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Research paper

High Convertion Ratio Power Converterfor Electric Vehicle Application

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Abstract

In Electric Vehicle applications, the converters play a significant role by stepping up or stepping down the input voltage and feeds the motor. The implementation and the mathematical analysis of the DC-DC Converters are analysed and presented here. This paper gives the better view of Zeta converter, Superlift Luo converter and Cascaded boost converterruns the BLDC motor with constant voltage for the electric vehicle and the simulation is carried out by the MATLAB/SIMULINK. The simulation results of the proposed DC-DC converters are compared with the analysed values.

Keywords: *Solar array, battery,Power converters.*

1. Introduction

Nowadays the major concern about the environment is pollution. Transportation is the main cause of the pollution. To avoid the pollution the electric vehicles are presented instead of conventional vehicles. The input of the electric vehicle may be battery, solar array or fuel cells. These sources can produce only low voltage so the power converters are used to boost the input voltage level.Conventionally, the DC-DC converters performs either increasing or decreasing the input voltage level. Boost Converter, Buck Converter, Buck-Boost Converter, Zeta Converter, Luo Converter and Sepic Converter are the DC-DC converter topologies.

In [1], PV module is used as input source to feed the zeta converter. It can boost or buck the input voltage because it contains two inductors and two capacitors [2]. Zeta converter is a dc-dc converter used in renewable source applications where the advantage is low output voltage ripple and small in structure. It gives better efficiency [3]. Comparatively, Zeta converter is preferred for power factor correction. The harmonic distortion factor is low and simple circuit. In [4], it works in discontinuous conduction mode. It is suitable for the power grid as well as renewable energy sources. In this paper [6], the superlift luo converter is used for the power conversion at the input side. The solar panel connected at the input provides the dc voltage which is boosted. This Converter achieves the good voltage conversion gain. The performance of the superlift luo converter at different duty cycles is compared with conventional dc-dc converters and also the structure is simple [7]. The proposed converter controls the voltage and current ripple. It boost the voltage more than the conventional luo converter [8].

Out of this, the preferred converter for high step up operation is Two-stage Cascaded boost Converter.When the performance of conventional boost converter and cascaded boost converter is compared, the boost converter is chosen for low cost but it cannot yield the designed output voltage level even at the high duty ratio.Therefore, the cascaded boost converter is presented[9]. The benefit of this converter is even at the low duty cycle it can offer high voltage gain and also high efficiency [10].Here, the PV system feds the input voltage to the cascaded boost converter. It achieves high voltage conversion only with coupled inductor and the drawback is the turn’sratio [11]. Usually the PV panel can produce only low voltage but the load requires high voltage, hence the cascaded boost converter is used. But the conventional converter is not applicable for high power applications because of the input inductor current and switching stress. But the modified topology overcomes these effects by splitting the inductor [12].

Along with the high voltage conversion ratio, cascaded boost converter can also provide less harmonic distortion and power factor correction applications[13]. Initially the proposed converter step up the input voltage and then it gains high voltage conversion by using the coupled inductor and snubber circuit. Here, the soft switching technique is preferred in the converter for the better efficiency[14]. In this paper, the presence of DC snubbercircuit and cascaded conversion structure has the advantage of high voltage gain. It converter controls the power devices of the converter by using only one duty cycle.The proposed converter produce high efficiency with synchronous rectification[15]. The main disadvantage of the conventional converter is the conduction losses of the input inductors. Such reduction losses are reduced by implementing a new circuit topology. This circuit is the series combination of boost converters. The conduction losses and switching losses in the proposed converter are neglected[16].

Hence, the analysis, working principle and simulation results of the three dc-dc converters arepresented in this paper for electric vehicle application.

2. Zeta Converter

The circuit diagram of the conventional zeta converter is shown in Fig.1. This dc-dc Converter is preferred for stepping up the dc constant input voltage given to the converter. Depending on the duty ratio of the Mosfet, it can boost or buck the input voltage to the required voltage.

2.1. Operating Modes of Proposed Converter

During ON period, the switch conducts and the input capacitor C_1 charges and also the inductor current increases toi_{L1}. During OFF period, the current across the inductor L_1decreases.

