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A Review on SEPIC Converter Topologies

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***Abstract*: Now a days renewable energy sources attain lot of attention because they reduce the consumption of fossil fuel and provide clean power and it will not cause any environmental issues. The solar photovoltaic system has been installed all over the world and different DC-DC converters are employed to get the required DC output. There are many DC-DC converters used for solar PV application and SEPIC converter is one of the most commonly used one because it has the advantage of having non-inverted output. There are different SEPIC converter topologies available and this paper mainly concentrated on the comparative study of different SEPIC converter topologies used in standalone solar PV system. Here mainly plain SEPIC converter, bidirectional interleaved SEPIC converter and floating point bidirectional interleaved SEPIC converter are compared.**

***Keywords*: DC-DC Converter, SEPIC Converter, Solar Photovoltaic System.**

1. Introduction

The fossil fuels are most commonly used for the power generation mainly because of its convenience to use but it has limited period of supply. So we introduce the renewable energy sources for power generation which produce clean and pollution less power. The renewable energy also helps to progress the energy independence and security. New technologies are introduced to produce electrical power from renewable sources like solar, wind, biomass, geothermal etc. Most of the renewable energy sources are intermittent in nature, so power electronics devices and energy storage systems are used to overcome this disadvantage [1].

The solar energy is abundant in nature and we can convert it into electrical energy using solar energy conversion technologies. The solar photovoltaic (PV) cell converts solar energy directly into electrical energy. The solar PV system can be mainly classified into two types off grid and on grid. In grid connected system the electric grid will stores the excess energy and it will provide the required energy when the solar PV system is deficient to meet the load demand [1]. In off grid system or standalone PV system, there is no grid connection and the energy system systems are used to feed the load when the solar PV source is unable to supply the power.

Energy storage system used to balance the power fluctuations between source side and load side. The power electronic converter (DC-DC Converter) interconnects the energy storage system with DC bus. Currently different DC-DC converter topologies are available and it can mainly classified into three types, buck converter, boost converter and buck-boost converter [2]. Single Ended Primary Inductor Capacitor (SEPIC) converter is a boost converter having the non-inverter output. It reduces the current/voltage ripple in output/input side. There are different SEPIC converter topologies present and in this paper a comparison of some topologies are include. This paper mainly focuses on the review of some commonly used SEPIC converter topology [3].

2. Different SEPIC Converter Topologies

A. Plane SEPIC Converter

The buck, boost and buck-boost are the basic converter topologies and Luo, Cuk, and SEPIC are the commonly used derived converter topologies [4]. Among the derived converters the SEPIC topology is most preferred because it can provide buck or boost operation with non-inverted output, reduce input or output current ripple and lower the switching stress.

Even though the buck-boost converter performs the same operation as SEPIC converter its efficiency is lower when compared to SEPIC converter. Hence the high efficiency application like spacecraft's use SEPIC converter. It gives a constant output when the input varies. The SEPIC have high efficiency in the range of 90%-95% [5]. Open loop SEPIC has a lower efficiency as compared to the closed loop SEPIC and it is not widely used in practical applications. It is preferred to use the SEPIC converter with feedback to hold a single output without the need for control when using a SEPIC as part of a large circuit.

The SEPIC configuration provides both buck and boost mode of operation in a single device depending on duty cycle. If the duty cycle is higher than 50%, then it acts as a boost converter and if it is less than 50%, then it works as a buck converter. The output is same as the input when the duty cycle is exactly 50% [6]. The Fig.1 shows the circuit diagram of the plane SEPIC converter. The open loop SEPIC has more ripple current and voltage and it is also not automatic hence the duty cycle needed to reset when the input is varied to get the desired output. So it is essential to design an automatic control on SEPIC converter. The automation is brought by the feedback loop and the main controlling component of the feedback loop is the PI Controller which also helps to reduce the steady state error voltage. The PI

Controller make the SEPIC becomes more robust and gives good dynamic response.

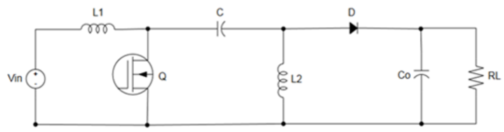

Fig. 1. Circuit diagram of SEPIC converter

The output voltage of the plane SEPIC converter is given by

$$V_{out} = \frac{D}{1-D} V_{in} \quad (1)$$

Where V_{out} is the output voltage, D is the duty cycle and V_{in} is the input voltage. The duty cycle is given by,

$$D = \frac{V_{out}+V_d}{V_{in}+V_d+V_{out}} \quad (2)$$

Where V_d is the voltage across the diode

The SEPIC can also be designed to behave as a multiple output isolated DC-DC converter. The main difference is that the input to the SEPIC is applied through a transformer with 1:1 turns ratio and the secondary coil is wound around the same core for all the multiple outputs [7].

