EVALUATING DIFFERENT DC TO DC CONVERTER TOPOLOGIES FOR PV CELL USING P AND O METHOD IN MATLAB SIMULINK

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Abstract— there has been recent increase in the immerging trends in the non-conventional energy resources utilization. Solar is one of the prominent renewable source of energy in the world of non-conventional energy resources, but still there has been some question marks on the effective utilization of solar energy. Solar cells are the prominent way to use solar energy, however, the initial cost of solar cell are very high along with its life span. Hence it is necessary to use solar cell efficiently throughout its life span so that the maximum output can be achieved from it. In this paper the detail comparison study of the possible dc to dc converter along with its comparison on the basis of design and operation, with the use of perturbs and observes (P & O) technique.

Index Terms—Solar Module, Dc to Dc Converter, Maximum Power Point Technique, Perturb and Observe Algorithm.

I. INTRODUCTION

There are various forms of non-conventional energy resources like sun; wind etc. sun is the best option among all because of its availability on earth. Sun is the never ending source of solar energy. In countries like India from 365 days, 250 to 300 days ample amount of solar irradiation is available. Today India is having installed capacity of 229 Giga watts, which will about to increase up to 285 Giga watts by the year 2020. To achieve above without creating environmental problems like pollution, global warming etc. solar energy plays an important role. The main advantage of solar energy is that it is of free in nature without creating any environmental hazards. Solar cell is an perfect way of utilization of solar energy. This cell is nothing but a semiconductor device made of silicon materials along with some proper tri-valent and penta-valent impurities which convert the solar irradiation to electric current. However, the initial cost of solar cell is high along with life span of near about 20-25 years makes the designer to think for the use of solar cell because the electrical output of solar cell is completely depend upon solar irradiation which is not constant throughout. To avoid this problems solar cell are used with various dc to dc converters so that the overall efficiency of solar module get increased. These converters convert solar cell dc output to various magnitudes for convenience. This can be effectively achieved with the help of proper switching sequence to the various switches like SCR, MOSFET, and IGBT etc. of different dc to dc converters. The technique which enables the maximum power from solar module irrespective of solar irradiation along with various dc to dc converters having proper switching sequence is known as maximum power point technique.

II. PV CELL MODELLING.

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 penta-valent 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.

A. ONE DIODE MODEL.

The simplest version of one diode model is shown in Fig. 1. It consists of an ideal current source (representing the current generated by photons falling on the p-n junction) in parallel with a diode. The output of the current source is constant for a particular temperature and radiation condition. The two main parameters of a PV cell are the short circuit current (I_{SC}) and open circuit voltage (V_{OC}). Under short circuit conditions ($R_L = 0$), the photon generated current (I_{ph}) is equal to the short circuit current [4, 6].

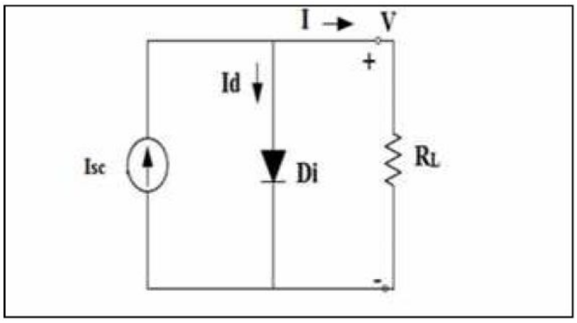

Fig: 1 equivalent circuit of PV cell representing one diode model

Under open circuit conditions, I_{ph} is shunted by the intrinsic p-n junction diode (Di). The current generated by the PV cell (I_{ph}) flows through the intrinsic diode (as R_L =∞). The PV module parameters are provided by the manufacturers in their datasheets for standard test conditions (STC). By applying Kirchhoff's current law (KCL) to the equivalent circuit of a PV cell, the current from the PV cell under any condition is obtained as follows:

