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Review of DC-DC Converters in Photovoltaic Systems for MPPT Systems

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Abstract - *This paper presents several DC-DC converters such as Buck, Boost, Buck-Boost, Cuk, SEPIC and Zeta converters to get maximum power of photovoltaic power systems. Depending on variations in solar irradiation and temperature of the photovoltaic system it has low-efficiency. To optimize the power of PV system a technique is require which is MPPT technique. A variation in temperature and solar irradiance is presented to evaluate output of DC-DC converters.*

Key Words: DC-DC converters, PV module, MPPT, Cuk, SEPIC, Zeta converter.

1. INTRODUCTION

Most of the energy demand requirement can be taken from fossil fuel based power plants (thermal power plants and gas power plants). Now a day, using of renewable power to use as power plant is an important thing because of depletion of fossil fuel reserves. Concerns over environmental effects such as climate changes, global warming, depletion of fossil fuels and increase in fuel prices are making renewable energies more attractive. Among the various renewable energy sources, solar energy is a promising energy source. Solar power generation represents currently one of the most promising sources of renewable green energy [1]. Due to the environmental and economic benefits, PV generation is preferred. Since they are clean, inexhaustible and require little maintenance [2]. PV cells generate electric power by directly converting solar energy to electrical energy. PV panels and arrays, generate DC power that has to be converted to AC at standard power frequency in order to feed the loads [3].

Generally, DC-DC power converters are used in solar PV systems to generate DC-DC power from one voltage level to another. These are also used for enhancing solar PV array power and for variable speed operation of motor drive. DC-DC power converters has two different classification one is the single inductor DC-DC power converter, such as canonical switching call, Buck, Boost, Buck-Boost, and secondly two inductor DC-DC power converter such as Cuk, SEPIC, Zeta converter

2. MODELING OF PHOTOVOLTAIC SYSTEM

The photovoltaic system converts sunlight directly to electricity without having any disastrous effect on the environment. The basic segment of PV array is PV cell, which is just a simple p-n junction device [4]. The fig. 1 manifests the equivalent circuit of PV cell. Equivalent circuit has a current source, a diode parallel to it, a resistor in series describing an internal resistance to the flow of current and a shunt resistance which expresses a leakage current [5].

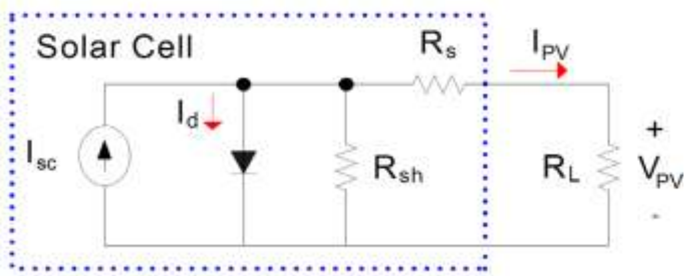

Fig. 1 equivalent circuit single diode model

The mathematical relationship for the voltage and current is given by

$$I = I_{ph} - I_0\left[\exp\left(\frac{a(V+IR_s)}{akTN_s} - 1\right)\right] - \frac{(V+IR_s)}{R_{SH}}$$

Where I_{ph} is photon current, I_0 is reverse saturation diode current, R_{sh} is shunt resistance, R_s is series resistance, 'a' is ideality factor of diode, V is module output voltage, I is output current of module, k is Boltzmann constant, T is temperature of module, N_s is number of series connected cells in module.

3. MPPT- P&O ALGORITHM

A slight perturbation is introduced in this algorithm. The perturbation causes the power of the solar module to change continuously. If the power increases due to the perturbation then the perturbation continued in the same direction [6]. The power at the next instant decreases after the peak power is reached, and after that the perturbation reverses. The algorithm oscillates around the peak point when the

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steady state reached. The perturbation size is kept very small in order to keep the power variation small.