B. *Bidirectional SEPIC Converter*

The bidirectional DC-DC converters are most widely used in standalone solar PV systems due to its high efficiency, cost reduction and better performance. The bidirectional DC-DC converter used to interface storage system between source and load in stand-alone solar PV system. It regulates the power flow of the DC bus voltage in both the direction in the system.

The conventional SEPIC converter can be converted to bidirectional converter by replacing the diode by a power switch like MOSFET, IGBT etc. The Fig.2 shows the evolution of bidirectional SEPIC from conventional SEPIC. The power can be flow in forward or backward direction, in forward power flow mode the bidirectional converter works as SEPIC converter and in negative power flow mode, it works as ZETA converter. SEPIC-ZETA converter works in both buck and boost mode of operation [8]. The performance of bidirectional converter is improved when the two separate inductors are replaced by a coupled inductor with a specific coupling coefficient. It reduces the output voltage ripple and voltage stress across the power switch [9].

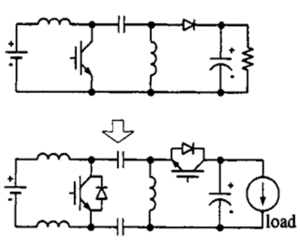

Fig. 2. Evolution of bidirectional SEPIC from conventional SEPIC

The output voltage of the bidirectional SEPIC converter is given by

$$V_{out} = \frac{D}{1-D} V_{in} \quad (3)$$

The bidirectional DC-DC converter can basically classified into two types, isolated converters and non-isolated converters. Flyback converter, Forward Flyback converter, half bridge and full bridge converter are the isolated converters. High voltage-gain can be obtained by adjusting the turns ratio of the high frequency transformer. However, the leakage inductance of the transformer results in high voltage spikes on semiconductor devices. A full bridge bidirectional DC-DC converter with a Flyback snubber circuit [10] and the bidirectional DC-DC converter with active clamp circuit [11] topologies will reduce the voltage stress caused by the leakage inductance. More additional circuits are required to recycle the energy of the leakage inductor and the switching losses will increase dramatically when the input and output voltages cannot match the turns ratio [12].

C. *Bidirectional Interleaved SEPIC Converter*

Interleaved converter is the parallel combination of two or more than two converters with relative phase shift of 360º. The interleaved converters have the advantages like current splitting, output current ripple reduction, higher efficiency, high-power density and, higher thermal capacity. The current is get splits in parallel circuit so the conduction losses of switch will reduce. The interleaved DC-DC converters reduce the input current ripple and output voltage ripple without increasing the switching losses which will leads to increase the system efficiency [13] [14]. The interleaving provides low ripple current and it will result in increase of MPPT efficiency. It also reduces the current stress and current rating of the switch. The fig.3 shows the circuit diagram of bidirectional interleaved SEPIC converter.

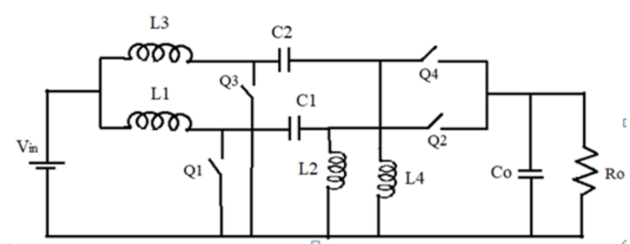

Fig. 3. Circuit Diagram of bidirectional interleaved SEPIC Converter

The output voltage of the bidirectional interleaved SEPIC converter is given by

$$V_{out} = \frac{D}{1-D} V_{in} \quad (4)$$

D. *Bidirectional Interleaved floating SEPIC Converter*

The bidirectional interleaved floating converter produces a higher DC voltage gain compared to conventional converters, and reducing the number of series connections for the PV and battery modules [15]. The bidirectional interleaved SEPIC converter is connected in parallel to obtain bidirectional

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interleaved floating SEPIC converter. The circuit diagram of this converter is shown in Fig.4.

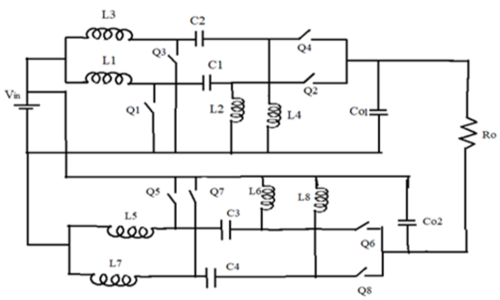

Fig. 4. Bidirectional interleaved floating SEPIC Converter

3. Conclusion

The voltage and current stresses of diodes and switches, in a conventional SEPIC converter, are much higher. In the continuous conduction mode (CCM), the SEPIC converters have large hard-switching losses, especially in high frequency operation. Therefore, the efficiencies are low for a traditional SEPIC converter operated in CCM. The power level is increased by interleaving two SEPIC converters. The bidirectional interleaved floating converter produces a higher DC voltage gain compared to conventional converters, and reducing the number of series connections for the PV and battery modules.

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