Comparative Study of Buck-boost, Zeta and SEPIC DC-DC Converters for Maximum Power Point Tracking Applications in PV Systems

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***Abstract*—The solar charge controllers which are used to charge the batteries consists of DC-DC converters which are essential components in photovoltaic systems. There are wide variety of DC-DC converters which are used for different applications depending on their characteristics, but when it comes to battery charging applications generally transformer less converters are preferred as they are compact and suitable for low power applications. In the transformer less DC-DC converters there are different topologies, generally for battery charging applications and MPPT charge controllers the converters which has low output transients and fast response are preferred.**

In this paper the design and simulation of buck-boost, zeta and SEPIC converters are done and the comparison of their transient responses are obtained based on which a particular convert is selected for the given application.

Index Terms—Duty cycle, Output ripple, transient response, charge controllers, MPPT.

I. INTRODUCTION

Shortage in Power, Depleting Non- renewable resources has started a revolution towards the use of renewable energy sources. The power obtained from the photovoltaic cell varies with respect to time and environmental factors. batteries are used for storing the excess energy when available and which can be used later. since the power i.e., voltage and current varies at the output terminal of the PV cell the charge controllers are used as an interface between the PV cell and the battery.

The charge controller controls the flow of power into the battery and it also provides protection against the reverse flow of power to the PV cell. a solar charge controller essentially consists of two major units:

1 . DC-DC converters

2 . MPPT control mechanism.

The DC-DC converter is a power electronics device that converts dc power of one level(voltage) obtained at the terminals of the PV cell to the required level (voltage) for charging the battery. There are various types of DC-DC converter topology based:

1. BUCK-BOOST CONVERTER
2. ZETA CONVERTER
3. SEPIC CONVERTER

In this paper we have considered the DC-DC converters which can step-up as well as step-down the input voltage. The converters are designed for battery chargers (charge controllers) therefore the transient response of the converter is essential for the effective and efficient operation of the chargers. The converters which have minimum peak overshoot, minimum settling time and less transients are considerable for this application.

II. BUCK-BOOST CONVERTER

A buck-boost converter is a DC-DC converter which can either step-up or step down the input voltage. fig1 shows an inverting buck boost converter. as the name suggests this converter provides negative voltage at the output terminal. it is a second order converter as it uses two energy storage devices. For the simulation purpose we consider the output voltage to be same as the input voltage i.e., 18v. and the switching frequency is 10Khz.

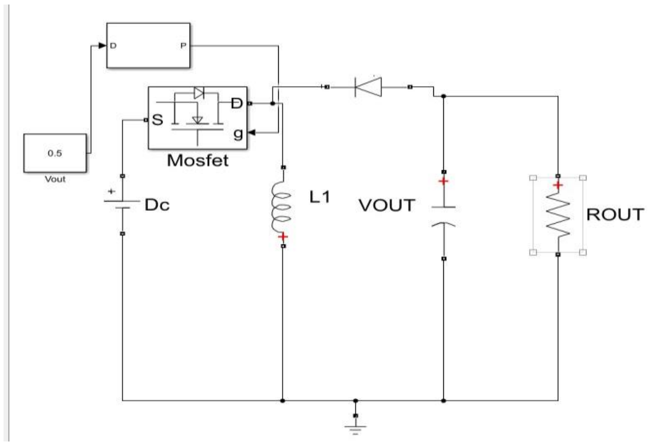

Fig.1 Simulink Model of Buck-boost converter

The design equations are given below considering the load to be 1kohm:

$$Vo/Vin=-(D/(1-D))$$
$$L=(Vin*D)/(IL_{(pp)}*Fsw)$$
$$IL_{(pp)}=K*Iin$$

Generally, the value of k is between 0.2 and 0.4

Table.1 Design parameters of Buck-Boost converter

INPUT VOLTAGE (V_{IN})	18V
OUTPUT VOLTAGE (V_{OUT})	-18V
DUTY CYCLE (D)	0.5
INDUCTOR (L)	170mH
CAPACITOR (C)	800µF
OUTPUT RESISTANCE	1KΩ
SWITCHING FREQUENCY Fsw	10,000 Hz

Using the design equations and considering the nominal value of capacitor Table.1 is obtained and substituting the values into the Simulink model the output response obtained is as shown in fig.2