$$I_{SC} = I + Id \qquad \text{i.}$$

$$\text{i.e. } I = I_{SC} - Id \qquad \text{ii.}$$

Where, Id is diode current by the schottkey diode equation as follows

$$Id = Is\left(\frac{e^{qV}}{n_{ideal}kT - 1}\right) \qquad iii.$$

Where,

Is is reverse saturation current of diode (A), q is electron charge (1.602×10^{-19}C),
V is the volt across diode or PV cell (V),
k is Boltzmann's constant (1.381×10^{-23}J/K),
T is junction temperature in kelvin (k). n_{ideal} is the diode ideality factor.
From (i) and (ii)

$$I = I_{SC} - Is\left(\frac{e^{qV}}{n_{ideal}kT - 1}\right) \qquad iv.$$

The parameters of the one diode model (e.g. I_S, n_{ideal} etc.) are extracted using numerical computational methods. The representative I-V and P-V characteristics of the PV cell/module/array are given in Fig. 2. The electrical quantities that are important for a PV system operation are open circuit voltage (V_{OC}), short circuit current (I_{SC}), maximum power point voltage (V_{PV}|MPP), maximum power point current (I_{PV}|MPP), peak power (PPV|MPP) and fill Factor (FF). The PPV|MPP is a unique point near the knee of the P-V characteristics that represents the PV power that must be extracted for optimum utilization of the PV source. Fill factor represents the quality of the PV cell and is defined as the ratio of maximum power to the product of V_{OC} and I_{SC}.

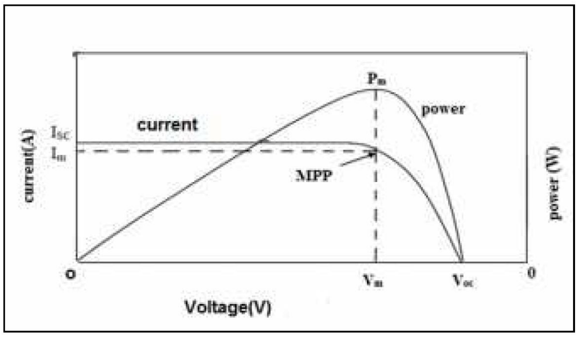

Fig: 2 PV and IV characteristics of solar cell/Module/array

Equation (iv) represents the simple one diode model of a PV cell, where, the losses are not included. To account for the losses in a PV cell, series resistance (R_S) and shunt resistance (R_{SH}) are included in its equivalent circuit, which makes the model more accurate although with increased complexity [6] as shown in Fig. 3. The modified characteristic equation is given

$$I = I_{SC} - Is\left(\frac{e^{qV}}{n_{ideal}kT - 1}\right) - \left(\frac{V + R_S}{R_{SH}}\right) \qquad v.$$

Where, R_S is series resistance of the cell and R_{SH} is shunt resistance of the cell.

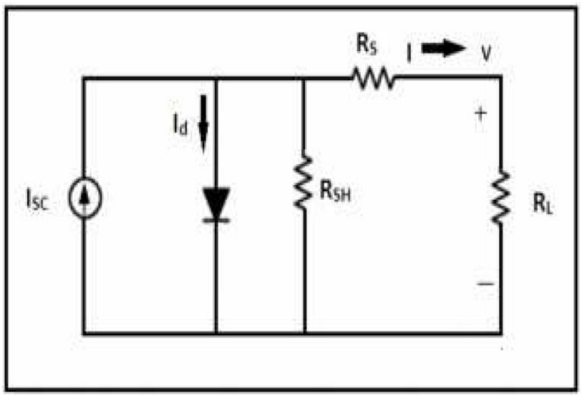

Fig:3 equivalent diagram of a PV cell representing one diode model with losses.

Series resistance loss is associated with the resistance offered to the current path through the semiconductor material, the metal grid, contacts, and current collecting bus. Shunt resistance loss is associated with a small leakage current through a resistive path in parallel with the intrinsic diode [4]. The I-V characteristics of a PV cell are affected by R_S and R_{SH} as shown in Fig. 4. The effect of series resistance variation is more prominent in the open circuit region while variation in shunt resistance value reflects in the short circuit region, as highlighted in Fig. 4.

