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PV fed ZETA Converter for LED Application

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Abstract

The demand of renewable energy is always at an increasing pace because of the energy crisis in the world. Among the renewable energies obtained, solar energy is one of the clean and valuable source of energy which is being implemented at many places in the world. The output obtained from this solar energy is boosted by zeta converter and applied for LED street lighting. Zeta converter, a DC-DC converter, provides a positive output voltage and regulates power supply with no voltage polarity reversal. The voltage input and output value are assigned in correspondence with the street light rating. This design aims to have lower losses, maximize the added advantages of the proposed converter such as low ripple, high efficiency and low electrical stress on the components.

Keywords: LED Lights, Solar Panel, Zeta Converter.

INTRODUCTION

The consumption of non-renewable sources of energy like oil, gas and coal is increasing at an alarming rate All energy sources have some impact on our environment. Fossil fuels — coal, oil, and natural gas, do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions[1]. In the current scenario, renewable sources like solar, wind and geothermal energy are being explored to reduce our dependence on the dwindling oil and coal reserves. Out of the available energy resources, solar energy the most viable source [2].

The sun is the most important source of energy for all life forms and it has been producing this energy for millions of years. Solar energy being a renewable and free source of energy is being used in many fields in our lives. Solar energy has tremendous potential to replace the use of fossil fuels in transport and electricity generation. The progress of solar energy has been stunted due to its low conversion efficiency with the conventional techniques. This has been the focus of our project – to boost the efficiency of the electricity produced by photo voltaic solar panels. The solution to this, was found in the form of a Zeta converter [3].

The Zeta converter (inverse Sepic convertor), is rapidly gaining popularity among electronic systems and is being used many applications [4-5]. Its input is the output of the solar panels strings. It converts the DC input to high frequency AC, and then back to a different DC voltage and current in order to match the panel voltage to that of the batteries. The Zeta converter showed itself as very attractive because it operates as step up as well as step down voltage, beside the fact of being a naturally isolated structure and processing power at one single stage. Such an operation is possible, with the help of two inductors working in combination with two capacitors that act as dynamic storage devices. In essence, the Zeta converter is a DC-DC converter of the fourth order [6]. It has two modes of operation depending on its application (i) continuous conduction mode and (ii) discontinuous conduction mode.

This paper not only focuses on increasing the efficiency of energy from the PV panels, but also looks at decreasing the cost of making effective use of this energy. Standard street lights use sodium-vapor or mercury-vapor bulbs. These have been in use for many years and are inefficient, both in terms of brightness and electricity consumption [7]. LED lights provide the best compromise of both high efficiency and low cost. They are lighter, cheaper and have a longer life span when compared to the standard street lights. They also require less maintenance, thus reducing the overall expenditure of governments on providing public lighting facilities. The high efficiency of LED lights, when added to the effectiveness of a Zeta converter can make solar energy more feasible than ever before [8-9].

BLOCK DIAGRAM

The block diagram for the proposed model is shown in Figure 1.

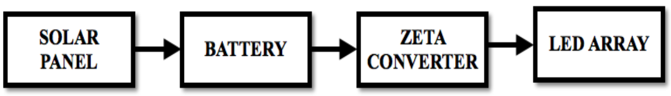

Figure 1: Block Diagram of the Whole System

Solar Panel

Solar panels are responsible for absorbing the incident solar energy and converting it into a useful form of electricity. It is also known as a photovoltaic (PV) module and it is made of photovoltaic cells. The photovoltaic effect is the working principle behind this module. However, solar panels, as a standalone source, are highly inefficient. It will take a very long time to recover the installation and operation cost. The efficiency of a solar panel averages around 20% which is very poor, considering the large area needed, cost and time of installation.

Battery

The battery has two important purposes. It must store the electrical energy absorbed by the solar panel with minimal losses and provide a constant electrical energy output to the Zeta converter. They are also referred to as accumulators, and are available in different shapes and sizes depending on the application. Lithium-ion batteries are highly efficient and are commonly used for most installations.

Zeta converter

The Zeta converter is in essence a DC-DC converter. It uses electronic circuits to boost voltage from a lower level to a higher level or vice versa. It has a wide operating range from a few volts to many thousand volts. The converter offers a high level of controllability over the voltage levels, as the duty cycle of the charging voltage can be easily varied to suit the application. This coupled with the high efficiency of the converter make it perfect for this application.

LED Arrays

LED Arrays consist of a number of individual light emitting diodes (PN junction diodes) arranged in patterns. LEDs have many advantages when compared to normal incandescent street lights. They are lighter, cheaper, brighter, occupy less space and are easier to install. It is also easier to control them with simple circuitry and integrating with IoT is also possible to save more electricity by infusing an automatic power schedule.

