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An Overview of Converters for Photo Voltaic Power Generating Systems

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ABSTRACT
The photovoltaic (PV) systems exhibits nonlinear I-V characteristics and maximum power point varies with solar radiation or insolation and temperature. An intermediate pulse width modulation dc to dc converters can increase efficiency of the system by providing impedance matching between the PV system and the load and operating the PV cell arrays at their maximum power point using MPPT techniques. This paper provides an overview of different types of dc to dc converters used with PV systems.

Keywords
Photo Voltaic system, MPPT, Interleaved converters

1. INTRODUCTION
The industrial development of nations in recent years leads to global warming and other environmental issues. The problems of global warming and energy exhaustion leads to the use of renewable energy sources such as wind, solar, tidal etc. Among them Solar cells using semiconductors is currently considered as more suitable because of the absence of fuel cost, noise and wear due to the absence of moving parts. The maintenance cost is less for PV cell and it has more than 20 years of life cycle [1].

The scheme of power conditioning which transmits the power to the load from the cell always need high efficiency but the output power from the solar cell is easily changed by the environmental conditions like irradiation and temperature and the efficiency goes down. The power conversion is done in the power conversion system by dc to dc converter using the maximum power point tracking under varying irradiation conditions. The switching converter may be dc-dc converter or dc-ac inverter depending upon the load type. The block diagram of a photo voltaic conversion system is shown in figure 1. [2]

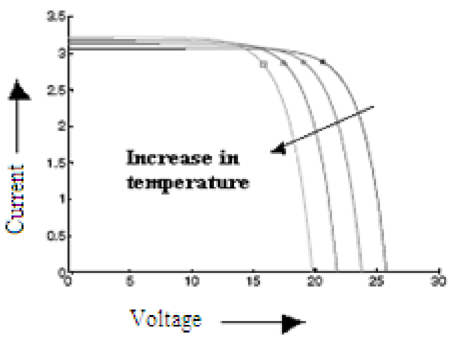

Fig 3: I-V curve of solar cell under different temperature

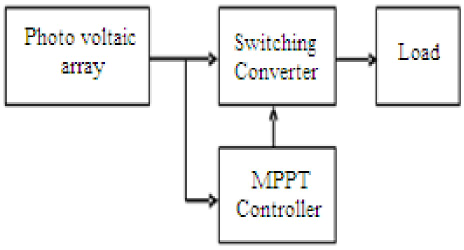

Fig 1: Block diagram of PV conversion System

2. CHACTERISTICS OF A PV CELL [3]
The power conversion unit of a photovoltaic system is the PV cell. The characteristics of the PV cell are given by its I-V characteristics shown in figure 2 and figure 3.

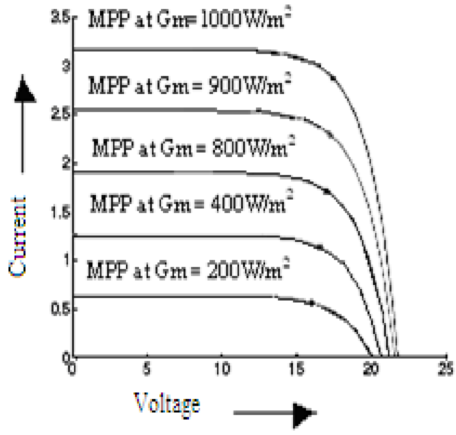

Fig 2: I-V curve of solar cell under different illumination

This characteristic gives two important values, the short circuit current (Isc) which is the maximum current at zero voltage and the open circuit voltage at zero current (Voc) which is the maximum voltage at zero current. For each point on the I-V curve the power output is obtained by finding the product of current and voltage. The maximum power point (P_m) is the point where the product of I and V is maximum on the I-V curve.

The fill factor is the ratio between P_m and the product of Isc and Voc. The cell efficiency is defined as the ratio of the power P_m and the radiation power incident on the cell. The solar insolation and temperature decides the conversion efficiency of the solar cell.

