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Comparative Analysis of Design of Electric Vehicle Battery Charger Using Quasi-Z-Source Converter and LUO Converter

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Abstract:
The development in DC/DC converters is required today because it is widely utilized in power generation using wind and solar.Hence, this work proposes two different topologies namely, a DC/DC Quasi Z Source Converter (QZSC) and positive LUO converter for solar power generated in the DC micro grid. A PV is connected as an input to converter. However, due to the varying nature of the PV, the output of the system oscillates. Hence, to maintain a constant output supply for load, PI controller is implemented. Thus the behavior of the proposed convertersis analyzed using MATLAB simulation. From the analysis, it is demonstrated that among these two proposed converter, Luo converter exhibits high voltage gain and efficiency than QZSC.
Keywords*: Quasi Z Source Converter, PV system, PI controller, Luo converter.*

I Introduction

The advancement in the industrial revolution,the diminution of fossil fuels and an increased level of pollution and the shortage of energy have made it necessary to develop an alternate energy resources using renewable energy sources (RES)[1, 2]. However, the output voltage of RES is very low and also far from the gridconnected inverters. Hence, the demand for high step-up DC/DC converters hasraised.Apart from RES, many applications like Xray systems and EV also needs a DC converters with higher voltage conversion ratio [3, 4].Among the various NIBDC topologies, the conventional boost converter is commonly utilized for step-up purpose. Theoretically, the output voltage of this converter is higher than its input voltage at duty ratio 1. But in practical, due to parasitic parameters of the circuit, the duty ratio is limited. As a result, voltage gain of this also limited [5, 6, 7]. Hence to overcome this problem and to acquire high voltage gain, the boost converters werecoupled in series[8]. But this converter will be more complicated due to presence of numerous components and additive control units. This will results in increased size and cost. So that the efficiency and reliability converter declines.Thevoltage gain of the converters can also be increased by incorporating coupled inductors [9, 10].But its leads leakage inductance problem. This can be rectified by adding snubber circuits. However, the results in low efficiency[11-13].A converter with interleaved configuration depictedby Henn et al 2010, obtains a high voltage gain.

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Prudente et al 2008 and Tseng KC et al 2014 alsoproposed stepup converters (DC/DC)using voltage multiplier configuration. By integrating switched-inductors can also increase the voltage gain of the converter [14 -22]. But the DC/DC converters discussed so far are complex in nature and their output voltage gain is not enough for practical applications. Hence to overcome this problem, in 2003, an idea of a ZSN was proposed by [23]. Thus the ZS impedance network comprisestwocapacitors and inductors and are connected together in Xshaped configuration. It was first tested inAC inverters, and hence the inverter can be operated in both buck and boost conversion. Thus, it employsST zero state to acquire higher voltage gain. Hence, the ZSI becomes more suitable for RES power generationand as a result,modified version of ZSIcalled and quasi-Z-source inverter (qZSI) is introduced [24-29].Galigekere 2012 proposed a PWM ZS DC/DC converter exhibits higher voltage gain than the traditional boost converter.A novel ZS(DC/DC) converter [30] was formulated by, replacing the inductor of a boost converter with the ZSN. However, the output voltage gain of ZS(DC/DC) converters discussed so far is not large enough for many industrial applications. Thus the voltage gain of the converter remains as major challenge while designing a DC/DC converters. This QZSunit exhibits lower capacitor voltage stress along with the characteristics of the ZSI. Apart from the inverter application, the QZS network can also be implemented as a DC/DC converter to increase the voltage gain. Similarly, the positive output lift Luo converter is a new series of DC-DC converters which has high-voltage transfer gain/ power density/high efficiency and reduced ripple voltage/ current. Hence keeping this view, this work, proposed a novel QZS and positive Luo converter with PI controller for PV application and its performances are examined.

II SYSTEM DESCRIPTION

System description

The structure of the proposed system depicted in figure 1 comprises a PV system, QZS converter and a controller unit.