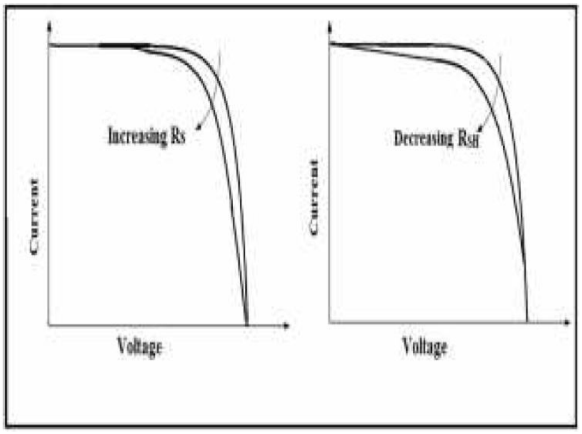

Fig: 4 the I-V characteristics of a PV cell affected by R_S and ^{R}SH

B. *TWO DIODE MODEL.*

One diode model (including losses) is sufficient to represent the characteristics of a PV cell. However, it doesn't take into account recombination in the depletion region of PV cells. Therefore, a second diode is added to further enhance accuracy of the characteristics representation at the expense of increased complexity. The second diode provides non-ohmic current path in parallel with the intrinsic PV cell as shown in Fig.[5].

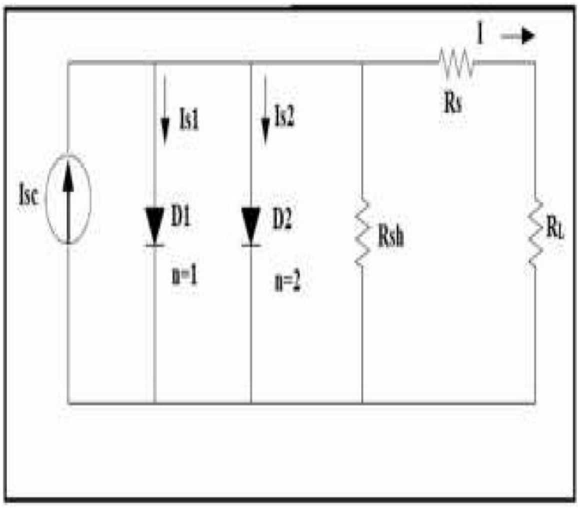

Fig :5 Equivalent diagram of a PV cell representing two diode model with losses.

The effect of shunt resistance dominates under low irradiance and temperature conditions as the value of R_{SH} becomes comparable to R_S. Under normal or high irradiance conditions, the R_{SH} value is very large as compared to the R_S value and therefore can be neglected. In most cases, the two-diode model does not give high accuracy. Therefore, one-diode model is accurate enough [7] in those cases. A PV module can also be modeled in the same way as PV cell by scaling up the voltage values if cells are connected in series and scaling up the current values if cells are connected in parallel.

Where, Ns is the number of PV cells connected in series and Np is the number of PV cells Connected in parallel.

II. PARTIAL SHADING CONDITION

In a series connected solar photovoltaic module, performance is adversely affected if all its cells are not equally illuminated. All the cells in a series array are forced to carry the same current even though a few cells under shade produce less photon current. The shaded cells may get reverse biased, acting as loads, draining power from fully illuminated cells. If the system is not appropriately protected, hot-spot problem [1]-[2] can arise and in several cases, the system can be irreversibly damaged. In the new trend of integrated PV arrays, it is difficult to avoid partial shading of array due to neighboring buildings throughout the day in all the seasons. This makes the study of partial shading of modules a key issue. With a physical Solar PV module it is difficult to study the effects of partial shading. A Matlab model of a PV module consisting of 36 cells in series has been developed to carry out this study. The model is used to study the effect of shade on varying number of cells on the power output of the module and stresses on the shaded illuminated cells under various illumination levels.

