers for analytics and load forecasting.

The problem in mppt technique is to automatically find out the maximum point of volatge and current so that the solar panel will operate at maximum power. This can be done in two ways i.e either in indirect technique or in direct technique. Indirect technique includes the measuement of external parameters such as irradiation, module tempreture, electrical parameters such as open circuit voltage, short circuit current etc. Direct technique based on sensing the pv current and volatge and using that information in an appropriate algorithm. There is no requirement of prior pv source characteristics in direct technique. The commanly used direct techniques are perturb and observ (p&o), increamental conductance, diffrerntial based techniques, feedback based voltage techniques, fuzzy logic based tehnique and neutral based technique. In this paper we will concertrate on only p&o technique .

3.2 Perturb and observe method.

In this method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

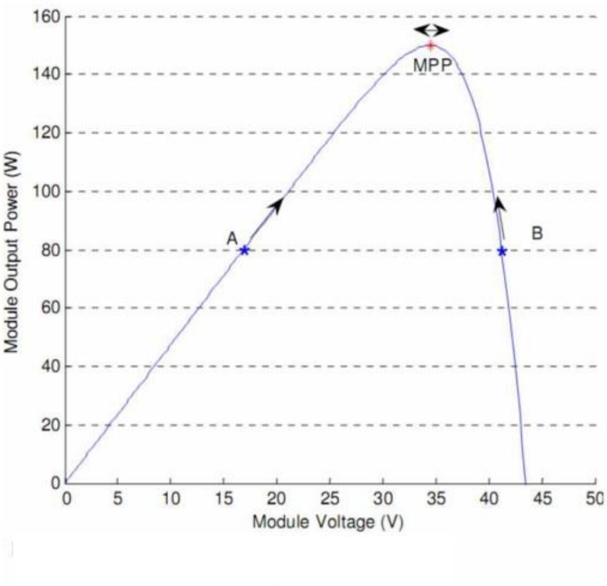

Figure 5 Perturb and Observe method

3.3 Incremental Conductance Method

Incremental conductance method is used to overcome the disadvantage of P & O method to track the peak power under fast varying condition. The IC method stops perturbing the operating point when the MPPT reach the MPP. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dI/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. This algorithm has advantage over P & O is that it can determine when the MPPT has reached the MPP, where P & O oscillates around the MPP.

3.4 Parasitic capacitance Method

It is the most novel technique in the MPPT. It is somewhat similar to the Incremental conductance technique. The only change in the parasitic capacitance method is that the charge is stored in pn junction of the solar cells. And if capacitor is added to the lighted diode the equation we obtain is given as

$$I = IL - Io\left[\frac{\exp(Vp + Rs\, I)}{a-1}\right] + Cp\left(\frac{dvp}{dt}\right) = F(Vp) = Cp\left(\frac{dvp}{dt}\right)$$

The above equation shows the two components of I and the function of F_{vp} and the current. In this method the maximum power can be obtained by multiplying the above equation by array voltage V_p to obtain the power of array and differentiating the result.

3.5 Open circuit voltage Method

In this method the V_{oc} is used to calculate the maximum point voltage. As the Voc is obtained the maximum point voltage is calculated by the following equation.

$$Vmp = k \times Voc$$

Where,

K= 0.70 to 0.80.

In this method it is require to update the V_{oc} occasionally for the compensation of the any changed in the temperature. Actually it uses some fraction of the V_{oc} to determine the maximum power point module voltage. In this method fraction is always less than 1, for the measurement of V_{oc} solar array is temporarily isolated from the MPPT.

3.6 Short circuit current Method

As in the case of open circuit method, in the short circuit method the Isc is used for the calculation of the Imp.

$$Imp = k \times Isc$$

Where,

K= 0.9 to 0.98.

A short load pulse is used in this method to generate the short circuit condition. But at the time of short circuit pulse the input voltage will go to zero and hence the power conversion circuit must be supplied from the other source. One of the main advantages of this system is that it has good tolerance for input capacitance than the V_{oc} method.

IV. DIFFERENT CONVERTER MPPT TOPOLOGY

Maximum power point converter is nothing but the dc to dc converter which helps for getting maximum output from the solar cell irrespective of the solar irradiation and temperature condition using the appropriate algorithm. There are various types of converter such as buck converter boost converter and buck-boost converter. This converter is inserted between the solar cell and its load. Since there are various types of dc to dc converter hence it is quite difficult to understand which converter is suitable. Hence there should be an appropriate method which going to deal with these issues. The dc to dc converters are mostly work near about 100% efficiency and many designers have succeeded to get near about this efficiency.