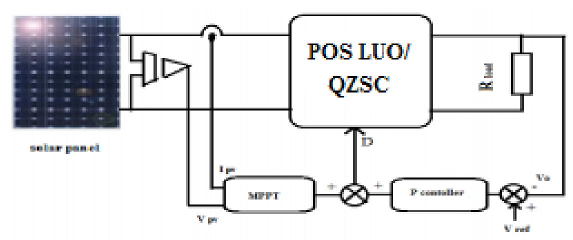


Figure 1. Block Diagram of Proposed System

III DESIGN OF PV UNIT

The basic building block of PV arrays is the solar cell. Theequivalent circuit of a PV cell is represented in Figure 2.

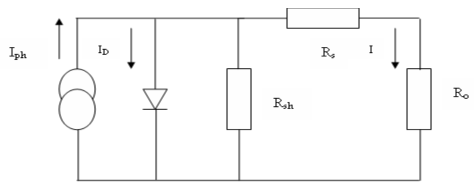


Figure 2. Equivalent circuit (PV cell)

Thusa mathematical model of a PV array can be expressed as

$$Ipv = n_{pa} I_{pho} - n_{pa} I_s \left[exp\left(\frac{q}{KTA}\right) * \right.$$
$$Vpvnser-1 \quad (1)$$

where

I_{pho} - Photo Current

Ipv - PV array 's output current

Vpv - PV array 's output voltage

n_{ser} - No. of series cell

n_{pa} - No. of parallel cell

q - Charge

K - Boltzmann's constant [8.62 x 10-5 eV/K]

A - Ideality factor.

T - Cell temperature (K)

In this model, the value of I_s varies with temperature and the I_{pho}depends on the radiation and cell temperature of the sun.

IV Design of Converters

A. QZS converter

The structure of proposed QZS converter is displayed in Fig. 3,

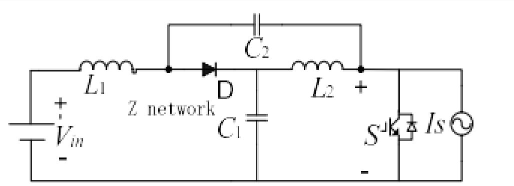


Figure 3. Circuit of QZS converter

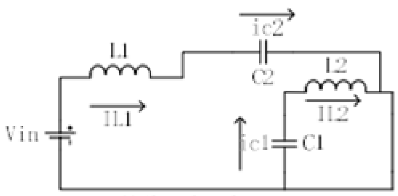
Working Principle of the Proposed Converter

A QZSC exhibits two working states during one switching period.

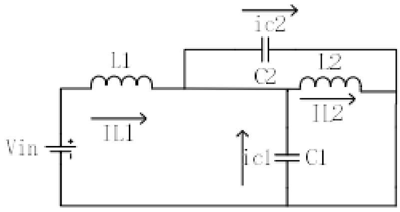
Shoot through state(STS)

Non-shoot through state (NSTS).

During ST condition, the diode is subjected to reverse biased and the capacitor discharge throughthe load and its equivalent circuit is depicted in Fig. 4(a).



(a) STS



(b) NSTS

Figure 4. Operating modes of QZS

During NSTS condition, the diode is forward biased and hence the input voltage(Vin) is supplied to the load and its equivalent circuit is displayed in Fig. 4(b). From the analysis of two states , it is obtained that

$$V_{C1} = \frac{T_1}{T_1 - T_0} V_{dc} \quad (2)$$

$$V_{C2} = \frac{T_0}{T_1 - T_0} V_{dc} \quad (3)$$

$$V_i = V_{C1} + V_{C2} = \frac{1}{1-2D} V_{dc} = BV_{dc} \quad (4)$$

B=Boost factor. The factor B decides step-up factor of the QZS converter.

