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Improving the Performance of PV Module by using Dc to Dc Buck and Buck-Boost Converter with Maximum Power Point Perturb and Observe (P and O) Algorithm: A Review

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ABSTRACT: Now a day the energy crises are one of the important issues at the global level. So the solar energy is the renewable energy source available to overcome these kinds of issues. By considering the present scenario of the electrical energy in the world it is highly important to generate electrical power by using non-conventional resources. Solar energy is the key answer to all these questions. But the main disadvantages with solar energy is that its initial cost and its output is greatly depends upon the atmospheric condition. Hence a maximum power extracting technique should be used so that the above problem with solar energy can be avoided. In this study, we have gone through the last decade research papers and at last this research paper shows the comparison between various dc to dc converters.

KEYWORDS: PV module, dc to dc buck converter, buck-boost converter, MPPT technique, P and O algorithm.

I. INTRODUCTION

On this earth almost every source of energy is because of the SUN directly or indirectly. On this earth India is richest in terms of solar radiation where almost India receives 250 to 300 days per year solar radiations. This is enough to provide 6000 Trillion Kwh per year. Now to extract this much power from the sun solar cells plays an important role. But since the output of solar cells is adversely affected by the atmospheric condition, there should be a technique which is used to get maximum amount of power from these solar cells. 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. There are various types of converters out of witch specific type should be applicable to appropriate one.

II. PV CELL MODELLING

PV cell consist of semiconductor material. It is made up of N type and P type semiconductor layers with trivalent and pentavalent impurities respectively. There has been tremendous work done for the modelling of pv cell by di dio, d.la cascia. There are two ways to model the PV cell into matlab Simulink one by using one diode model and either by using two diode model. Hence the modelling of PV cell can be represented by either one diode model or two diode model. Since there are five unknown parameters [7]; I_{ph} , I_o , N , R_s and R_p and two diode models has seven unknown parameter I_{ph} , n_1 , I_{o2} , n_2 , R_s , and R_p . On the other hand, solar panel is composed of parallel combination of several cell strings and a string contains several cells in series. Therefore, both the models can be also stated for a solar panel. In this research, the idea is to compare the accuracy of the two mentioned model for

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solar panel. However the characteristics of one diode model as compared with two diode model is not having much difference from known unknown parameter point of view. Hence the focus is given on the modelling of one diode model for solar panel. Hence it can be represented by single diode model or two diode model. Though two diode models shows the substantially good characteristics than the one diode model but it doesn't provide that much difference with increase in complexity hence in this paper one diode modelling is preferred.

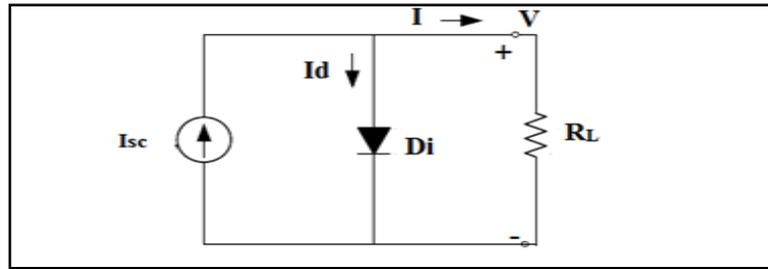


Fig:1 Equivalent circuit of PV cell representing one diode model

Fig. 1 shows the one diode model in which an ideal current source is represented along with the parallel diode (this diode represents the output voltage polarity of a PV cell). There are two main parameters of PV cell i.e. open circuit voltage (V_{OC}) and short circuit current (I_{SC}). Under short circuit condition $R_L=0$ hence the short circuit current equals the total current I ($I_{SC}=I$). On the other hand under open circuit condition $R_L=\infty$ hence the current bypasses through the intrinsic diode (D_i) therefore by using Kirchhoff's current law (KCL)

$$I_{SC} = I + I_d$$

i.e. $I = I_{SC} - I_d$

Where, I_d is diode current given by the Shockley diode equation as follows.

$$I_d = I_s \left(e^{\frac{qV}{n_{ideal} kT}} - 1 \right)$$

Where, I_s is reverse saturation current of diode (A),

q is electron charge ($1.602 \times 10^{-19} \text{C}$),

V is the volt across diode or PV cell (V),

k is Boltzmann's constant ($1.381 \times 10^{-23} \text{J/K}$),

T is junction temperature in kelvin (K).

n_{ideal} is the diode ideality factor.