III. POWER ELECTRONICS CONVERTER

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 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 Vg. 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.

IV. MAXIMUM POWER POINT TRACKING

The photovoltaic source is a prominent and popular source among the available renewable energy sources. However, because of various factors such as high fabrication cost, low energy conversion efficiency etc., its usage is in question. Further, the critical age of the PV source is about ~ 20-25 years. These drawbacks can be further reduced by maximizing the power outputs from these sources. It is desirable to maximize the power output that the manufacturing process should be improved, soling effects should be removed. However, once the PV module has been manufactured and installed the power optimization can be performed in two ways: (i) Mechanical tracking to track most of the available solar radiation (ii) Using electrical maximum power point tracking (MPPT). Therefore, basic background related to the electrical tracking of maximum power is presented in the following paragraphs. The I-V and P-V characteristics of a PV module depend upon many factors. The I-V characteristics have a unique point near the knee which is called the maximum power point (MPP) at which PV module operates with maximum efficiency and produces maximum power for a given set of environmental conditions, as shown in Fig. It is important to operate the PV module at maximum power point to extract the maximum power. The maximum power extraction from a PV source is difficult because of its non-linear characteristics which change with environmental conditions. The MPPT process is based on the principle of impedance matching between load and PV source to transfer maximum power. This is realized by using a dc-dc converter, where the duty cycle of the switch is changed such that the reflected load (=f(R_L, *d*)) across the PV source corresponds to maximum power operating point of the PV source as shown in Fig. There are two major MPPT philosophies: (a) Modeling based or indirect techniques and

(b) Voltage and current measurement based direct techniques. The indirect techniques involve the measurement of external factors like irradiation and module temperature or electrical performance parameters such as short circuit current and/or open circuit voltage of the PV module. These parameters are used in the models/equations (developed with regression analysis) for maximum power prediction. Direct techniques are based on sensing PV current and/or voltage and using that information in an appropriate algorithm.

A. PERTURB AND OBSERVE METHOD.

Because of the simple structure and reliability of the Perturb and observation method is widely used in the MPPT algorithm. They use to perturbing, increment and decrement the array terminal voltage and current periodically and it gets compared with previous perturbation cycle. In this if the power increases then perturbation will follow the same direction in the next cycle, if not then the direction will be reversed.

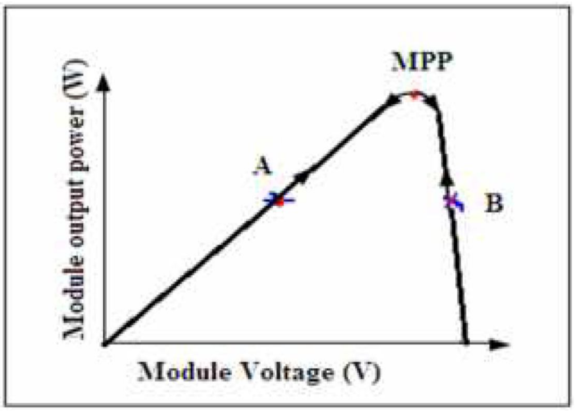

Fig. 6 Perturb and Observe method

B. INCREMENTAL CONDUCTANCE METHODS

Since we know that perturb and observation methods have some limitations like it does not work properly under the continuous change in the environmental condition. Hence with the use of incremental conductance methods is used. This method consists of slope of derivative of the current with respect to the voltage to reach the MPP. To obtain this maximum point di/dt should be equal to the –i/v. By applying the variation in voltage towards the biggest value or smallest value it affect the power value.

C. 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

$$I = I_L - I_O\left[\frac{exp(V_P + R_S I)}{a-1}\right] + C_P\left(\frac{d_{VP}}{dt}\right) = F(V_P)$$

$$= C_P\left(\frac{d_{VP}}{dt}\right) \qquad vi.$$

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.