Thus the output dc voltage is

$$V_s = \frac{1}{1-2D} V_{dc} \quad (5)$$

Parameter Design

In the Z network, two inductors and capacitors are there. For simplicity, same value of inductance (L) and capacitance (C) are considered. While choosing the inductors, the following points:

(1) The value should not be too small, otherwise it will increases the complexity of the control system.

(2) The ripple in the inductor current (I_L) should be low ie. Ripple should be off 20% of the ratedI_L.

Thusinductance can be calculated using

$$L = \frac{\Delta t}{\Delta I} V_L \quad (6)$$

D -Duty cycle,

f -Switching frequency,

I - average value of I_L.

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Similarly the Capacitance C can be calculated by

$$C = \frac{\Delta t}{\Delta V_c} X I_C (9)$$

B. OPERATION OF THE LUO CONVERTER

The power circuit diagram of the POESLLC is shown in Fig. 5. It includes dc supply voltage, capacitors C1, CO, and inductor L1, switch, freewheeling diodes D1 and D2 and load resistance R.

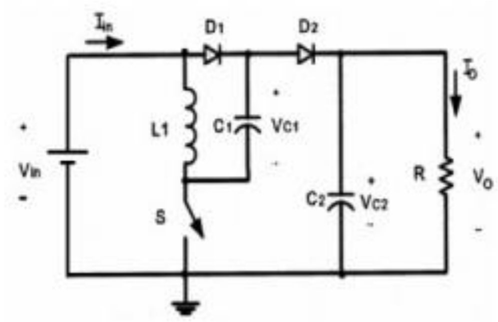

Figure 5. The positive output elementary LuoConverter.

In the describing of the converter operation, it is assumed that the converter operates in a continuous conduction mode (CCM). The operation of the LUO converter comprises two modes. During mode 1, the switch S is closed; voltage across storage capacitor C1 is charged to Vin and the inductor current iL1 flowing through L1 increases with voltage Vin as shown in Fig. 5. In mode 2, the switch S is open; the voltage across the inductor L1 becomes (Vo - 2Vin).

V. MPPT ALGORITHM

Among the various types of MPPT tracking algorithm, perturb and observe (P&O) algorithm shown in figure6 is commonly implemented in all practical PV system. This is preferred because of its simplicity.

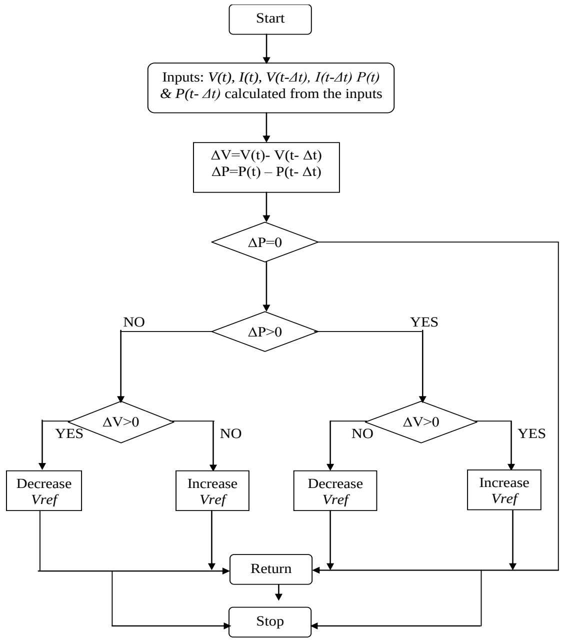

Figure6.Flowchart of P&O algorithm

VI SIMULATION ANALYSIS

Hence, to evaluate the performance of the designed converter, MATLAB simulation is carried out. Table 1 depicts the circuit parameters used for simulation purpose.

Table 1.Circuit Parameters

Parameter	**Value**
Vin	12V from PV
L1=L2	50microH
C1=C2	150micrfarad
Switching Frequency	100kHz
D	0.4
Filter Capacitance	1.2 mf
Load Resistance	10 Ω
Kp	50
Ki	15

The QZS converter was simulated with PI controller using MATLAB. Figure 7shows the output voltage and current of PV system and the figure 8 depicts the output voltage and current.