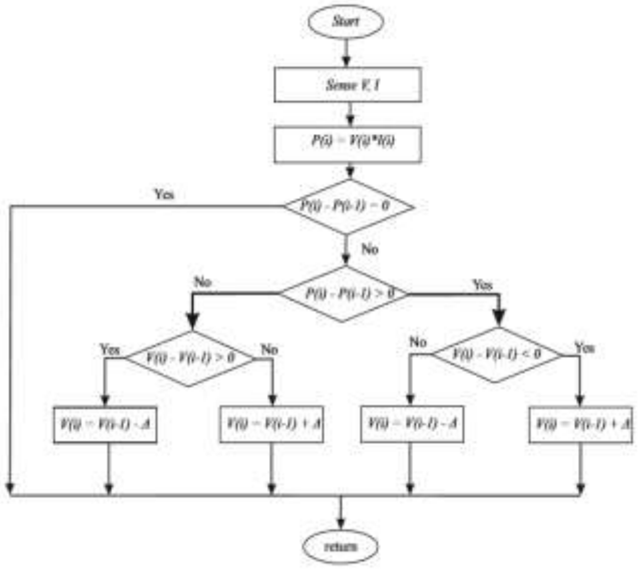


Fig. 2 Flowchart of P & O algorithm

The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module [7]. A PI controller is used to move the operating point of the module to that particular voltage level. It is shown in Fig. 2.

4. DC- DC CONVERTERS

DC-DC power converters have a very large presence in all kind of electronic circuits, from industrial applications (space craft power systems, DC motor drives, telecommunication equipment) to personal applications (PCs, office equipment, electrical appliance) [8]. These systems provide a regulated DC voltage level from unregulated DC voltage level. The different types of DC-DC converters discussed below.

4.1 Buck converter:

A Buck converter is a step-down DC/DC converter. Buck converters step-down its input to its output. It is a class of SMPS typically containing that uses two switches (a transistor and a diode, an inductor and a capacitor). The circuit diagram of buck converter as shown in fig. 3.
To reduce voltage ripple, filters made of capacitors are normally added to such a converters output and input [9].
Switching converters (such as buck converters) provide much greater power efficiency as DC-DC converters than linear regulators. Buck converters can be highly efficient, making them useful for tasks such as converting components main supply voltage down to lower voltages needed by USB and CPU.

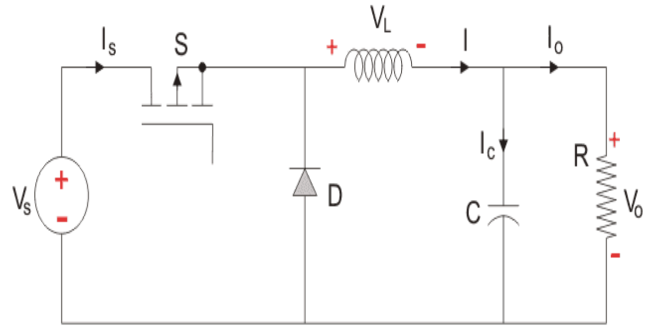


Fig. 3 Buck converter

4.2 Boost converter:

A boost converter (step-up converter) is a DC-DC power converter with an output voltage greater than its input voltage [10]. It is a class of SMPS containing at least two semi conductor switches (a diode and a transistor) and at least one energy storage element which is capacitor, inductor, or the two in combination shown in Fig. 4. Filters made of capacitors (sometimes combination of inductors) are normally added to the output of the converter to reduce output voltage ripple.

