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PV Fed Zeta Converter for Street Lighting Application

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***Abstract* -This Paper deals with the performance analysis of PV fed zeta converter. Zeta converter is designed with an intention to be used for charging a battery, which can be used to power the streetlights. Zeta converter like Sepic converter topology provides a non-inverted output voltage. It provides a constant output voltage though there is variation in the input voltage. The proposed scheme consists of solar panel, Zeta converter and a PI controller. The closed loop control of a Zeta converter fed from PV panel is simulated using MATLAB.**
***Keywords:* Zeta Converter, Closed Loop Control, PI Controller, Sepic Converter, Cuk Converter, PV Panel**

I. INTRODUCTION

With the increase in energy demand, renewable energy particularly the solar energy has gained the popularity. The output of the solar panel is a varying quantity which needs to be regulated in order to utilize it for an application. Here, the output of the solar panel is regulated using a Zeta converter. Zeta converter is a fourth order DC-DC converter which increases or decreases the voltage level depending upon the duty ratio. It operates similar to a buck boost converter with the major difference that it provides a non-inverted output voltage. The solar irradiation is a varying quantity, because of which the output voltage of the solar panel is also a varying one. The duty cycle of the converter has to be decided based on the output voltage of the solar panel. Here, a PI controller is used in order to fix the duty cycle for the zeta converter depending upon the output voltage of the solar panel.

II. WORKING OF ZETA CONVERTER

A. Zeta Converter

Zeta converter though belongs to the topology of Sepic and Cuk converter has a lot of advantages. Zeta converter has four energy storage elements i.e., two inductors and two capacitors. The output current of the zeta converter is a continuous one and it is free from ripples. It gives a non-inverted output voltage.

1. Modes of Operation: Zeta converter consists of a switch, a diode, two inductors and two capacitors. It is assumed that Zeta converter operates at continuous conduction mode. The working of zeta converter can be explained by two modes of operation namely on and off modes. The circuit diagram of the Zeta converter is given in Fig. 1. The first mode which is the one mode occurs when switch Q1 is turned on,

a) Mode 1: This mode can be called as charging mode. It is assumed that capacitor C1 is already charged. When the switch Q1 is turned on, the diode D1 is reverse biased, the inductor L1 is charged through the input voltage and L2is charged through the capacitor C1.

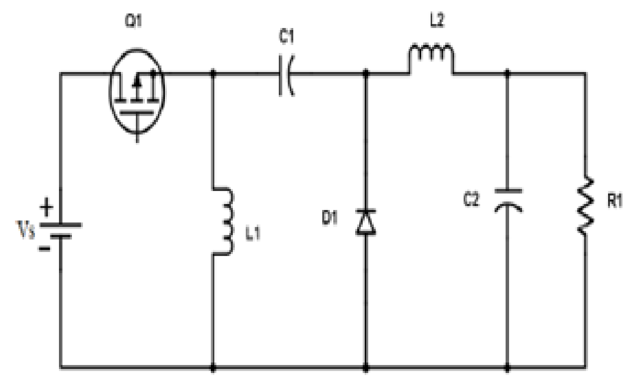

Fig. 1 Zeta converter

Due to this, the current through the inductor L1 and L2 increases linearly. This mode1 operation is depicted in Fig. 2.

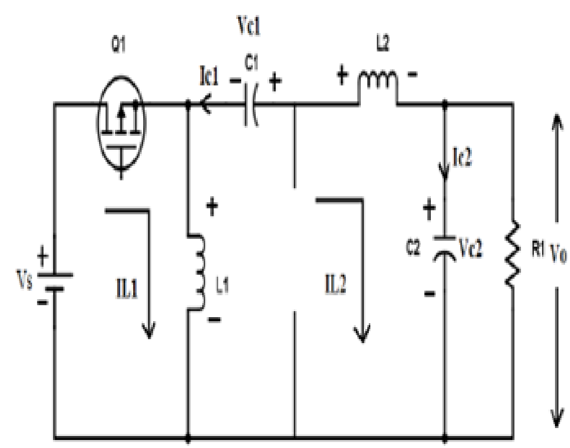

Fig. 2 Operation of Zeta in Mode 1

b) Mode 2: In mode 2 discharging of inductor L1 and L2 occurs. Switch Q1 is off and the diode D1 is forward biased. The previously charged inductors L1 and L2 discharge through capacitors C1 and C2. During this mode the inductor currents iL1 and iL2 decreases linearly.