PROPOSED MODEL AND OPERATING PRINCIPLE OF ZETA CONVERTER

The equivalent circuit of Zeta converter is as shown in the Figure 2. It comprises of a switch, a diode, two capacitors C1 and C2, two inductors L1 and L2 and a standing resistive load.

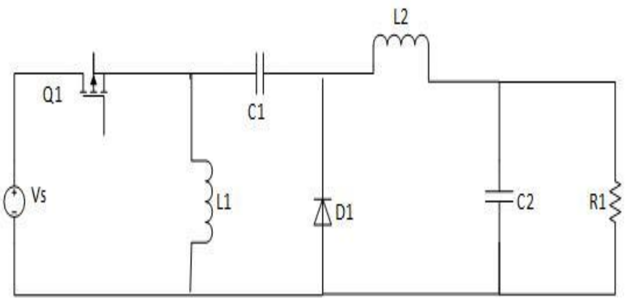

Figure 2: Zeta Converter Topology

A. Mode 1

In this mode, the switch q_1 is on and the diode D1 is reverse biased. Inductors L_1 and L_2 is charged from the source and the inductor current i_{L1} and i_{L2} increases linearly. Also, discharging of C_1 and charging of C_2 take place. The operation during mode 1 is shown in the Figure 3.

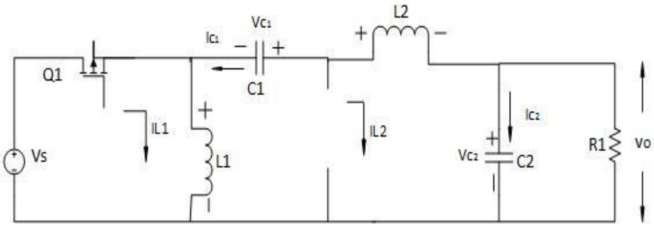

Figure 3: Mode 1 of Zeta Converter

By kirchoff's voltage law,

$$L_1 * \frac{DiL_1}{dt} = V_s \quad \ldots (1)$$

$$Di\frac{L_2}{dt} = \frac{Vs}{L_2} + \frac{VC_1}{L_2} - \frac{VC_2}{L_2} \quad \ldots. (2)$$

By kirchoff's curent law ,

$$C_2 * \frac{DV_{C2}}{dt} = i_{L1} \quad \ldots. (3)$$

B. Mode 2

In this mode, the switch Q_1 is off and the diode d_1 is forward biased. During this interval, previously charged inductor L_1 starts to discharge. So stored energy in L_1 and L_2 are discharged through capacitors C_1 and C_2 therefore, the inductor currents i_{L1} and i_{L2} decrease gradually. The operation during mode 1 is shown in the Figure 4.

By kirchoff's voltage law, voltage across inductor (L_1) is given by,

$$L_1 \frac{Di_{L1}}{dt} = -V_1 \quad \ldots (4)$$

Voltage across inductor (L_2) is given by,

$$L_1 \frac{Di_{L2}}{dt} = -V_{L2} \quad \ldots (5)$$

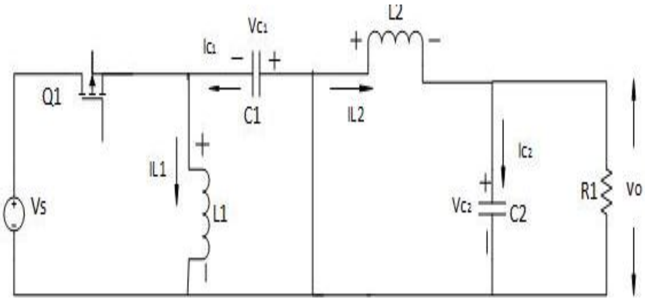

Figure 4: Mode 2 of Zeta Converter

By applying kirchoff's current law, current through the capacitor C_1 is,

$$i_{L1} = C_1 * \frac{DV_{C1}}{dt} \quad \ldots (6)$$

The relation between input voltage, output and the duty cycle(D) of zeta converter in CCM is given by,

$$D = \frac{V_O}{V_O + V_S} \quad \ldots (7)$$

Therefore,

$$\frac{V_O}{V_S} = \frac{I_{IN}}{I_O} = \frac{D}{D-1} \quad \dots (8)$$

By volt second balance,

$$V_S * T_{ON} + (V_S - V_{C1}) * T_{OFF} = 0 \quad \dots (9)$$

Taking average over one cycle,

$$V_O = \frac{D}{D-1} * V_S \quad \dots (10)$$

By applying volt –second balance, the relation between output voltage and input voltage is given by

$$V_O = \frac{1}{D-1} * V_S \quad \dots. (11)$$

DESIGN SPECIFICATION

The zeta convertor is designed as follows;

The input inductor L_1 is given as,

$$L = \frac{1}{2}\frac{V_{IN} * D}{\Delta i_{L1} F_S} \quad \dots (12)$$

where, Δi_{L1} is the permitted ripple current in inductor L_1 and considered to be 10% of output current I_o.