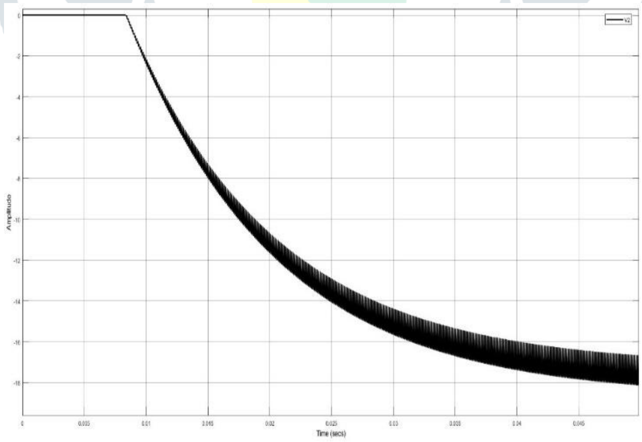

Fig.2 Output Voltage of Buck-boost converter

From fig.2 we can obtain transient response parameters of buck-boost converter and it can be compared with the response of other converters. for buck boost converter the settling time is very less but the output is inverted and also has more ripples.

III. ZETA CONVERTER

The ZETA converter topology provides a positive output voltage from an input voltage that varies above and below the output voltage. The ZETA converter needs two inductors and a series capacitor, sometimes called a flying capacitor. It is a fourth order converter as it uses four energy storage devices. Unlike the SEPIC converter, which is configured with a standard boost converter, the ZETA converter is configured from a buck controller that drives a high-side P-MOSFET. For the simulation purpose we consider the output voltage to be same as the input voltage i.e., 18v. and the switching frequency is 10Khz.

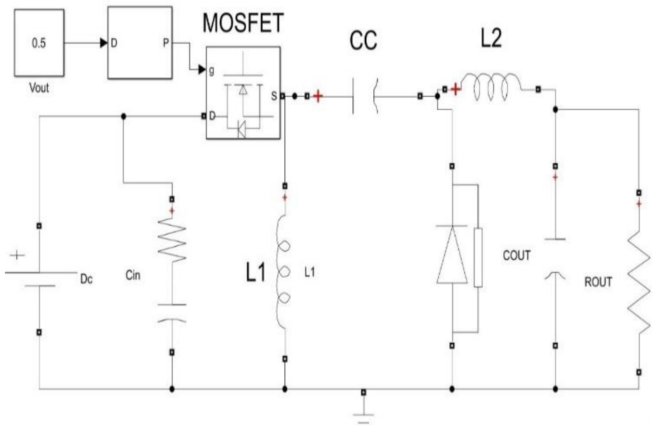

Fig.3 Simulink Model of zeta converter

The design equations are given below

$D=(Vout/(Vin+Vout))$

$L=(Vin*D)/(IL_{(pp)}*Fsw)$

$IL_{(pp)}=K*Iin$

Considering the value of k to be 0.3 for zeta converter.

Table.2 Design parameters of zeta converter

INPUT VOLTAGE (V_{IN})	18V
OUTPUT VOLTAGE (V_{OUT})	18V
DUTY CYCLE (D)	0.5
INDUCTOR (L)	170mH
CAPACITOR (C)	5µF
OUTPUT RESISTANCE	1KΩ
SWITCHING FREQUENCY Fsw	10,000 Hz

Using the design equations and considering the nominal value of capacitor Table.2 is obtained and substituting the values into the Simulink model the output response obtained is as shown in fig.4

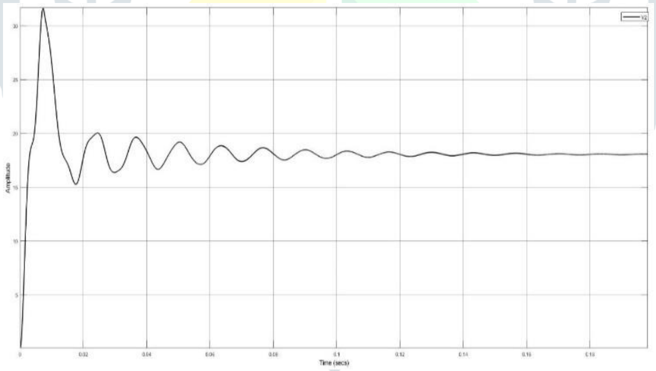

Fig.4 Output Voltage of zeta converter

From fig.4 we can obtain transient response parameters of zeta converter and it can be compared with the response of other converters. For zeta converter we can see that there are less transients in the output response.

IV. SEPIC CONVERTER

The single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter that allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle.

A SEPIC is essentially a boost converter followed by an inverted buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output. For the simulation output voltage and input voltage are considered to be 18v and the switching frequency is 10khz.