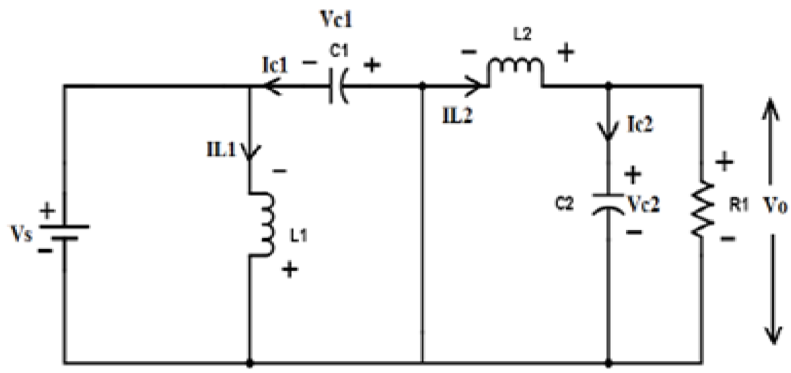

Fig. 3 Operation of Zeta in Mode 2

The relation between the input voltage, output voltage and the duty cycle can be explained by means of the following relation.

$$D = \frac{V_0}{V_0 + V_s} \quad (1)$$

$$V_s * t_{on} + (V_s - V_{c1}) * t_{off} = 0 \quad (2)$$

The output voltage V_0 is given by,

$$V_o = \frac{D}{(D-1)} V_s \quad (3)$$

II. SIMULATION OF THE PROPOSED SYSTEM

The proposed system consists of PV module, Zeta converter and a resistive load along with a controller.

A. Simulation of Solar PV Array

A photo voltaic system converts directly sunlight into electrical energy. The obtained energy depends upon the factors such as solar radiation, temperature and voltage produced in the photo voltaic module. Simulation is carried out using MATLAB/SIMULINK the PV array is simulated using solar cell.

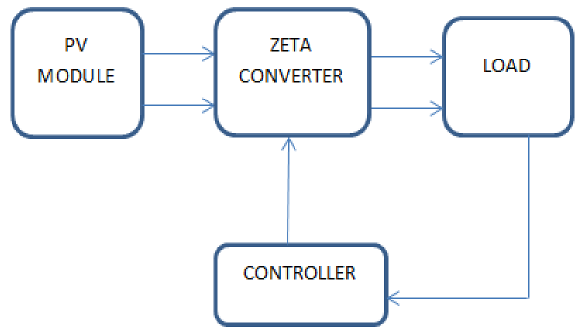

Fig. 4 Proposed model of the system

A string which consists of 5 cells in series is formed. Five such sets were connected in parallel. The irradiation level is set to 1000 W/m^2. The output of the solar panel has been observed as 12V. The simulated model of the solar panel is shown in Fig. 4. The voltage, current and Power wave forms of the solar panel has been observed for different irradiance level. The output from the solar panel is given as input to the Zeta converter.