The output inductor L_2 is given as,

$$L_1 = L2 \quad \dots (13)$$

The value of output C_2 is given by,

$$C_2 = \frac{DV_S}{8*\Delta V_S*(F_S)^2 * L_2} \quad \dots(14)$$

DESIGN PARAMETRES

Simulink model of proposed convertor is implemented with the following design parameters.

Table 1: Simulation Parameters

SL.NO	ATTRIBUTES	VALUES
1	INPUT VOLTAGE(VS)	17V
2	OUTPUT VOLTAGE(VO)	54V
3	SWITCHING FREQUESNCY(FS)	100kHz
4	DUTY RATIO (D)	75%
5	INDUCTOR L1=L2	45mH
6	INPUT CAPACITOR	0.5µF
7	OUTPUT CAPCITOR	2 µF

SIMULATION STUDIES AND RESULTS

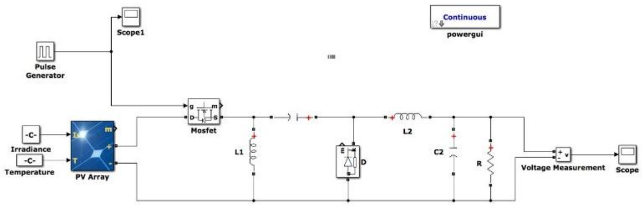

Figure 5 : Simulation Model of PV fed Zeta Converter

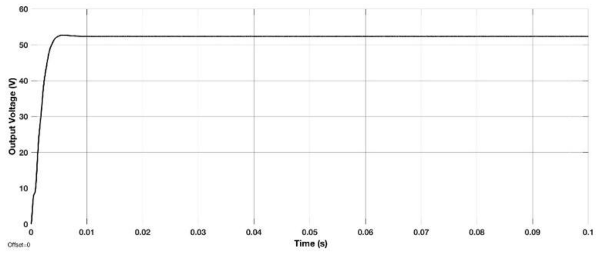

Figure 6: Output Voltage (V) of PV fed Zeta converter

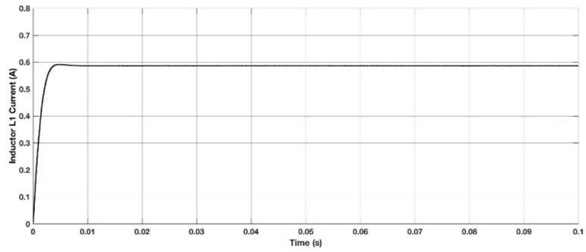

Figure 7: **Inductor L2 Current (A) Vs Time (s)**

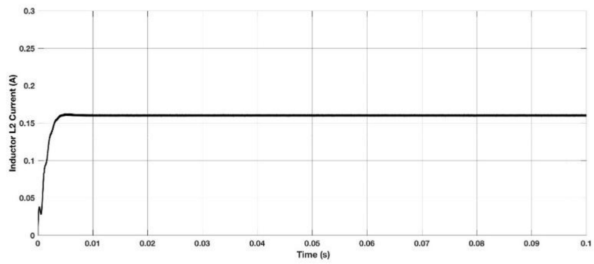

Figure 8: Inductor L2 Current (A) Vs Time (s)

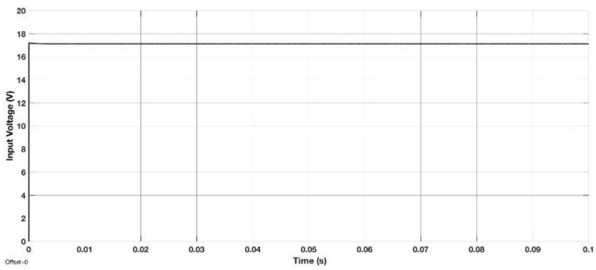

Figure 9: Input Voltage (V)of PV fed Zeta converter

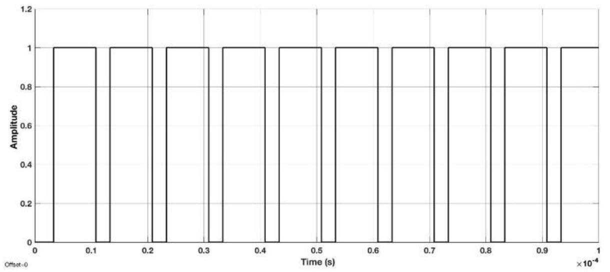

Figure 10: Pulse generator pulses

CONCLUSION

The analysis of Zeta converter is performed using the given design values for inductance and capacitance. The output obtained is ripple free and can be used to power the LED array with fewer losses. The steady state is obtained very early during the operation which increases the efficiency of this model. The Zeta converter thus provides a substantial boost of the input voltage which increases the overall efficiency of operation of this circuit.

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