As the one diode model including losses is sufficient to represent the characteristics of PV cell but it does not consider recombination in the PV cell. Hence one extra diode is added in to the above one diode model which gives non ohmic current path in parallel with intrinsic PV cell.

III. MAXIMUM POWER POINT TRACKING

There are two types of maximum power point tracking technique these are direct technique and indirect technique. In the direct technique the current and voltage of the PV cell are measured and these measured value is compared in the given algorithms and the appropriate maximum power point (MPP) is taken. In the case of indirect technique, external actors such as irradiation and module temperature or electrical performance parameters such as short circuit current and open circuit voltage of the PV module. Among these two techniques direct technique is used in this paper.

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There are several types of direct technique algorithms such as follows:

1. Perturb and Observe method (P&O).
2. Incremental conductance method(IC).
3. Parasitic capacitances.
4. Voltage control maximum power point tracker.

Out of which P & O method is simple and easy to apply hence here this method is used. This algorithm uses a simple feedback loop and some measured parameter. In this method a periodically module voltage is perturb and the corresponding power is compared with that at previous perturb cycle. In this algorithm some perturb is introduced in the system. Because of which there are various power levels of the module. As the power increases the perturbation continuous in the same direction and if power decreases then the same perturbation continues in the opposite direction as shown in fig 2. As the steady state condition occur the maximum power point oscillate along the maximum point therefore the value of perturbation should be as small as possible.

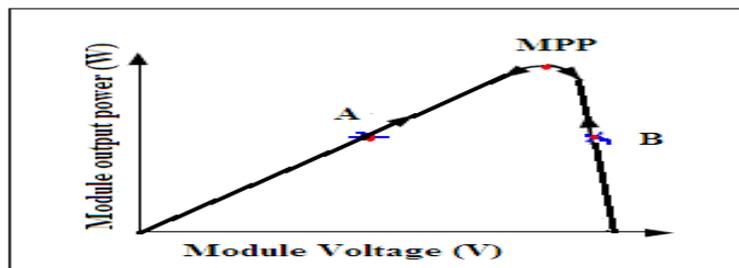


Fig. 2: Graph of power v/s voltage of P & O method.

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.

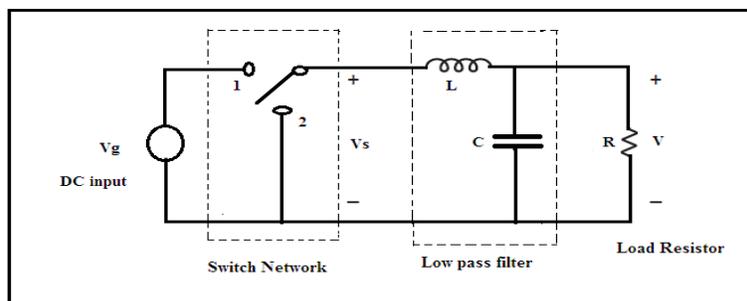


Fig. 3: Basic buck converter circuit.

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A basic dc to dc converter is known as buck converter whose circuit diagram is shown in fig 3 which employs of a dc input voltage (V_g), switch network which is a single pole double through (SPDT) switch, low pass filter and a load resistor (R). When the switch is connected to position 1 then the switch voltage (V_s) is equal to the DC input voltage (V_g) and when the switch is connected to position 2 then switch voltage (V_s) is zero. Here the SPDT switch can be realized by using power semiconductor devices such as MOSFET, IGBT, and BJT etc.