D. OPEN CIRCUIT VOLTAGE METHODS

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

$$V_{mp} = k \times V_{OC} \qquad vii.$$

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.

E. 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 $I_{MP.}$

$$I_{mp} = k \times I_{SC} \qquad viii.$$

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.

V. 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.

A. BUCK CONVERTER

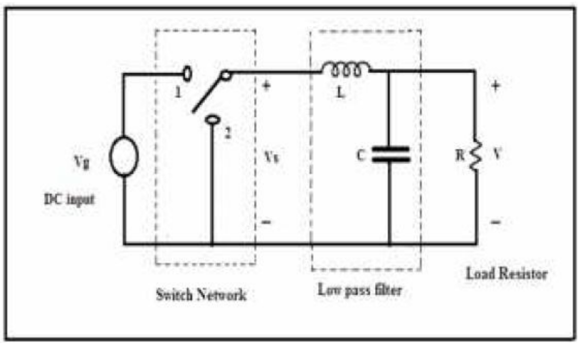

Fig. 7 Buck Converter

A basic dc to dc converter is known as buck converter whose circuit diagram is shown in fig 7 which employs of a dc input voltage (Vg), 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 position1 then the switch voltage (Vs) is equal to the DC input voltage (Vg) and when the switch is connected to position 2 then switch voltage (Vs) is zero. Here the SPDT switch can be realized by using power semiconductor devices such as MOSFET, IGBT, and BJT etc.

B. BOOST CONVERTER

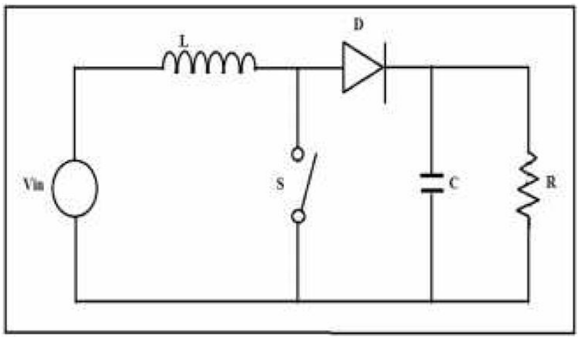

Fig. 8 Boost Converter

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 is consist 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.

C. BUCK-BOOST CONVERTER

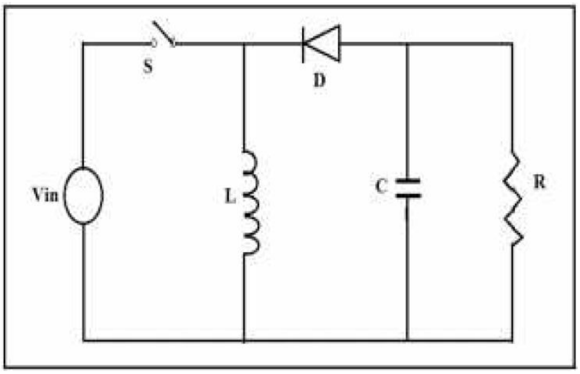

Fig. 9 Buck-Boost Converter

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.

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

When switch is off (open) then charged inductor L gets connected to the capacitor C and starts supplying to the load

VI. RESULS AND SIMULATION

All the simulation result of buck, boost and buck-boost converter are shown below along with the perturb and observe maximum power point algorithm. The complexity and simplicity of the circuit have been determined based on the literature. The comprehensive approach towards comparison between the various converters is shown. The PV module used in this simulation having the voltage of 123.3 Volt and current of 8.305 Ampere without loading and considering irradiation and temperature constant.

A. BUCK CONVERTER

The proposed buck converter is tasted in the matlab Simulink environment along with the perturb and observe algorithm for switching control which shows input and output power waveform.