The variation of output power characteristics of solar cell by illumination and temperature are shown in figure 4 and figure 5. The open circuit voltage (Voc) and short circuit current (Isc) increases with increase in intensity of radiation. The increase in temperature causes some increase in short circuit current decrease in cell voltage at the rate of 2.2mv per degree rise of temperature. [2]

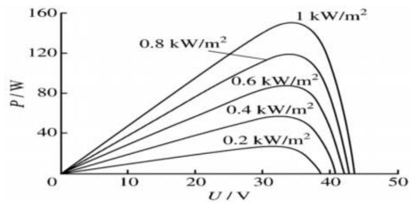

Fig 4: P-V curve of solar cell under different illumination

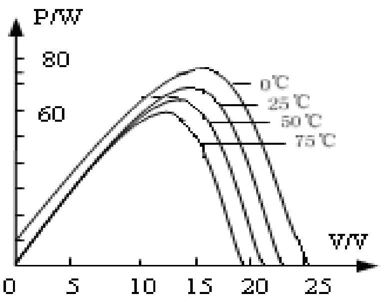

Fig 5: P-V curve of solar cell under different temperature

3. PV EQUIVALENT CIRCUIT [4]

A solar cell basically is a p-n semiconductor junction. When exposed to light, a dc current is generated. The generated current varies linearly with the solar irradiance. The standard equivalent circuit of the PV cell is shown in Fig.6. [4]

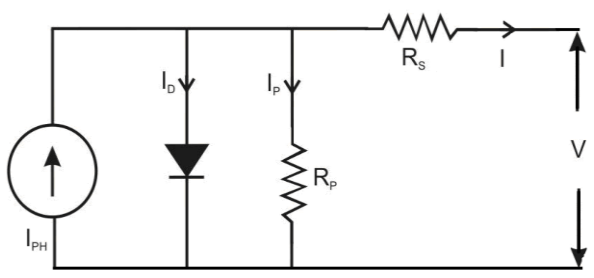

Fig 6: Equivalent circuit of PV solar cell

I is the cell current (A).

I_{PH} is the light generated current (A).

Io is the diode saturation current.

q is the charge of electron = 1.6x10-19 (coulomb)

K is the Boltzmann constant (j/K).

T is the cell temperature (K).

Rp, Rs are cell series and shunt resistance (ohms).

V is the cell output voltage (V).

4. DC-DC Converters

In PV conversion system the PV array can be connected to the load either directly or through a converter. In direct connection the power absorbed by the load will be smaller than the maximum power available at given illumination and temperature for an operating point on the non linear I-V characteristic of the PV array. A dc-dc converter can be connected between the PV array and load to make the PV array to operate around the maximum power point under varying solar radiations and temperatures. The dc-dc converter can increase or decrease the voltage of the PV system depending on the load requirements. The various dc-dc converters commonly used with PV array for impedance matching are discussed below:

4.1 Buck Converter

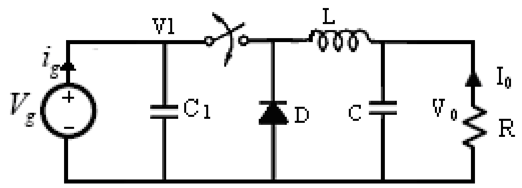

Fig 7: Buck Converter

A buck converter cannot emulate smaller impedances than the load impedance. So it does not reach values near the short circuit current of the PV module. It has low output ripple current and high input ripple current. The average voltage V_0 is smaller than the voltage Vi of the PV array terminals. For an ideal buck converter

$$V_g/V_i=D \tag{1}$$

Where the duty cycle (D) is the ratio of the time of conduction (Ton) to the switching period (Ts). Buck converters are used in situations where array voltages are higher than battery voltages. [5], [6]

4.2 Boost converter

Boost converter cannot emulate greater impedances than the impedance of the load. So it does not reach values near the open circuit voltage of the PV module.