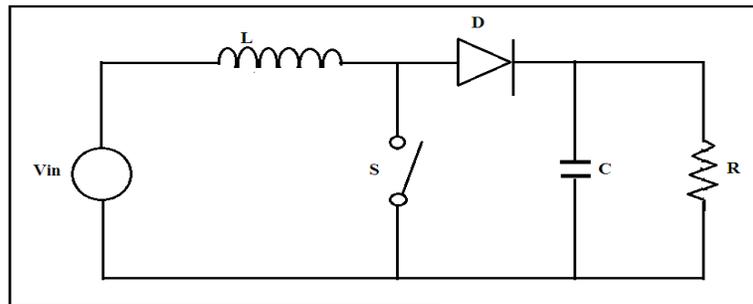


Fig. 4: Basic boost converter

Above boost converter is an alternative way for the buck converter. Boost converter is required to step up the input voltage to the desired output voltage with the help of a transformer action. It consists of an inductor L , diode D , capacitor C , resistor R , switch S and input voltage V . All these components in the co-ordinated manner supply power to the load in a greater magnitude than in input. The control action of the boost converter is depending upon the switching frequency of the switch (S). The operation of boost converter is depending upon charging and discharging of the capacitor C shown in the above fig. When switch S is open then inductor L starts charging the capacitor through diode D , as soon as switch S is closed charged capacitor starts discharging through load resistor R .

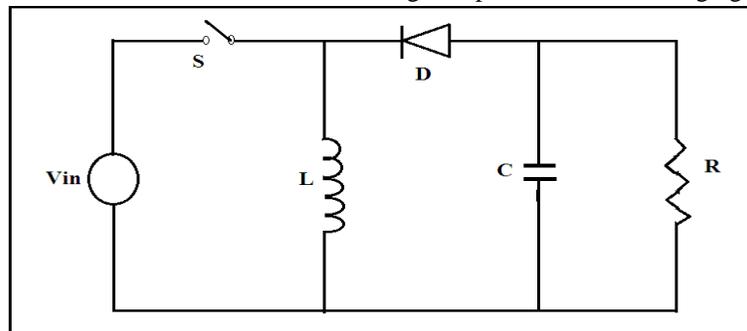


Fig. 5: Buck-Boost Converter.

A Buck-Boost converter is a dc to dc converter which can step up and step down the output voltage with respect to its input voltage. The buck-boost converter is a combination of buck converter and boost converter in the cascaded form. The output of this converter is also depend upon the switching frequency along with the product of both buck and boost converter duty cycles. The main advantage of buck-boost converter is that it has wide range of output voltage from maximum to almost zero. In the inverting topology the output of this converter is exactly opposite to the input one. Along with all the advantages of the buck-boost converter it has a major drawback that there is no neutral connection in the circuit because of which there is no isolation between input and output supply. The operation of the buck-boost converter is very simple. First we will assume that initially capacitor is charged.

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1. When switch is on (closed) inductor L directly connected to the supply and hence energy starts accumulating in the inductor. At the same time charged capacitor starts supplying to the load.
2. When switch is off (open) then charged inductor L gets connected to the capacitor C and starts supplying to the load.

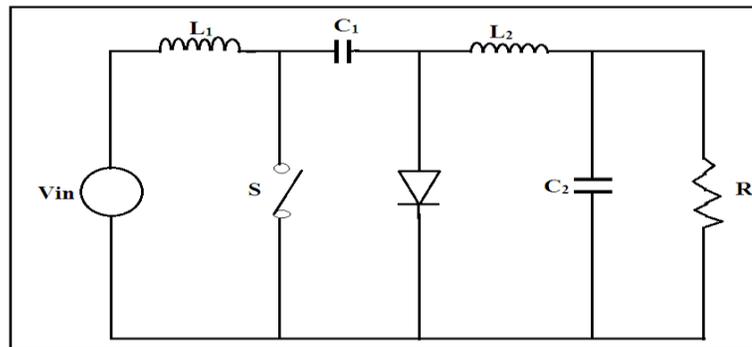


Fig. 6: Basic Circuit diagram of Cuk Converter.