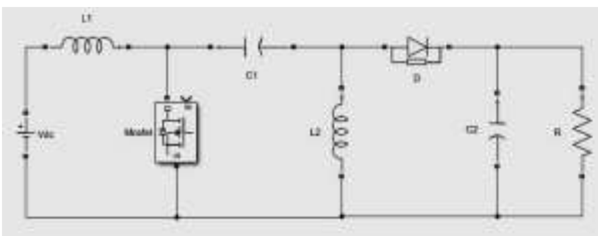

Fig.1: Equivalent Circuit diagram of Zeta Converter

The zeta converter is the next level of the input solar array or battery. The design part involves the analysis of capacitors and inductors for the assigned load. The duty ratio leads the design calculation of the zeta converter. The input voltage stepped up for the duty ratio of 0.7. The mathematical analysis of the zeta converter is carried out by the following equations.

$$\frac{V_0}{V_{in}} = \frac{k}{1-k} \quad (1)$$

$$L_1 = \frac{DV_{in}}{f\Delta I_{L1}} \quad (2)$$

$$L_2 = \frac{(1-k)V_0}{f\Delta I_{L2}} \quad (3)$$

$$C_1 = \frac{kI_0}{f\Delta V_{c1}} \quad (4)$$

$$C_{2,rated} = \frac{I_0}{6\omega_{rated}\Delta V_0} \quad (5)$$

$$C_{2,min} = \frac{I_0}{6\omega_{min}\Delta V_0} \quad (6)$$

As mentioned in[5],ω represents the fundamental frequency. For high frequency application, the low capacitance value is selected. The circuit parameters used for the simulation of zeta converter from the design analysis is presented here.

Table 1: Calculated Circuit Parameters

Parameter	Value
Input Voltage	250V
Output Voltage	530V
Duty ratio	0.7
Inductor	L_1=200mH L_2=100mH
Capacitor	C_1=1μF C_2=20μF
Resistor	R=1000Ω

2.2. Simulation Results

The simulated output voltage is nearly 600V and 700V for the constant dc source and the battery fed converter shown in Fig.2 and Fig.3 respectively where load current is 5A and the power is 3Kw.

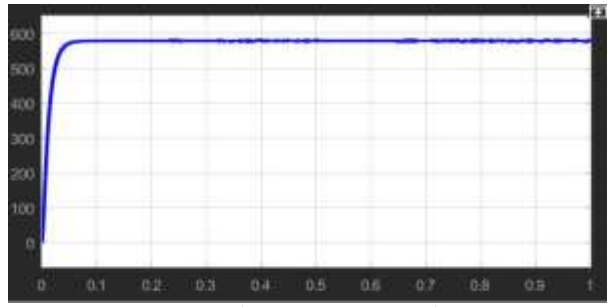

Fig.2: Output Voltage of Constant DC Source fed Zeta Converter

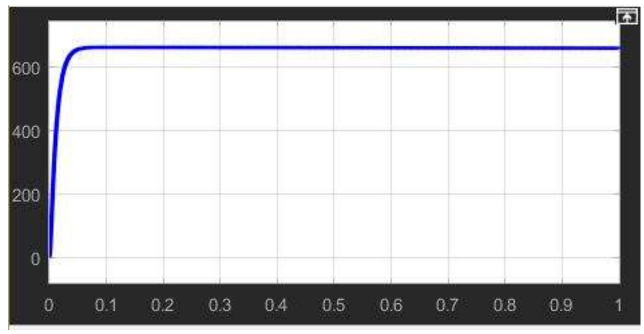

Fig.3: Output Voltage of Battery fed Zeta Converter

3. Super Lift LUO Converter

The circuit diagram of the proposed superlift luo converter is shown in Fig.4. This proposed converter can boost the dc voltage to high voltage for low duty ratio. It can be applicable for either high power or low power applications. It is more suitable for solar PV array because it provides only low voltage.

3.1. Operating Modes of Proposed Converter

During ON period, the switch conducts and the voltage across the input capacitor C_1 charges and also the inductor current increases toi_{L1}. During OFF period, the current across the inductor L_1decreases.

