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Zeta Converter Based Battery Charger for Ev

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Abstract. Abstract—This paper proposes a zeta converter-based battery charger. A Zeta converter is a DC-DC converter that has non inverted output and works as buck-boost converter. The converter output can be adjusted to get maximum power from the PV system. This power is used to charge the EV battery. Using P & O method Simulation is done through MATLAB The Hardware consists of Zeta Converter which is fed through PV Array and the converter is triggered using Arduino nano, therefore battery gets charged by Zeta Converter.

1 Introduction

Any vehicle's operating and maintenance costs make up a sizable portion of the overall cost of ownership. It is now widely known that EV purchasers spend significantly less on fuel energy and maintenance because EVs have fewer moving parts than a gasoline engine, which makes it simpler to operate applicable criteria that follow.

EVs have a relatively a smaller number of parts that could malfunction and require maintenance. By use of Electric Vehicle, we can reduce carbon dioxide emissions by switching to electric vehicles. A DC-DC converter is required in EVs and is used to converting between different voltage levels. A zeta converter will be used to construct the suggested system. A fourth order DC-DC converter is a zeta converter. It performs the same function as a typical buck-boost, except the output voltage polarity is not inverted. Alternatively expressed, the input and output terminals share a common ground [1,2]. The Zeta converter topology generates a positive output voltage from an input voltage that tends to vary above and below the output voltage. It consists of two inductors and a series capacitor, also referred as a flying capacitor. It is another alternative for regulating an unregulated input-power supply [3]. The Zeta converter is proposed to charge battery from PV Array. By using P&O Technique the converter is triggered.

2. Zeta Converter

Controlling of Zeta converter is done based on the block diagram as shown in Figure 1. As shown in the block diagram, switching control is based on the status of battery charging instant and the energy provided by Solar PV array.

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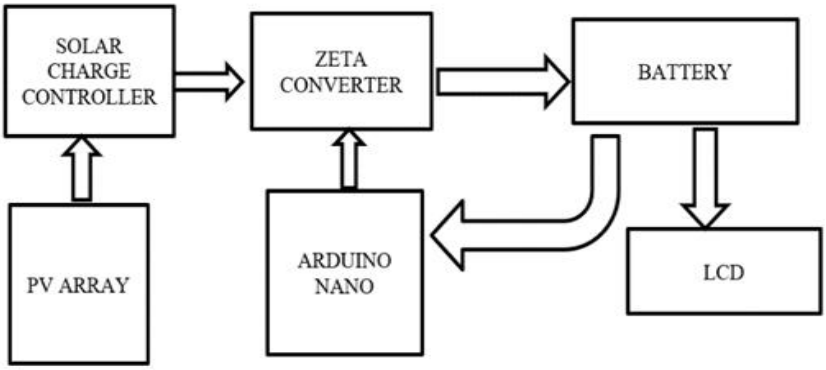

Figure 1: Block Diagram of Zeta Converter

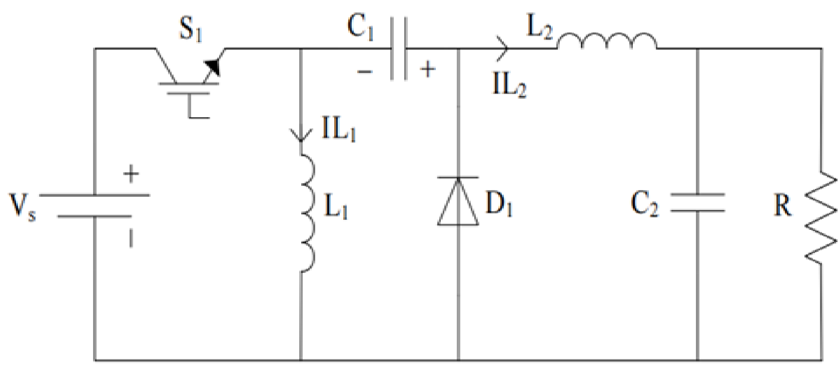

Figure 2: Circuit diagram of Zeta Converter

Zeta converter is a buck boost converter with non-inverted output. The circuit consists of a diode (D1), switch (S1), two inductors (L1 and L2), two capacitors (C1 and C2) and a load (R). Zeta Converter shown in Figure 2 operates in two modes of operation. They are:

2.1 On Mode

The ON mode occurs when switch (S) is turned on and diode (D1) is open circuited as shown in Figure 3. The energy storage elements inductors L1& L2 are charged in this mode. The inductor L1 is charged from input source. The inductor L2 is charged from capacitor C1.