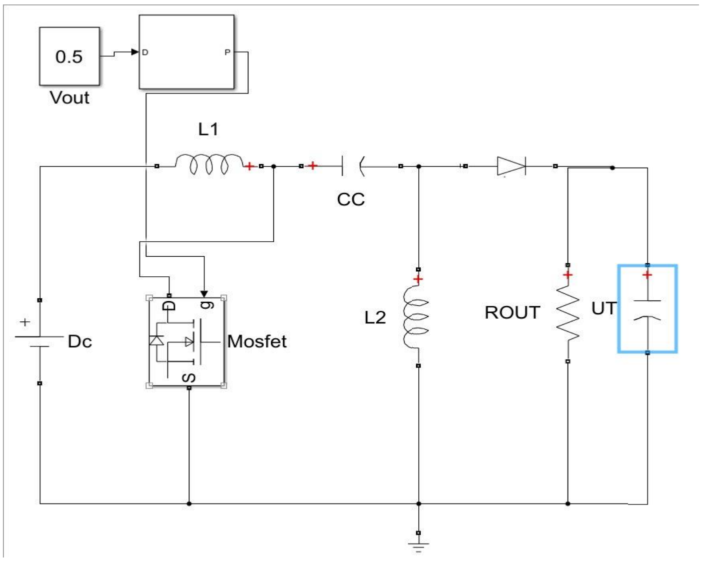

Fig.5 Simulink Model of SEPIC converter

The design equations are given below

$$D=(Vout/(Vin+Vout))$$
$$L=(Vin*D)/(IL_{(pp)}*Fsw)$$
$$IL_{(pp)}=K*Iin$$

Considering the value of k to be 0.25 for SEPIC converter

Table.3 Design parameters of SEPIC converter

INPUT VOLTAGE (V_{IN})	18V
OUTPUT VOLTAGE (V_{OUT})	18V
DUTY CYCLE (D)	0.5
INDUCTOR (L)	200mH
CAPACITOR (C)	1000µF
OUTPUT RESISTANCE	1KΩ
SWITCHING FREQUENCY Fsw	10,000 Hz

Using the design equations and considering the nominal value of capacitor Table.3 is obtained and substituting the values into the Simulink model the output response obtained is as shown in fig.6

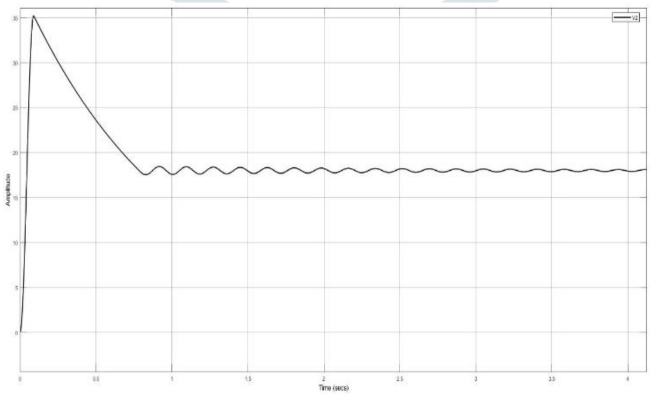

Fig.6 Output Voltage of SEPIC converter

From fig.6 we can obtain transient response parameters of SEPIC converter and it can be compared with the response of other converters. For SEPIC converter we can see that the settling time is more when compared to other converters.

V. COMPARASION

All the three converters are designed for a standard application needed and the simulation results are obtained in Simulink.

By analyzing the results obtained from the above-mentioned converter circuits, a comparison table (table 4.) is formed discussing various output parameters.

Table.4 Comparison table

Parameters	Buck-boost	zeta	SEPIC
Output voltage	Inverted	Non-Inverted	Non-Inverted
Peak overshoot	No	Moderate	High
Settling time	0.05	0.1	1.5
Output ripple	High	Low	Moderate

By referring to the above table and output response of various converters, it was seen that zeta converter proved to be the most effective for battery charging purpose since there is very low ripple in the output voltage and also it has less settling time therefore provides faster response.

Advantages of zeta converters:

1. Provides a non-inverted output.
2. Stable output response is obtained.
3. Low settling time therefore faster operation.
4. Fewer transients in the output response.

VI. CONCLUSION

The buck-boost, zeta and SEPIC DC-DC converters are designed for standard requirements and simulated in the Simulink. The results obtained are studied and compared for various parameters like settling time, output ripple etc., by which we can conclude that the zeta converter is best suited for MPPT and battery charging applications as the transient response of zeta converter is better than buck-boost and SEPIC converter.

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