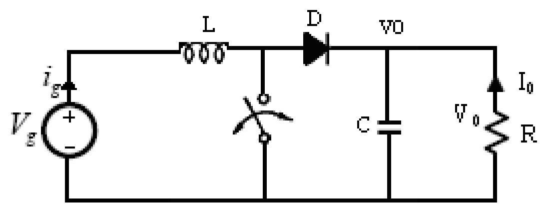

Fig 8: Boost Converter

The output voltage will be greater than the input voltage. For an ideal boost converter

$$V_g/V_i=D_0 \text{ where } D_0=1-D \tag{2}$$

Boost converters are used in situations where array voltages are lower than battery voltages. [5],[6]

4.3 Cascaded converters

The buck-boost characteristics can be had by the cascade connection of the Buck converter and boost converter. The input- output voltage conversion is multiple of the conversion ratios of the two converters in cascade. But the switches of the two converters must have the same duty cycle.

4.3.1 Buck-Boost Converter

The buck-boost converter can be formed by having buck converter as the first stage. The buck-boost converters figure.6 can sweep the whole range of the I-V curve in CCM (Continuous Current Mode) from open circuit voltage(Voc) to short circuit current (Isc). For a buck–boost converter the conversion ratio is V0/Vi=D0 where D0=1-D. Buck-Boost converters are used in situations where array voltages and battery voltages are nearly matched. This converter provides to have either higher or lower output voltages compared to input voltages. The buck boost converter operates through inductive energy transfer. The number of devices used is less in Buck-Boost converter compared to Boost –Buck converter. But the voltage stress in the switches will be high. It has non pulsating current characteristics. [4], [5]

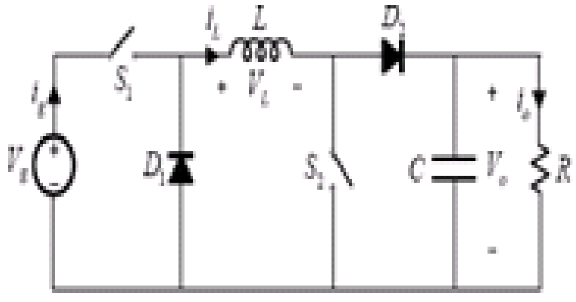

Fig 9. Buck- Boost Converter

4.3.2 Boost-Buck Converter

The boost-Buck converter can be formed by connecting the boost converter as first stage converter. The boost-buck converter operates through capacitive energy transfer.
The number of devices used will be higher than the Buck-Boost converters. But the voltage stress to the devices will be less. [5]

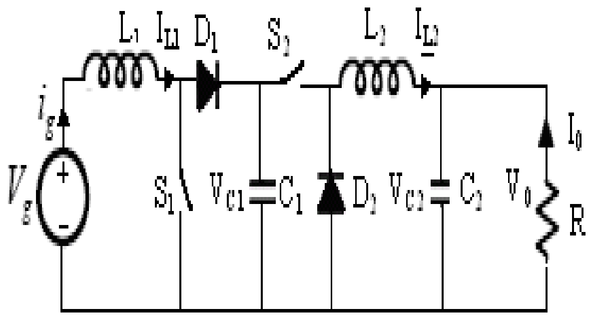

Fig 10: Boost Buck converter

4.4 Cuk converter

The cuk converters have low switching losses and the highest efficiency. It can provide better output current characteristics due to the inductor on the output stage. [6], [7] and [8]

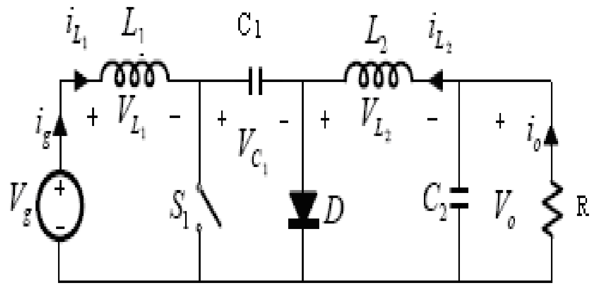

Fig 11: Cuk Converter

The relation between output and input voltage and currents of cuk converters are given below.