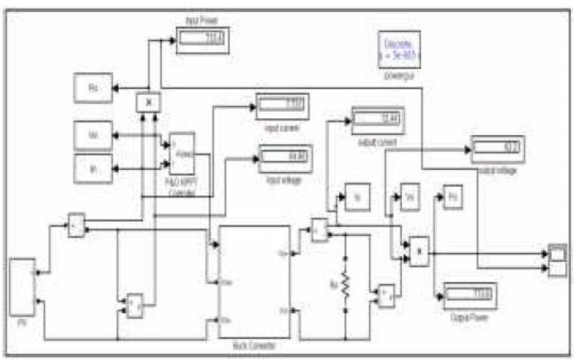

Fig. 12 Buck converter using P & O algorithm with i/p & o/p Power waveform

B. BOOST CONVERTER.

The proposed boost converter is tasted in the matlab Simulink environment along with the perturb and observe algorithm for switching control which shows input and output power waveform.

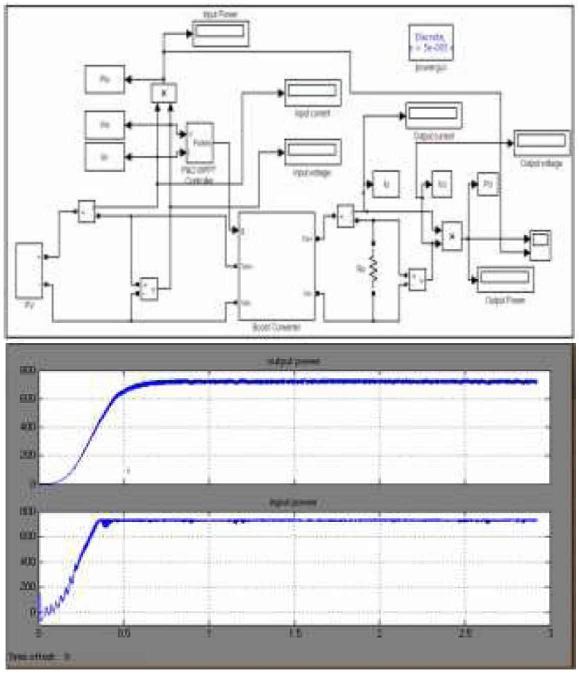

Fig. 13 Boost Converter using P & O algorithm with i/p & o/p Power waveform

C. BUCK-BOOST CONVERTER

The proposed buck converter is tasted in the matlab Simulink environment along with the perturb and observe algorithm for switching control which shows input and output power waveform.

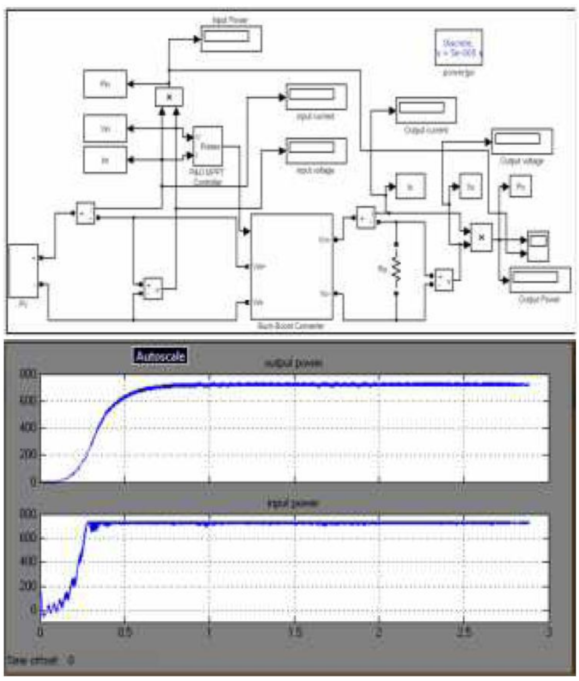

Fig. 14 Buck-Boost Converter using P & O algorithm with i/p & o/p Power waveform.

Table: Comparison of different dc to dc converter.

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

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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