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 6. 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-boost 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.

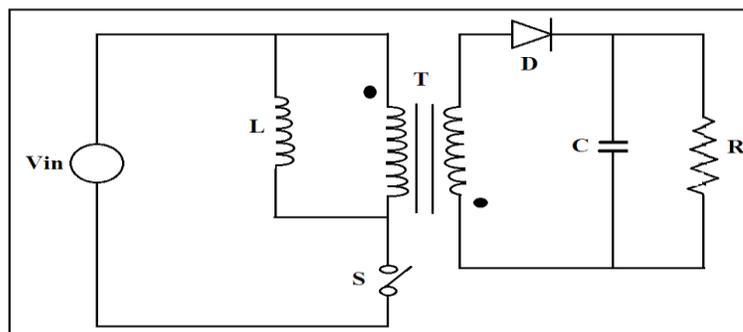


Fig. 7 Basic Circuit of Fly-Back Converter.



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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.

V. DIFFERENCE BETWEEN CONVERTER TOPOLOGY

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. In this way by using a suitable algorithm to a suitable converter the operation of solar cell at its maximum power point is insured having continuously varying atmospheric conditions such as solar irradiation, temperature etc. In the field of solar, power electronic converter plays a very important role. If there is an partial condition on the PV array then the overall maximum power point will get disturb because of which there is difficulty in finding out the maximum power point which could be resembles to the point at the time of complete isolation. In this the role of power electronic dc to dc converter like buck converter, boost converter, buck-boost converter etc. For the low output application buck converter is a suitable one which shows a high efficiency compared to boost and buck-boost converter with P & O methods [7]. While if the isolation level of the PV cell is less comparatively then there is no any use of the buck converter hence in this situation boost converter is suitable [8]. The use of buck-boost converter can also be suggested for the both buck and boost operation, giving less efficiency compared to buck but the advantage of having greater control can also be achieved [9]. In this way a suitable converter can be suggested depending upon the industrial application. A simple dc to dc regulator can also be used in the place of these converters though they are simple and easy to implement but from the efficiency point of view it is not suitable to use these simple regulator [10]. To avoid the problem in the boost converter in the sense of efficiency, soft switching boost converter this is nothing but the resonant switching converter where with the use of the inductor and capacitor the switching is controlled at the zero current/voltage condition [3]. A large number of dc-dc converter circuits are known that can increase or decrease the magnitude of the dc voltage and/or invert its polarity. The first converter is the buck converter, which reduces the dc voltage and has conversion ratio $M(D) = D$. In a similar topology known as the boost converter, the positions of the switch and inductor are interchanged. This converter produces an output voltage V that is greater in magnitude than the input voltage V_g . Its conversion ratio is $M(D) = 1/(1 - D)$. In the buck-boost converter, the switch alternately connects the inductor across the power input and output voltages. This converter inverts the polarity of the voltage, and can either increase or decrease the voltage magnitude. The conversion ratio is $M(D) = - D/(1 - D)$. The Cuk converter contains inductors in series with the converter input and output ports. The switch network alternately connects a capacitor to the input and output inductors. The conversion ratio $M(D)$ is identical to that of the buck-boost converter. Hence, this converter also inverts the voltage polarity, while either increasing or decreasing the voltage magnitude [10]. The use of suitable converter at the appropriate application will increase the overall efficiency of the system.



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VI. COMPARISON BETWEEN VARIOUS DC TO DC CONVERTERS

The below given table shows the comparison between various dc to dc converters:

Table1:Comparison between various dc to dc converters:

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. CONCLUSION.

When the external environment changes suddenly the system cannot track the maximum power point quickly. With the use of different types of dc to dc converter it is possible to track the maximum power point (MPP) with increase in efficiency of the system, but on the other hand with the excess use of dc to dc converter there can be decrease in overall efficiency of the system. 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.

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