4.1 Cuk Converter

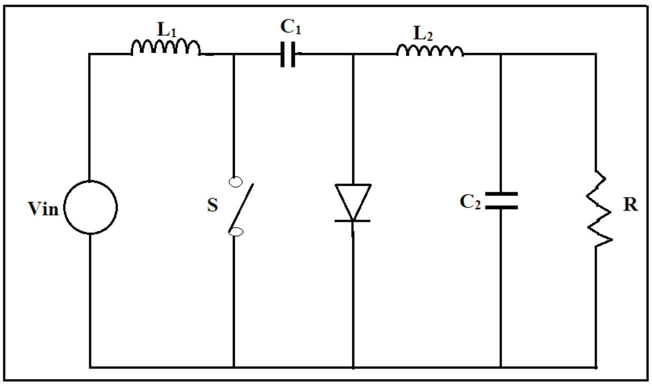

Figure 6. Cuk Converter

Many years ago Dr. Cuk has invented the integrated magnetic circuit called DC transformer, where the fluxes created by inductor L1 winding which is connected to the input side is equal and opposite to the fluxes created by the inductor L2 winding as shown in fig 10. Hence DC fluxes are opposite to each other and thus results in mutual cancellation of the DC fluxes. Cuk converter is having more advantages over the buck-boot converter. The main advantages of cuk converter are that it provides the capacitive isolation between the input and output in the circuit which was not there in the case of buck-boost converter.

The operation of the cuk converter is dividing into two modes Mode1. When switch is off (open) the stored energy in the inductor L1 is connected to the load through the capacitor C1. Capacitor C1 plays a very important role in transferring the energy from inductor L1 to load.

Mode2. When switch S is turned ON (closed) then current through inductor L1 is rises at the same time capacitor C1 reverse biased diode D hence make it off therefore now capacitor C1 discharges through capacitor C2, inductor L2, and through load resistor R.

4.2 Fly back converter

Fig 7 shows the basic circuit of fly-back converter which is derived from boost converter. The basic operation of fly-back converter is dividing into two modes.

Mode1: when switch S is closed (ON) the primary winding (dot) get connected across the input supply due to which current in the primary winding starts increasing linearly. Due to which primary fluxes starts developing. On the other hand diode is connected to the secondary winding (un-dotted) of the transformer hence it gets reverse biased which tends to block the current flowing in the secondary winding.

Mode2: when switch S is open (off) after being closed for some time then due to the nature of the inductor it reverses its polarity at the same time primary current which were flowing through the primary winding interrupted because of which the diode D which was in the reverse biased earlier becomes forward biased and starts conducting.