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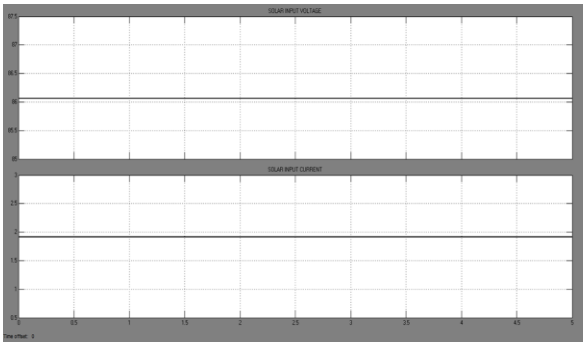

Figure 7. Output voltage and current of PV system

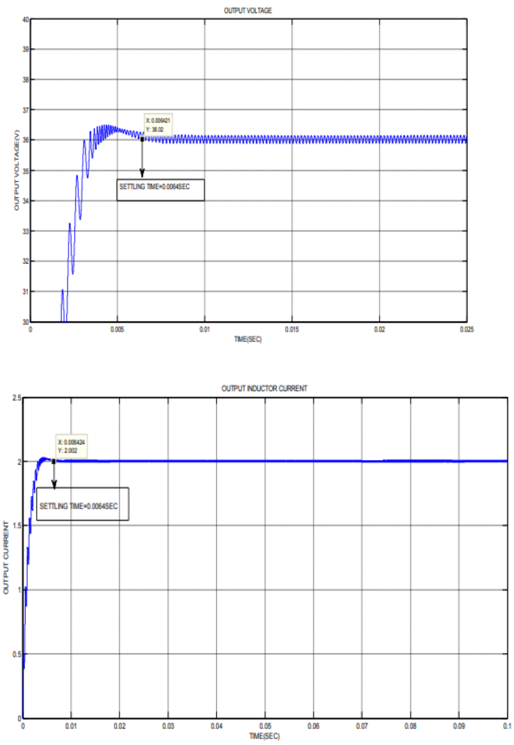

Figure 8. Output voltage and current of the QZS converter

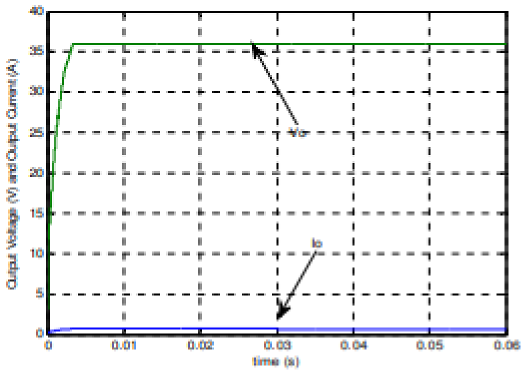

Figure 9. Output voltage and current of the LUO converter

Table-2: Comparative analysis of converters in terms of efficiency and settling time

Converters	%	Settling time(Ts)
QZS	88	0.006
Positive LUO	94	0.0045

From the table 2, it can be found that among these two proposed converters, LUO converter exhibits higher efficiency and less settling time than QZS converter.

VIII Conclusion

This work aimed to formulate a high gain QZS converter for a PV system. Thus, the formulated QZS converter regulates the DC bus voltage using PI controller.The simulation based performance analysis of a PI controlled positive output Luo converter circuit has been presented. For the two converters, The PI control scheme has proved to be robust and its triumph has been validated with transient region, line and load regulations, steady state region and also with circuit components variations. From the analysis, it is found that positive output elementary Luo converter with PI control exhibits better performance than QZS converter. Hence, it can implemented in applications such as, medical equipment's/ various industrial applications, especially where high voltage are required.

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