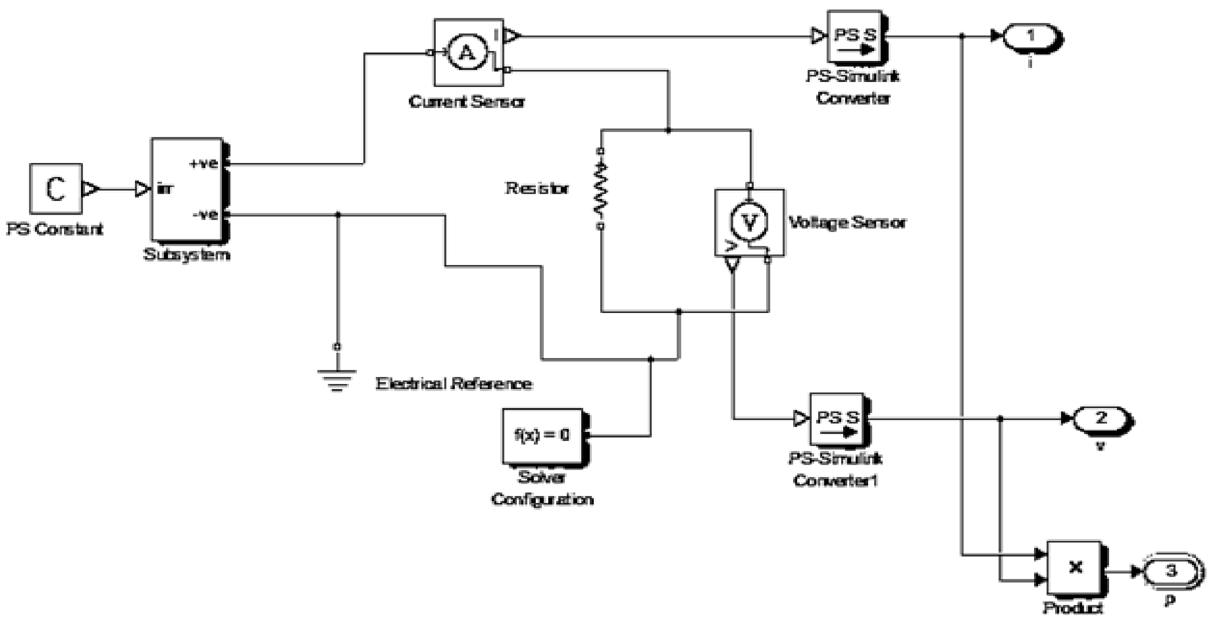

Fig. 5 Simulation of solar panel

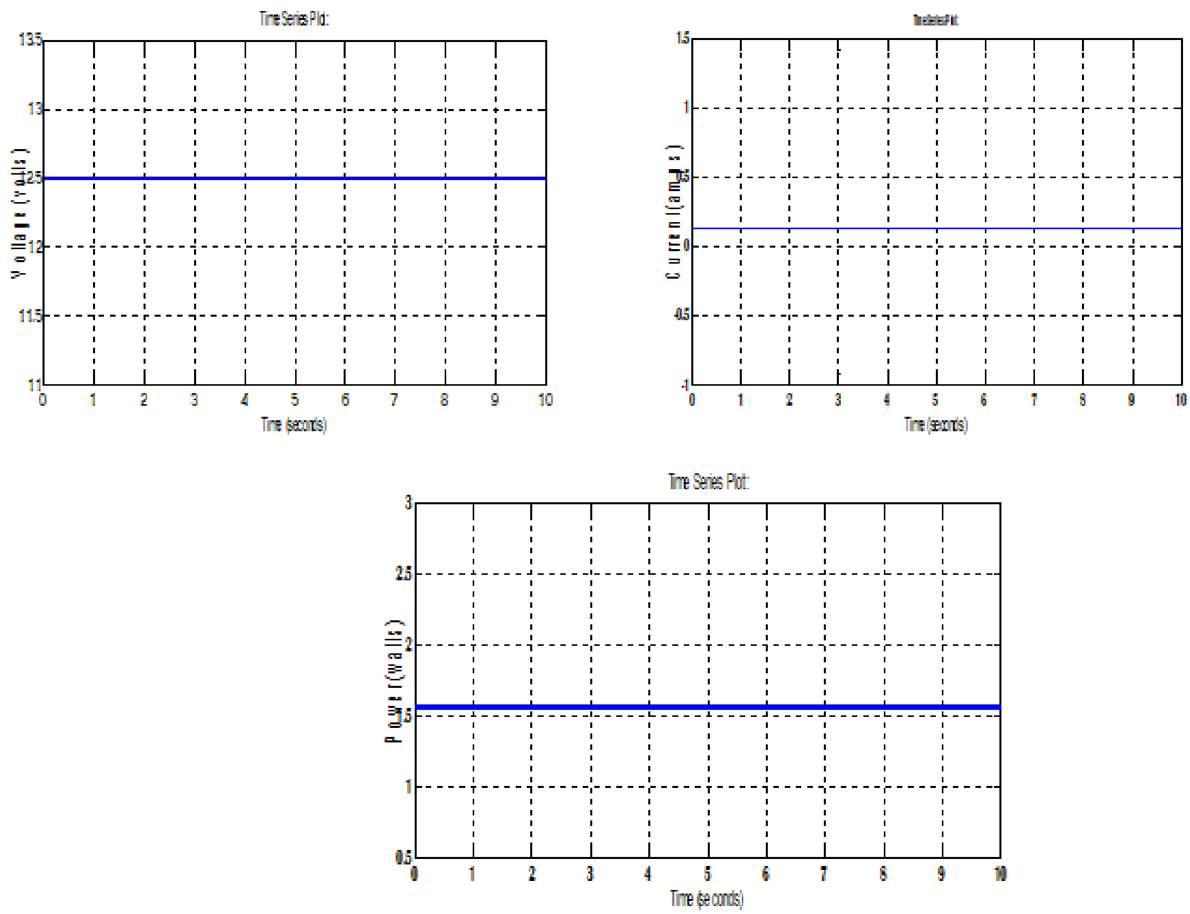

Fig. 6 Output Voltage, Current,Power of solar PV Panel for an irradiance of 1000 w/m^2

B. Simulation of Zeta Converter

The zeta converter is also simulated using MATLAB/ SIMULINK. The parameters for the zeta converter has been decided based on the design equations.
Inductor ripple current is given by,

$$\Delta Il = 0.2 * \frac{Vo*Io}{Vin} \quad (4)$$

The inductor values are chosen based on the equation,

$$L1 = L2 = 0.5 * \frac{Vin*D}{\Delta Il*f} \quad (5)$$

The capacitor value is calculated based on the equation,

$$Cc = \frac{\Delta Il}{8*\Delta Vo*f} \quad (6)$$

$$Cin = \frac{Io*D}{\Delta Vin*f} \quad (7)$$

The output voltage ripple should be

$$\Delta Vo = 1\%\, of Vo \quad (8)$$

$$Cout = \frac{D*Io}{\Delta Vo*f} \quad (9)$$

The zeta converter acts as a boost converter for duty cycle greater than 0.5 and as a buck converter for duty cycle less than 0.5 Due to the variation in the irradiation level; the output voltage of the solar panel as well as the input given to the zeta converter varies. In order to maintain the output voltage of the converter as a constant value the duty cycle of the Zeta converter has to be varied. To achieve this, a PI controller has been added in the proposed system. The detail of the proposed controller has been discussed in the next section.

TABLE I THE PARAMETERS OF THE ZETA CONVERTER

Parameters	Values
Inductor(L1,L2)	24.2mH
Capacitor(C1.C2)	3.48e-4F
Resistance	40ohms
Switching frequency	10 kHz
Input voltage	12.5 V

C. Closed Loop Control of Zeta Converter Using PI Controller

The open loop operation is insensitive to load and line variations. It is preferable to go for closed loop control of zeta converter. The closed loop control uses a comparator which compares the feedback signal from the system and a desired value of the voltage. The generated error signal can then be processed to control the converter in order to reduce the error. Processing of error signal is a complicated issue, because of delays in the system. It is preferable to use a PI controller in order reduce the steady state error in the proposed system. The error signal given as the input results in increased duty cycle. PI controller works based on the error signal generated. The error signal generated from the reference and the obtained output is given to the PI controller.