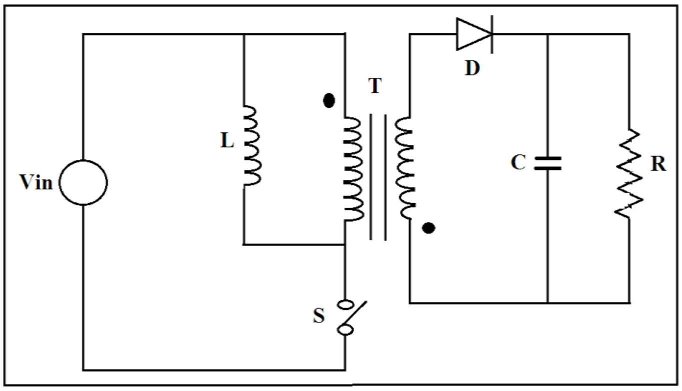

Figure.7.Fly-back Converter

V. SIMULATION RESULTS

5.1 Fly back converter

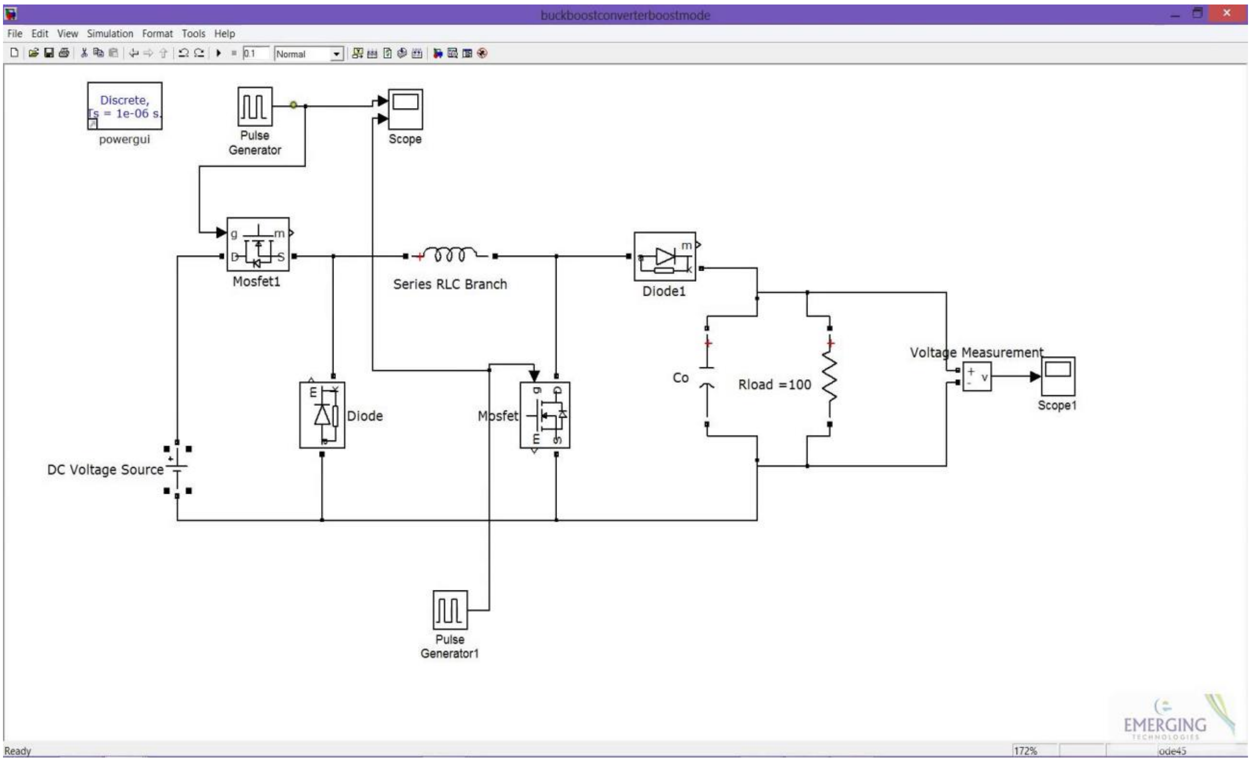

Figure 8. fly back converter

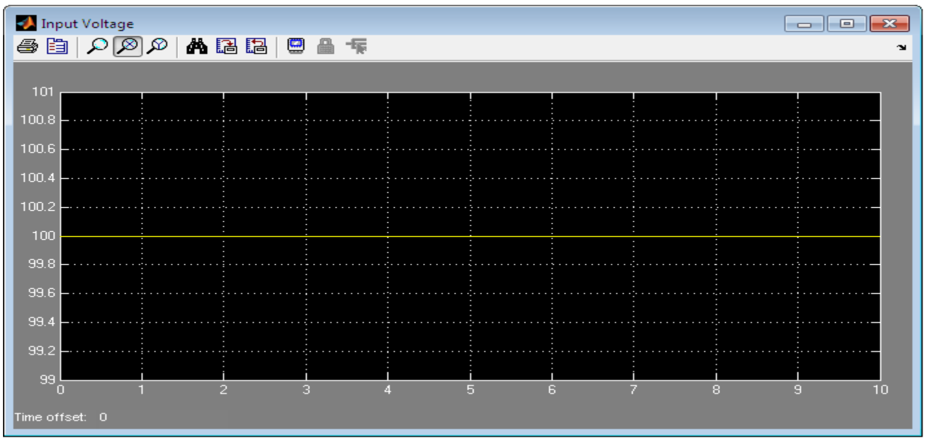

Figure 9.Flyback converter with input voltage

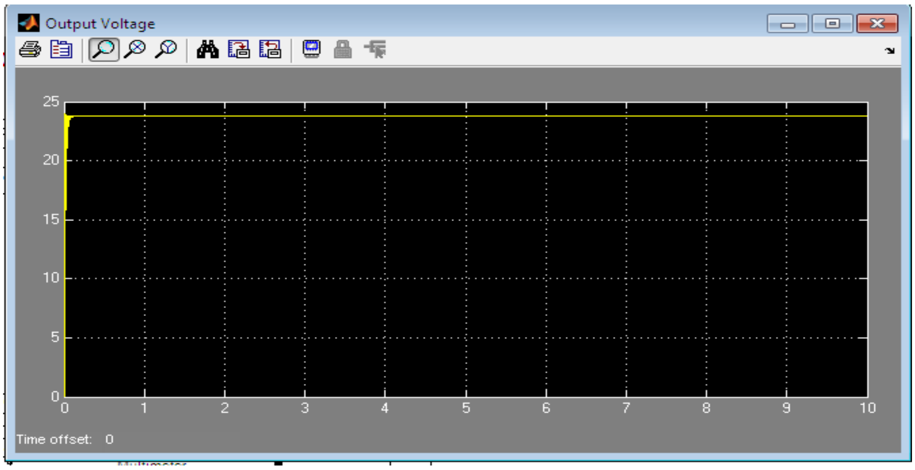