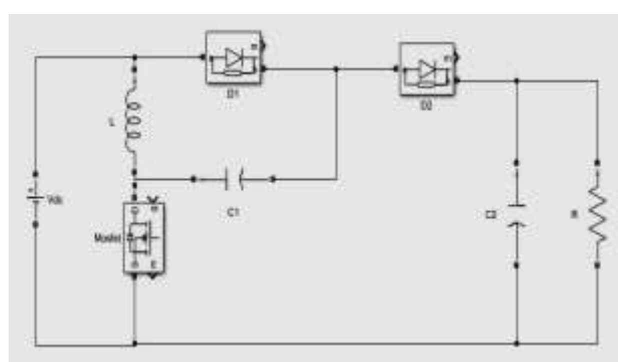

Fig.4: Equivalent Circuit diagram of Superlift Luo Converter

The design analysis of the proposed converter is described here by the following calculations.

$$\frac{V_0}{V_{in}} = \frac{2-k}{1-k} \quad (7)$$

$$\in = \frac{k(2-k)TV_{in}}{2L_1 I_{in}} \quad (8)$$

$$\Delta V_0 = \frac{(1-k)V_0}{fC_2 R} \quad (9)$$

In equations 8 and 9, $\in \& \Delta V_0$ are considered to be low values. The circuit parameters used for the simulation of superlift luo converter from the design analysis is presented here. The assigned output voltage of the converter is 530V.

Table 2: Calculated Circuit Parameters

Parameter	Value
Input Voltage	200V
Output Voltage	530V
Duty ratio	0.4
Inductor	L_1=200µH
Capacitor	C_1=1µF C_2=50µF
Resistor	R=1000 Ω

3.2. Simulation Results

The simulated output voltage is nearly 650V for the dc constant input voltage 200V and the battery fed converter is nearly 750V shown in Fig.5 and Fig.6 respectively where load current is 5A and the power is 3Kw.

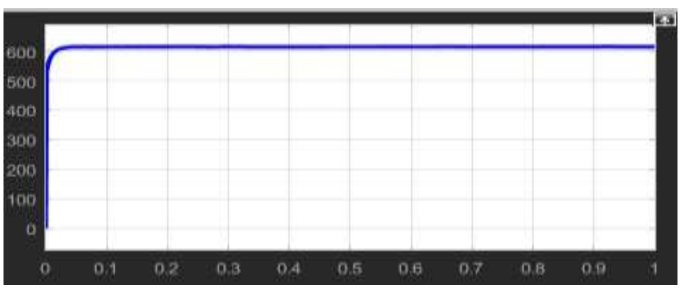

Fig.5: Output Voltage of Constant DC Source fed Superlift Luo Converter

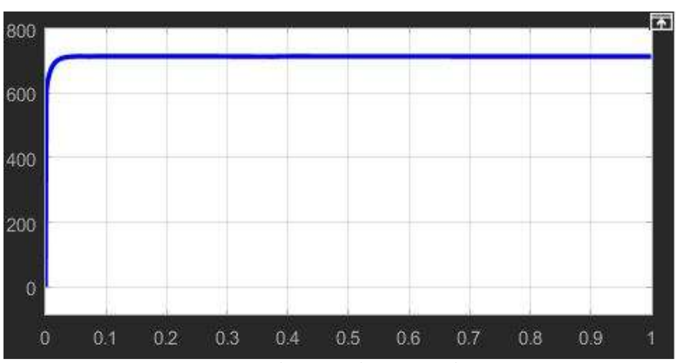

Fig.6: Output Voltage of Battery fed Superlift Luo Converter

4. Cascaded Boost Converter

The circuit diagram of the cascaded boost converter is shown in Fig.7.It is preferred to high voltage gain compared to other dc-dc converters. The cascaded boost converter represents the boost converter connected in series.The two operating modes of this converter is described here.