$$V_0/V_i=-(D/(1-D)) \quad (4)$$

$$Ii/Io=-(D/(1-D)) \quad (5)$$

4.5 SEPIC converter

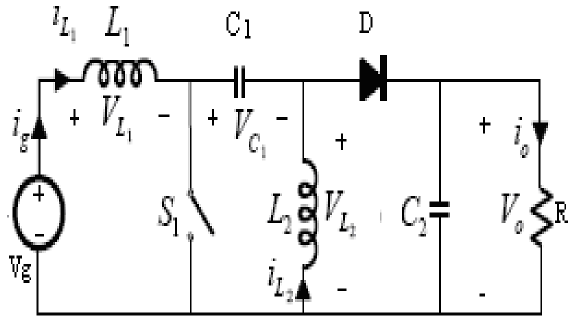

Fig 12: Sepic Converter

The SEPIC (Single Ended Primary Inductance Converter) has non-inverting buck-boost characteristics. It has simplified gate drive construction because of the grounding of switch terminal. SEPIC converter has non pulsating input current. It operates by the energy transfer between C_1 and L_1 and reduces the voltage stress in C_1 lower than cuk converter. This converter provides better input output isolation and have low input ripple and noise. [6], [7].

4.6 ZETA converter

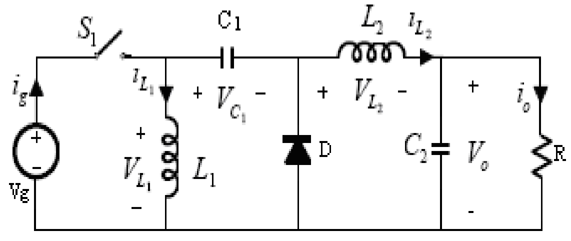

Fig 13: Zeta Converter

The Zeta converter is an inverse SEPIC converter because it can be formed by the interchange of power input ports and power output ports of SEPIC converter. This converter operates by the energy transfer between C_1 and L_1. It has non inverting buck-boost characteristics. The pulsating input current is the drawback of Zeta converter. This converter provides better input output isolation and have low input ripple and noise. [7]

4.7 Canonical switching cell (CSC) converter

The Canonical Switching Cell (CSC) converter forms the basic block for various converters.

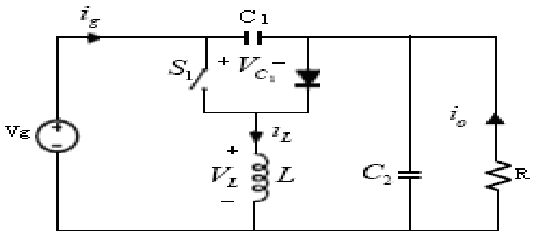

Fig 14: CSC Converter

Adding of inductors L1and L2 and removal of inductor L makes the Canonical Switching Cell (CSC) converter as Cuk converter. It works on the energy transfer between L and C. The advantage of this converter is the usage of low number of devices. The Canonical Switching Cell (CSC) converter has no pulsating input current. Hence the voltage stresses in C is the same as Cuk converter and greater than SEPIC converter. [7].