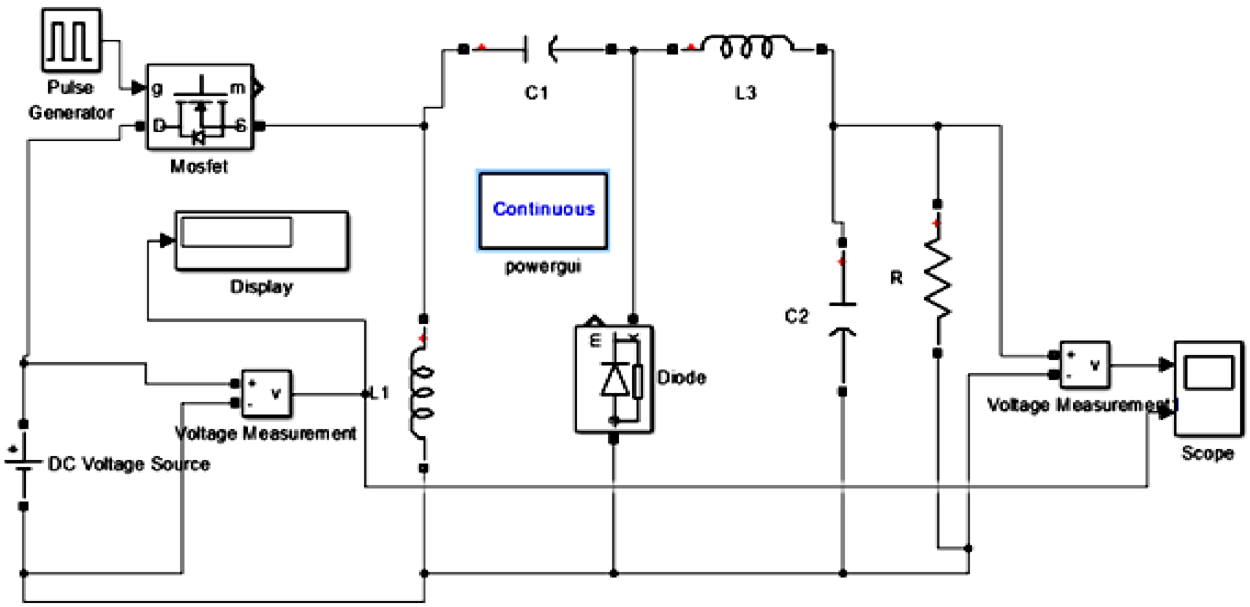

Fig. 7 Simulated model of Zeta converter

This PI controller's main function is to reduce the error signal. If error is high duty ratio will also increase which in turn increases the output voltage, as the load voltage increases it reduces the error signal.For a particular duty ratio, error signal will be minimum and hence PI controller will maintain the same duty ratio. PI controller has been introduced in the proposed system and the resultant waveforms are observed. The controller output is given by,

$$K_p e(t) + K_i \int e(t)dt \qquad (10)$$

Where e(t) is the error signal and K_p& K_i are the proportional and integral gains which are the tuning parameters. The proportional gain K_p has been chosen as 0.01 and integral gain K_i has been chosen as 3 for an input voltage of 12.5V. The output voltage from the zeta converter and a reference value of 18V is given to the comparator.

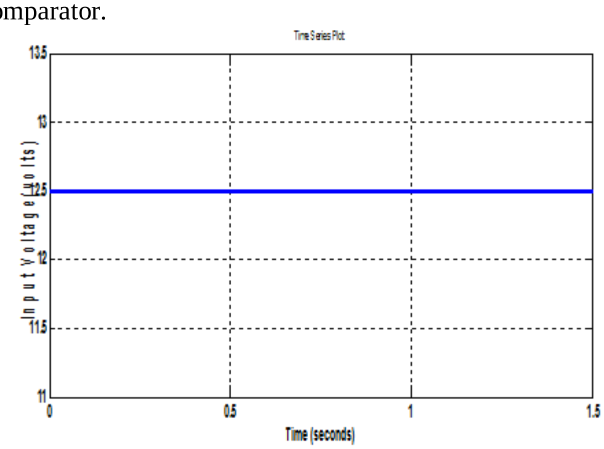

Fig.8 Input voltage waveform of Zeta converter

The error signal thus generated has been compared with the high frequency carrier signal in order to generate the gate pulse for the switch. Thus the closed loop control of the zeta converter is achieved with the addition of PI controller.