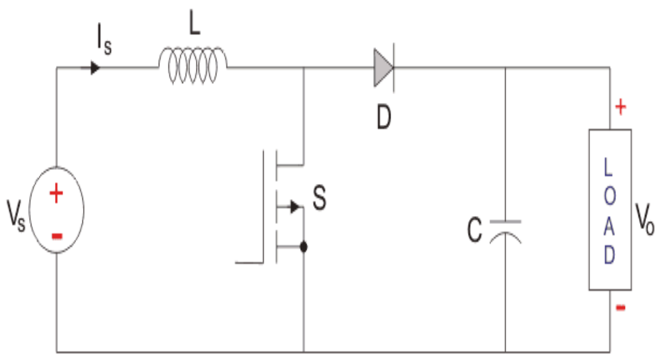


Fig. 4 Boost converter

4.3 Buck-Boost converter:

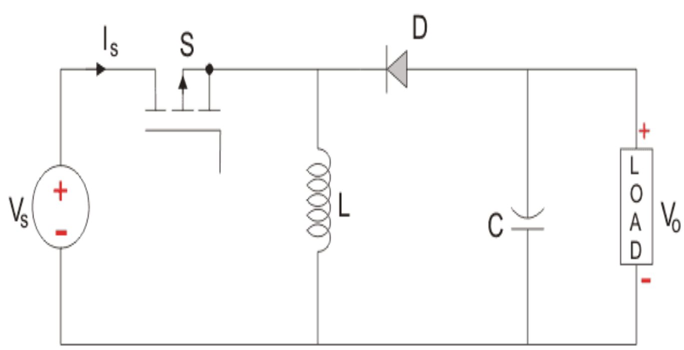


Fig. 5 Buck-boost converter

The buck-boost converter is a DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude [11]. It is equivalent to fly back converter using a single inductor instead of a transformer. The Fig. 5 shows the circuit diagram of buck-boost converter. The basic principles of the inverting buck-boot converter is While in the on state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. in this state capacitor supplies energy to the output load. While in the off state, the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R.

4.4 Cuk converter

The cuk converter is a type of DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude.

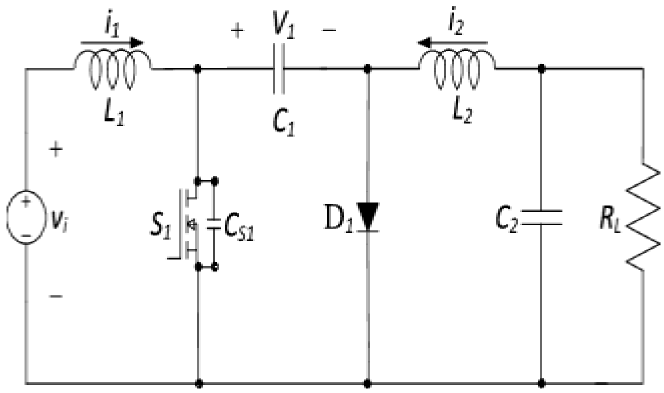


Fig. 6 Cuk converter

The cuk converter is like a buck-boost converter used to increase or decrease the input voltage. Fig. 6 shows the circuit diagram which uses a capacitor as its main energy storage device as opposed to an inductor like in the buck, boost, and buck-boost converters [12]. This circuit it was named after its inventor Slobodan cuk, the output voltage equations is the same as the buck-boost converter given in equation

Since the output voltage equation is linear, output voltage is controlled by feedback loop.

The two operating states of a non-isolated cuk converter, the diode and the switch either replaced by a short circuit when they are ON or by an open circuit when they are OFF. It can be seen that when in the off state, the capacitor C is being charged by the input source through the inductor L1. When on state, the capacitor C transferred the energy to the output capacitor through the inductor L2.

4.5 SEPIC converter

The single ended primary-inductor converter is type of DC-DC converter that allows the voltage at its output to greater than, less than, or equal to that at its input. The Fig. 7 shows the circuit diagram of SEPIC is essentially a boost converter followed by an inverted buck-boost converter. Therefore it is similar to a traditional buck-boot converter [13].

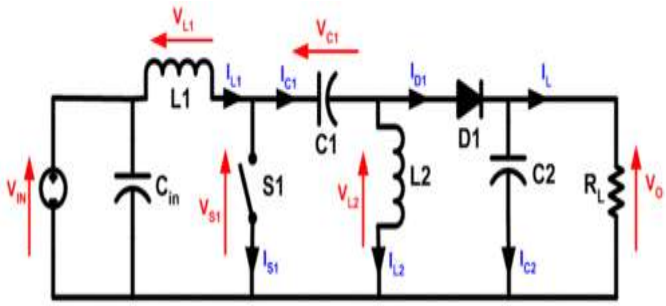


Fig. 7 SEPIC converter

But has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple the energy from input to the output, and being capable of true shutdown; when S1 is turned off enough, the output (V0) drops to ZERO volts.