Figure 10 Flyback converter with output voltage

5.2 CUK converter

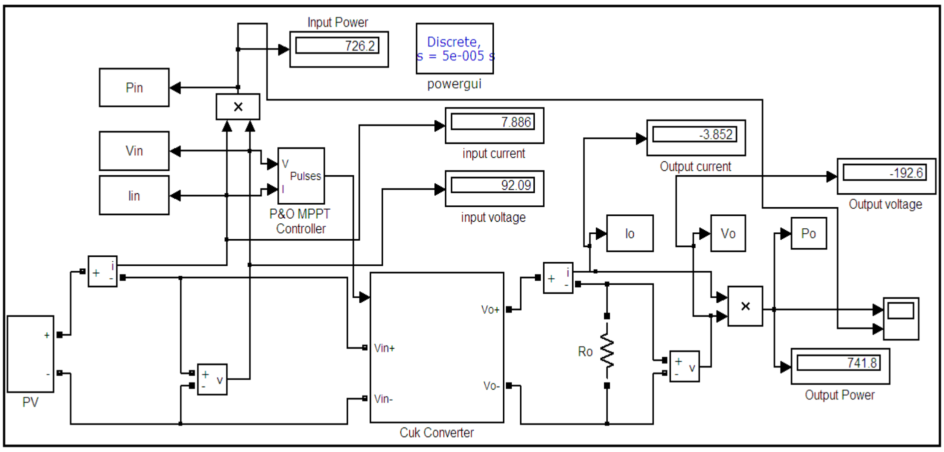

Figure 11.CUK converter

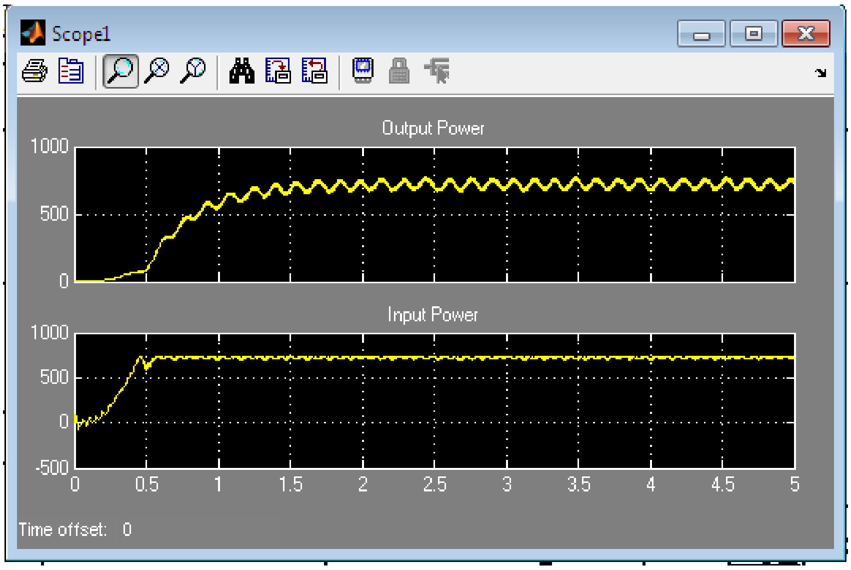

Figure 12.CUK converter with inut and output voltages

VI. COMPARISON

Table 1 Comparison between different topologies.