4.8 Flyback Converter

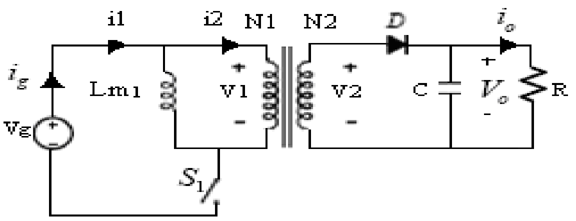

Fig 15: Flyback Converter

The Fly back converter is also a buck boost converter in which the inductor is split up to form a transformer. The fly back transformer provides isolation and also the voltage ratios are multiplied by turns ratio.
Fly back transformer model includes a inductance L_m and an ideal transformer with a turns ratio $N_{1/}$ N_2. The leakage inductance and losses of the Fly back transformer are neglected here. But the leakage inductance affects the switch and diode transitions.

$$V_0=|V_g|\ (D/\ (1\text{-}D)).\ N_2/N_1 \quad (6)$$

$$Ig=I_o\ (D/\ (1\text{-}D)).\ N_2/N_1 \quad (7)$$

The magnitude of L_m decides the boundary between CCM and DCM (Discontinuous Current Mode). The series connection of switch S_1 with dc generator results in pulsating input current. [7]

5. INTERLEAVED CONVERTERS

The converters so far discussed have both input current ripples and output voltage ripples which reduce the efficiency of the PV conversion systems and also deals with low power applications. For high current and high power applications interleaved boost dc-dc converters are used which improve the performance in terms of efficiency, size, conducted electromagnetic emission and transient response. Interleaving provides high power capability and improved reliability. But interleaving method requires additional inductors, power switching devices and output rectifiers. [12]

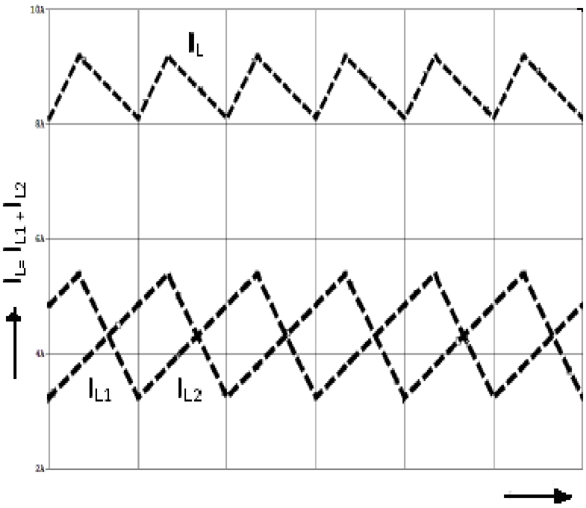

Fig 16: Ideal waveforms of the currents in the Inductors L_1 and L_2 for interleaved Boost Converter

In figure.16 the input current I for a two phase interleaved converter is the sum of the inductor currents IL_1 and IL_2 which are 180 degrees phase shifted so that the input current ripple get cancelled.

5.1 IDB (Interleaved Dual Boost) converter

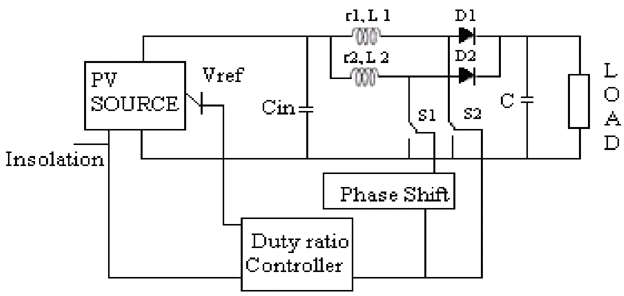

Fig 17: Interleaved dual boost converter

The ripple cancellation both in input and output current waveforms, lower the value of ripple amplitude and efficiency of the system can be improved by activating suitable number of converters in interleaved mode which are connected in the PV system depending on the physical condition. If the PV power decreases to a low level due to change in physical condition few converters are sufficient to transfer power to the load. If the power increases over the maximum limit of the activated converters then additional converters can be activated to transfer power to load and each converter will operate at an optimal power to increase conversion efficiency.

The parallel connection of converters reduces the device stress, increases flexibility and device tolerance. The assumptions made for interleaved operation are 1.Switching elements are ideal 2. Capacitors equivalent resistance is neglected and 3. The two switches operate in interleaved mode. In this interleaved dual boost converter switching losses will be high.