4.6 Zeta converter:

The circuit diagram of zeta converter is shown in fig. the zeta converter is capable of converting input voltage into a non-inverted output voltage, having either a lower or higher value than the input voltage. The zeta converter consists of components like power electronic switch (S), inductors, a diode, capacitors and a load (R).

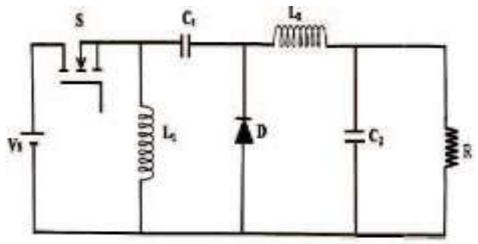
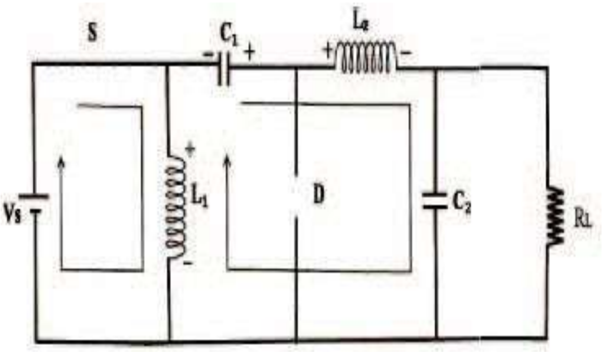


Fig. 8 zeta converter

Mode 1 is achieved, when diode (D) is off and switch (S) is on. The current through the inductor L1 and L2 are drawn from the source voltage Vs. The inductor current IL1 and IL2 increase linearly. This mode of operation is called charging mode.

Mode 2 operation is achieved, when diode (D) is ON and switch (S) is off. The energy stored in the inductors discharges and transferred to the load. The current in the inductors decreases linearly. This mode of operation is called discharging mode.



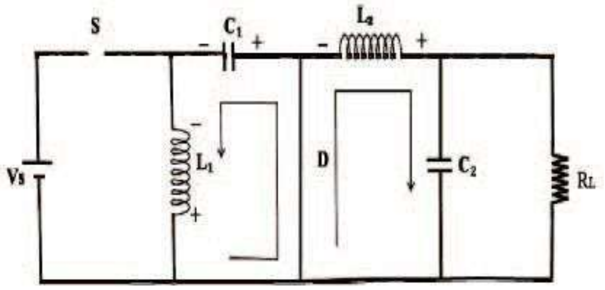


Fig. 9 mode 1 operation of zeta converter

Fig. 9 mode 1 operation of zeta converter

Advantages of zeta converter is to provides a non- inverted output, fewer transients in the output response and circuit losses are less compared to SEPIC.

5. Comparison between converters:

Table 1 comparison between converters

Buck-boost	SEPIC	Cuk
No boosting operation for larger values.	Difficult to control for slow varying applications.	Complex compensatory circuit is needed to make the converter operate properly.
Switching action of transistors create a high current ripple in input capacitors	A capacitor with high capacitance current handling capability is required, since the SEPIC converter transfers all its energy via series capacitor.	This complex compensation circuit slows down the performance of the converter.
Pulsed output current increases the output voltage ripple.	Like the buck-boost, SEPIC has pulsating output current.	Difficult to stabilize.
Buck-boost mode has higher switching and inductor current then boost side.	Only boost, no buck operation is performed.	Require capacitor with larger ripple handling capacity.

6. CONCLUSION:

In this literature review discussed on various types of DC to DC converters (Buck, boost, buck-boost, SEPIC, Cuk, and Zeta converters) and analyzed. Focused on comparison between various types of DC-DC converters and discussed their merits and demerits which helps the selection of converter for interfacing of MPPT and DC to AC converters.

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