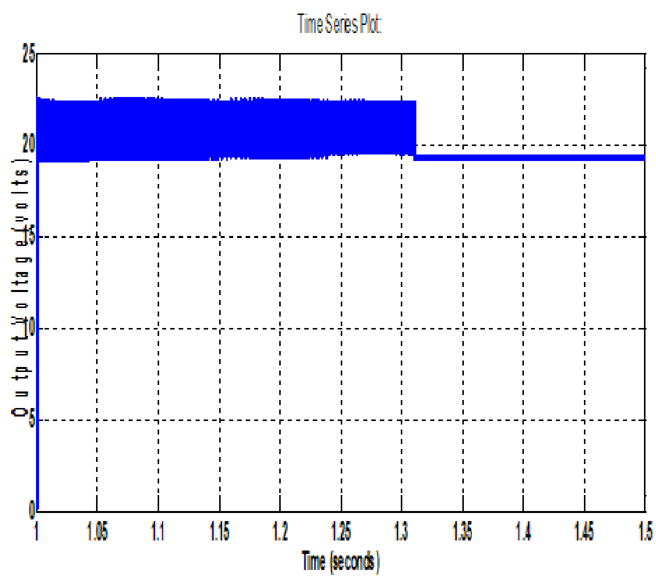

Fig. 9 Output voltage waveform with closed loop control

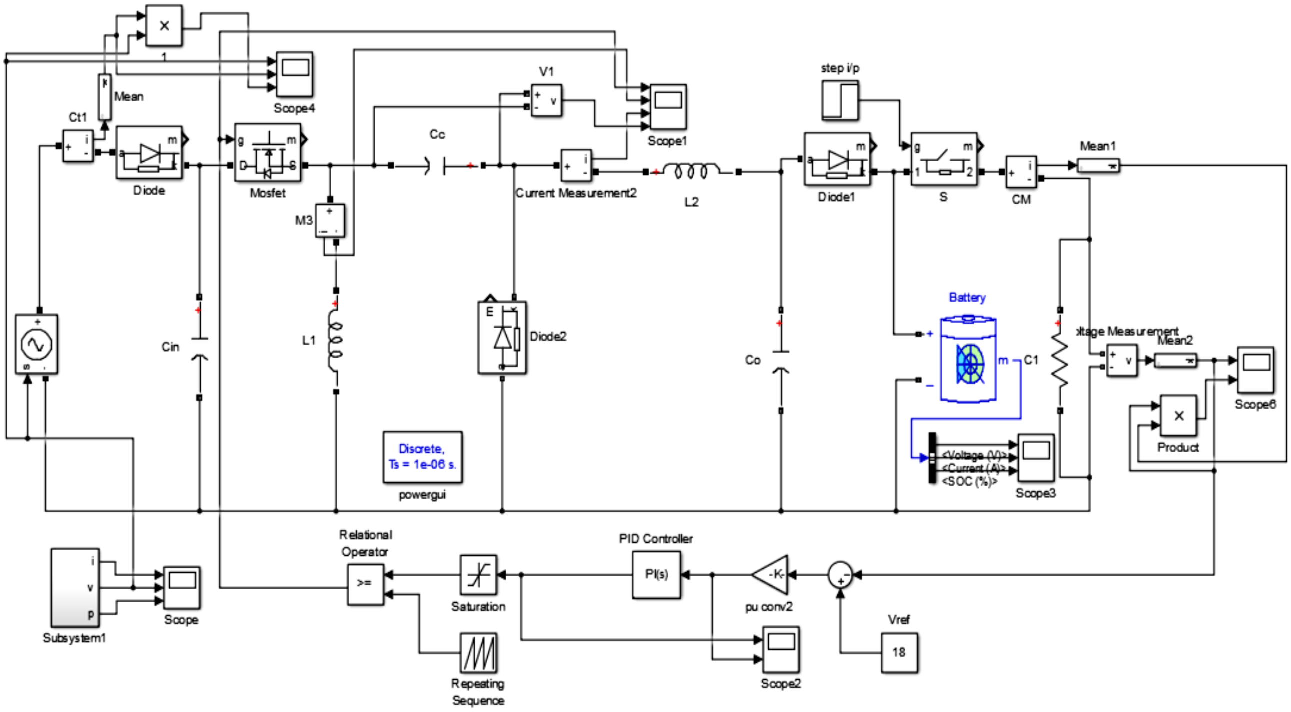

Fig. 10 Simulated model of the Zeta converter along with PI controller

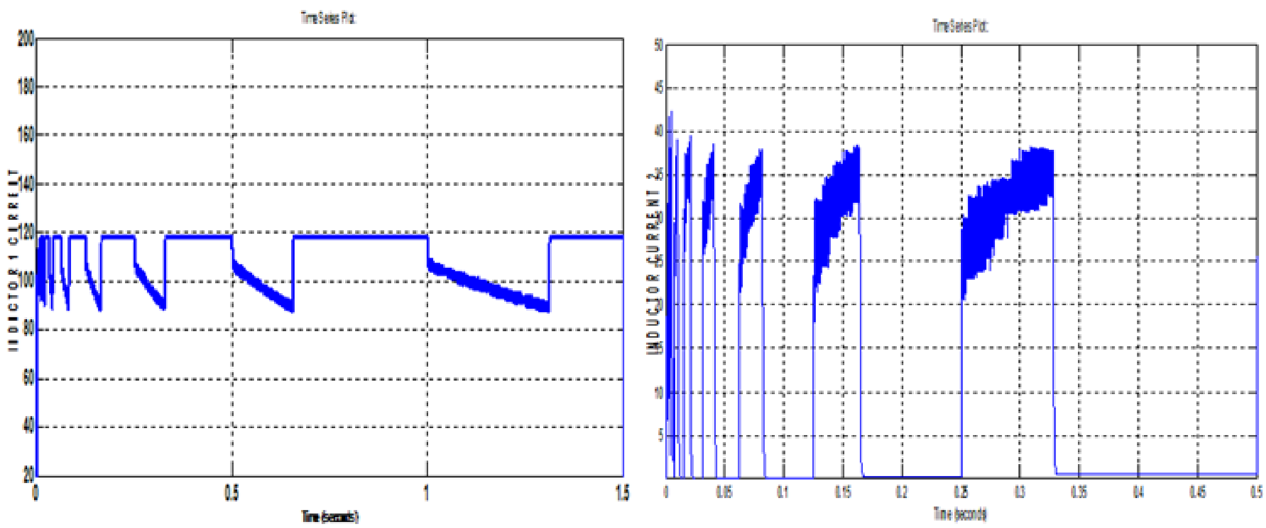

Fig. 11 Inductor current waveforms of Zeta converter

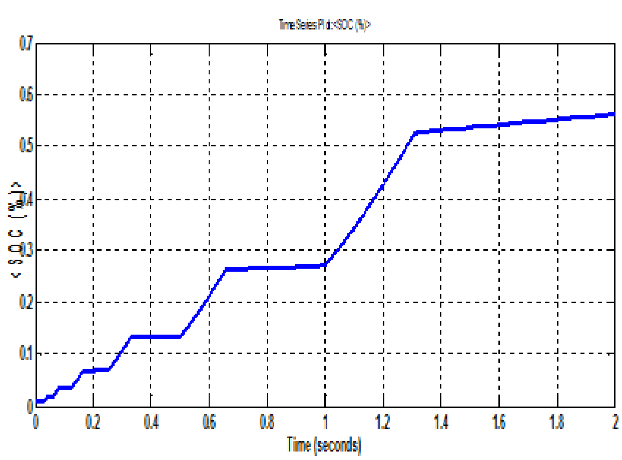

Fig. 12 Battery state of charging

D. Application of Zeta Converter

The output voltage from the solar panel is unregulated the steady state output voltage thus obtained from the system is utilized to charge the battery. The battery state of charging is also observed through simulation.

III. CONCLUSION

Zeta converter has simple design and gives continuous output current without ripples. Zeta converter can increase and decrease the level of output voltage. Compared to the buck boost converter, it provides noninverted output voltage. The subsystems of overall system such as PV panel, Zeta converter has been individually simulated before integrating the complete system. Then closed loop control has been implemented in the proposed system. With the addition of PI controller, the steady state error in the output voltage is reduced. The output of the zeta converter has been utilized to charge the battery with the intention to be utilized for street lighting application.