5.2 Interleaved zero current switch (ZCS) boost converter

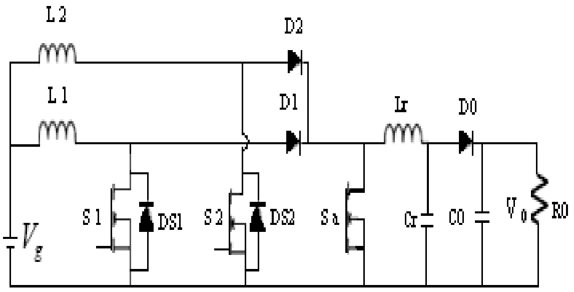

Fig 18: Interleaved ZCS Boost Converter

ZCS PWM (Pulse Width Modulation) boost converter uses only one auxiliary switch for soft switching operation. In this ZCS PWM boost converter soft switching is obtained for all semiconductor devices. So the reverse recovery losses of boost diodes are reduced. Due to the reduction of the switching losses efficiency of the converter also increased. IGBT switches are used for high power applications. To eliminate the tailing current losses interleaved zero current switching boost converters can be used. Due the reduction of the switching losses efficiency of the converter is 98.5% which is 2.7% higher than the hard switching circuits.[9]

5.3 Interleaved zero Voltage switch (ZVS) boost converter

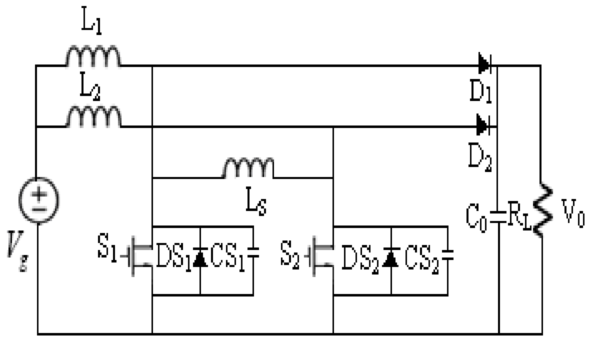

Fig 19: Interleaved ZVS converter

The interleaved ZVS boost converter consists of two soft-switching boost converters in parallel and an auxiliary inductor. This converter is capable of turning on both the active power switches at zero voltage and to reduce the switching losses and increases the conversion efficiency up to 95% while using MOSFET switches. [8],[10]

5.4 Interleaved soft switching boost Converter

Two single phase boost converters are connected in parallel to form a interleaved boost converter. The phase difference between the two PWM signals is 180 degrees. The switches are controlled by interleaving technique. The total current is the sum of the inductor currents L_1 and L_2. So the input ripple current is reduced.

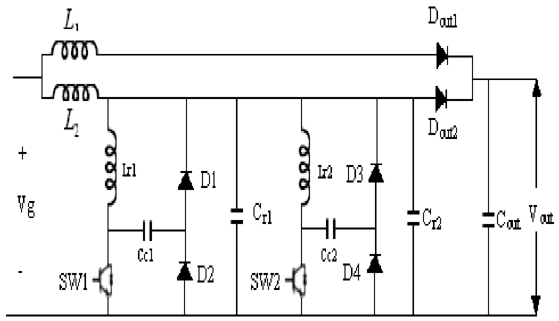

Fig 20: Interleaved soft switching boost converter

One resonant inductor, two capacitors and two diodes are added to normal boost converter to provide soft switching using resonance to each boost converter. The efficiency of the soft switching interleaved converter can be increased by 3.8% compared to the hard switching interleaved converters and a maximum of 98.5% efficiency can be obtained at full load condition. [11]

5.5 Interleaved fly back converters

The interleaved pulse width modulation boost-fly back converter has a high voltage conversion ratio because of its wide turn off period than the normal boost converters which have narrow turn off periods, which helps to get a higher output voltage and the interleaved operation reduces the input and output ripple currents and the size of the inductor and capacitor also reduced. The turn on of the power switches by zero current switching, reduces the switching losses.