S.N	Buck	Boost	Buck-Boost	Cuk	Fly-back	Forward
1.	Source current waveform is same as buck-boost	Source current is approximately smooth	Source current waveform is same as buck	Source current is smooth	Source current is smooth	Source current is smooth
2.	Because of more stresses on the input side	No such case	More stresses on the source side	No such case	No such case	No such case
3.	Efficiency is more	Less compare to buck	Less compare to buck but more than boost	Less compare to buck but more than boost and buck-boost	-	-
4.	Less voltage ripple at output	More	More	Less	Less	Less
5.	Same reference between input and output	Same	Same	Same	Different	Different
6.	Single output	Single	Single	Single	Multiple	Multiple

VII. CONCLUSIONS

This paper presents different types of DC to DC converters with their comparisons along with matlab outputs. A maximum power point tracker (MPPT) is nothing but the power electronics converter which is inserted between the solar cell and load. There are various such types of DC to DC converter as explained above. A suitable maximum power point algorithm is used to enable the switching phenomenon of these converters base on which the control action of the converter can be controlled. Hence there will be an approach where with the help of detail study of the comparison of dc to dc buck and buck-boost converter topologies, to suggest an appropriate converter.

VIII. SCOPE FOR FUTURE WORK

Application of PV array generally faces the shading problem of solar light ,this will lead to inconsistent power generation and low system efficiency. Future research can investigate to solve the partial shaded problems in photovoltaic power generation employing z source inverter. Z source inverter based power conditioning system can be extended for micro grid applications where inverter can run both in standalone and in grid connected mode.

REFERENCES

[1]A. Gow and C.D. Manning, "Development of a photovoltaic array model for use in Power electronics simulation studies", IEE Proc. Electr. Power Appls., vol. 146, no.2, Pp.193-200, Mar. 1999.

[2]http://powerelectronics.com/sitefiles/powerelectronics.com/files/archive/powerelectronics.com/mg/606PET25.pdf

[3]HairulNissahZainudinSaadMekhilef Department of Electrical Engineering University of Malaya Kuala Lumpur, Malaysia. "Comparison Study of Maximum Power Point Tracker Techniques for PV Systems ".Proceedings of the 14t International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, 2010, Paper ID 278.

[4] Robert W. Erickson. "DC-DC Power Converters". Department of Electrical and Computer Engineering University of Colorado Boulder, CO 80309-0425. Aerospace and Electronic Systems, IEEE Transactions on Volume: AES- 21, DOI:10.1109/TAES.1985.310664 Publication Year: 1985 , Page(s): 791 - 799 Cited By: Papers (42)

[5]V. Di Dio, D. La Cascia, R. Miceli Member IEEE, C Rando. "A Mathematical Model to Determine the Electrical Energy Production in Photovoltaic Fields Under Mismatch Effect". Clean Electrical Power, 2009 International Conference on 9-11 June 2009 46 – 51.

[6] Tomas Markvart, "Solar Electricity", John Wiley & Sons, New-York, 1994H. Khalife, N. Malouch, S. Fdida, "Multihop cognitive radio networks: to route or not to route," IEEE Network, vol. 23, no. 4, pp. 20-25, 2009.

[7] SrushtiR.Chafle, Uttam B. Vaidya Z.J.Khan "Design of cuk converter with Mppt Technique". M-Tech Student, RCERT, Chandrapur, India Professor, Dept. of Electrical & Power, RCERT, Chandrapur, India HOD & Professor, Dept. of Electrical & Power, RCERT, Chandrapur, India. International journal of innovative Research in electrical, electronics, Instrumentation and control engineering Vol. 1, issue 4, July 2013.

[8] Dr. B.J. Ranganath Dean academic EIT, Ummathoor, Mysore, India Mr.Amurth R.T Research Scholar JJTU, Jhunjhunu -333001, Mysore India. "Design of DC/DC Buck- Boost Converter Charge Controller For Solar Power Applications".

AUTHOR

Shailesh Subhash Gujar Received B.E. In Electronics and telecommunication from M.B.E.S. College of Engineering, in 2012.Currently pursuing his M.E. in (Power electronics and Power system), From V.I.T College Nagpur, - (R.TM.N. Nagpur University).