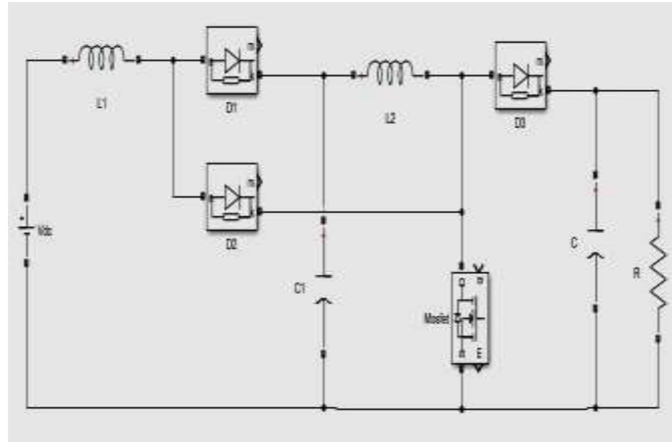

Fig.7: Equivalent Circuit diagram of Cascaded Boost Converter

4.1. Operating Modes of Proposed Converter.

Mode 1: ON period
The operation of this converter comprises two modes. The converter contains only one switch which conducts by the gate pulse represents mode 1. During the switch is in ON period, the inductor charges by the input voltage. The capacitor C_1 at the input side increases by the inductor L_2 and the capacitor C_2 gives the output voltage.

Mode 2: OFF period
It represents the operation of converter whenthe switch is in OFF condition. At this instant the inductors L_1 and L_2 discharges.The converter operates at the switching frequency of 80 KHz. The proposed converter is designed by the following equations given below[17].

$$\frac{V_0}{V_{in}} = \left(\frac{1}{1-k}\right)^2 \quad (10)$$

$$\in_1 = \frac{k(1-k)^4 R}{2fL_1} \quad (11)$$

$$\in_2 = \frac{k(1-k)^2 R}{2fL_1} \quad (12)$$

$$\in = \frac{k(1-k)^4 R}{2fC_2} \quad (13)$$

This converter provides high voltage for electric vehicle application from low input voltage. The values used for the simulation is mentioned in the table given below.

Table.3: Calculated Circuit parameters

Parameter	Value
Input Voltage	48V
Output Voltage	530V
Inductor	L_1=100µH L_2=2mH
Capacitor	C_1=100µF C_2=200µF
Resistor	R=1000 Ω

4.2. Simulation Results

The simulation of the converter is carried under MATLAB/SIMULINK. The simulated output voltage is nearly 700Vfor constant dc voltage and 800V for battery fed converter shown in Fig.8 and Fig.9 respectively where load current is 5A and the power is 3Kw.

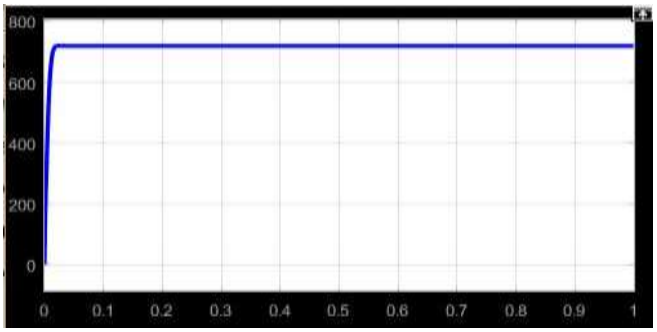

Fig.8: Output Voltage of Constant DC Source fed Cascaded Boost Converter

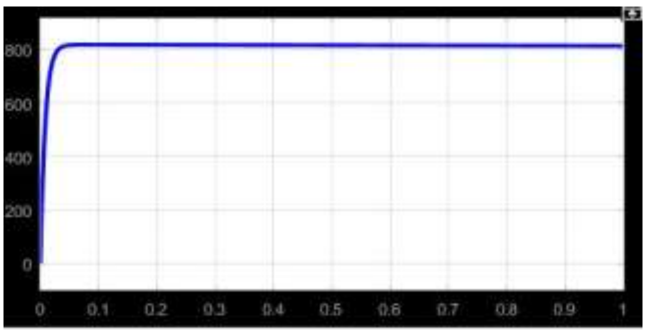

Fig.9: Output Voltage of Battery fed Cascaded Boost Converter

5. Conclusion

This paper concludes the mathematical analysis and simulation part of the three proposed dc-dc converters which can be applicable for high voltage applications. The performance is compared using the simulation results. Among the three converters, the cascaded boost converter gives the high voltage conversion ratio. Thus, the proposed converters can fed the BLDC motor with the output voltage of 530V for 3Kw in electric vehicle application.

Table 2:

Converter	**Input Voltage**	**Output Voltage**	**Voltage Conversion Ratio**
Zeta Converter	250V	580V	2.32
Superlift Luo Converter	200V	610V	3
Cascaded Boost Converter	48V	720V	15

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