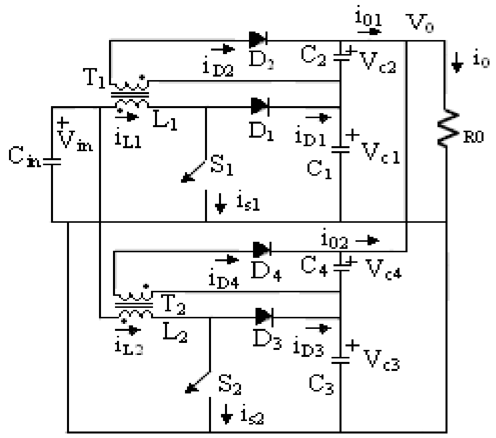

Fig 21: Interleaved Fly back Converter

6. CONCLUSION

In this paper an overview of various types of converters used as interface between photovoltaic system and load to increase the efficiency of the PV system were discussed**.** Each converter has its own advantages and drawbacks. The selection of a particular type of converter depends upon the output voltage requirement, cost factor and type of application used.

7. REFERENCES

[1] Ji. Y-H, Kim. J-H, Won. C-Y,and Jung.YC, "Ripple analysis of interleaved Soft switching boost converter for photovoltaic applications", International power electronics conference, 2010, 699 -702.

[2] Carles Jaen, Cristian Moyano, Xavier Santacruz, Josep Pou and Antoni Arias, "Overview of maximum power point tracking control techniques used in photo voltaic systems", International conference on ECS , 2008, 1099 – 1102.

[3] Zheng Shicheng and Liu Wei "Research and implementation of photovoltaic charging system with maximum power point tracking", IEEE conference on Industiral Electronics and applications , 2008 , 619 – 624.

[4] Thenkani. A and Senthilkumar.N, "Design of Optimum maximum power point tracking algorithm for Solar Panel", International conference on computer, communication and Electrical technology, 2011, 370 – 375.

[5] Nocci. F and Tosi. M "Comparison of converter Technologies in Photovoltaic Applications" ,Electro Technical conference on Integrating Research, Industry and Education in Energy and Communication Engineering,1989,11- 15.

[6] Duran.E, Sidrach-de-Cardona.J, Galan, M and J.M.Andjar " A New Application of the Buck-Boost Derived Converters to obtain the I-V curve of Photovoltaic Modules", IEEE Power Electronics Specialists Conference, 2007, 413-417.

[7] Duran.E,Sidrach-de-Cardona.J, Galan.M and J.M.Andjar "Comparative Analysis of Buck-Boost Converters used to obtain I-V characteristic curves of Photovoltaic Modules", IEEE Power Electronics Specialists Conference, 2008,2036 – 2042.

[8] Azadeh Safari and Saad MEkhilef, "Simulation and Hardware Implementation of Incremental conductance MPPT with Direct control method Using Cuk Converter", IEEE Transactions on Industrial Electronics, 2011 , 1154 – 116.

[9] Made Rezvanyvardom, Ehsan Adib and Hosein Farzanehfard, " A New Interleaved ZCS PWM BoostConverter" IEEE International Conference on Power and Energy, 2010,45-50.

[10] Yao-Ching, Hsieh,Te-Chin Hsueh and Hau-Chen Yen "An Interleaved Boost Converter With Zero- Voltage Transition" IEEE Trans on Power Electron, 2009,973-978.

[11] Ji,.Y-H. Kim, J-H. Won. C-Y,and Jung. YC, "Soft switching boost converter for photovoltaic power generation system", Power Electronics and Motion Control Conference, 2008, 1929-1933.

[12] Hegazy. O, Van Mierlo. J, Lataire. P,"Analysis,control and comparision of DC/DC boost converter topologies for fuel cell and Hybrid Vehicles", Conference on Power Electronics 2011, 1-10.