REFERENCES

[1] V. S. Eashwar, S. Kalithasan and K. V. Kandasamy, "Application of Zeta Converter for Automotive Battery Recharge",National Conference on Recent Trends and Developments in Sustainable Green Technologies, *Journal of Chemical and Pharmaceutical Sciences*, Special issue 7, 2015.

[2] Kambh Omkar Vijay, P. Sriramalakshmi, "Comparison between Zeta converter and Boost converter using sliding mode controller", *International Journal of Engineering Research and Technology*, Vol. 5, No. 7, July 2016.

[3] Alia M. Khatab, Mostafa I. Marei1 and Hadi M. Elhelw, "An electricVehiclebatterychargerbased on Zeta converter fed from a PV array", in *2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS*, June 2018.

[4] N. Soumya Smita Raj, B. Urmila "PV fed Zeta converter", *International Journal of Engineering Research and Applications*, Vol. 3, No. 4, July-Aug 2013.

[5] U. Jeyashree, R. H. Pearl Nightingale and S. Divya, "Implementation of basic MPPT techniques for zeta converter", *International conference on Science Technology Engineering Management, ICONSTEM 2017*, March 2017.

[6] H. Parthasarathy, L. Udayakumar and G. Balasubramanian, "Modelling and Simulation of PV Module and Zeta Converter", *InternationalConference Circuit, Power and Computing technologies [ICCPCT]*, March 2016.