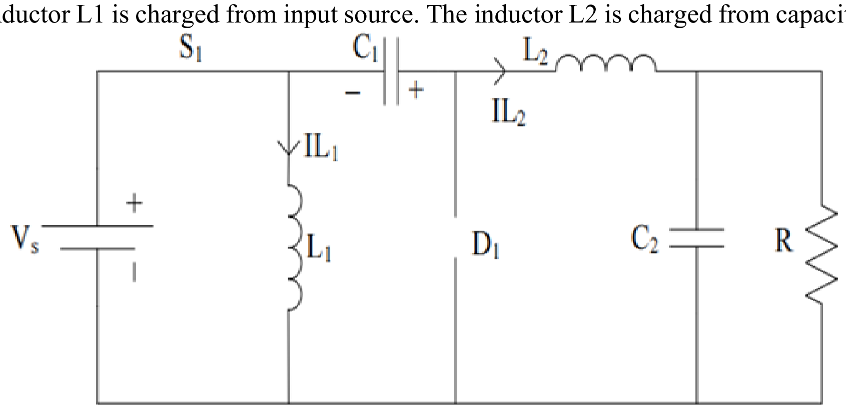

Figure 3: Zeta Converter when Switch is in ON MODE

2.2 Off Mode

The OFF mode occurs when switch (S1) is turned off and diode(D1) is turned on as shown in Figure 4. The elements inductors L1&L2 are discharged through capacitor (C1) and load. The current of the inductors decreases as they discharge. The figure 4 is the off-mode circuit of Zeta Converter.

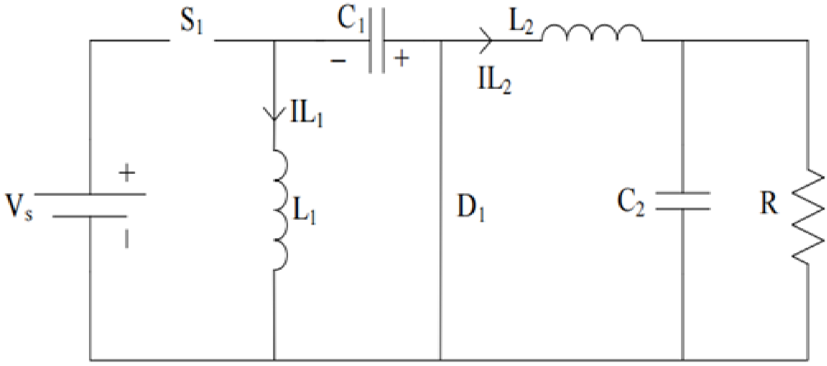

Figure 4: ZETA Converter Switch is in OFF MODE

The Mathematical State Representation of Zeta converter is obtained by using nodal and mesh analysis for switch ON and OFF modes of operation. The State Space Representation of Zeta converter is shown in eq.1[1,6].

$$\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\\ \dot{X}_3\end{bmatrix}=\begin{bmatrix}0 & 0 & \frac{-(1-K)}{L_1}\\ 0 & 0 & \frac{K}{L_2}\\ \frac{(1-K)}{C_1} & \frac{-K}{C_1} & 0\end{bmatrix}\begin{bmatrix}X_1\\ X_2\\ X_3\end{bmatrix}+\begin{bmatrix}\frac{K}{L_1} & 0\\ \frac{K}{L_2} & \frac{-1}{L_2}\\ 0 & 0\end{bmatrix}\begin{bmatrix}U_1 & U_2\end{bmatrix} \text{ (Eq. 1)}$$

Here X_1,X_2,X_3 are the three states which represents inductor currents IL_1 ,IL_2 and capacitor voltages VC_1.$\dot{X}_1,\dot{X}_2,\dot{X}_3$ are the derivatives of IL_1, IL_2, VC_1.U_1andU_2 are the input for the State Space Representation Model.V_s is the input voltage of Zeta Converter and V_{out} is the output voltage of Zeta converter.

$$\frac{V_{out}}{V_S}=\frac{K}{1-K} \quad \text{(Eq. 2)}$$

The eq. 2 gives the relation input and output voltages of Zeta Converter in terms of duty ratio (K).

The maximum current from PV array can calculated by eq. 3, input current for battery by eq. 4.

$$I_{mpp}=I_{mpp\ per\ module}\times\text{No. of modules per array} \quad \text{(Eq. 3)}$$

$$I_B=\frac{P_{mpp}}{V_{out}} \quad \text{(Eq. 4)}$$

3.Simulation

The Simulation of this project is done using MATLAB Software and it is shown in Figure 5. The PV Array ratings from simulation are the maximum power is 213.15W, Cells per module are 60, Open circuit Voltage is 36.3V, Short circuit current 7.84A, Parallel strings are 40 and series connected modules are 10 per string. The battery rating from simulation is battery used type is lead acid battery, Nominal Voltage is 200 V, Rated and Maximum Capacity are 5.4Ah,5.625Ah. Initial state if charge is 100% and battery response time is 30 sec. Cut -off Voltage is 150V, fully charged voltage is 217.7632 V, Nominal current is 1.08 A, Internal resistance is 0.37037Ω. L_1 and L_2 are of 1.5mH, C_1 and C_2 are of 1.5µF,2.5µF. MOSFET is triggered through P&O Algorithm. L_1 and L_2 are of 1.5mH, C_1 and C_2 are of 1.5µF,2.5µF. The diode forward voltage is 0.8V. The temperature is 50°C.

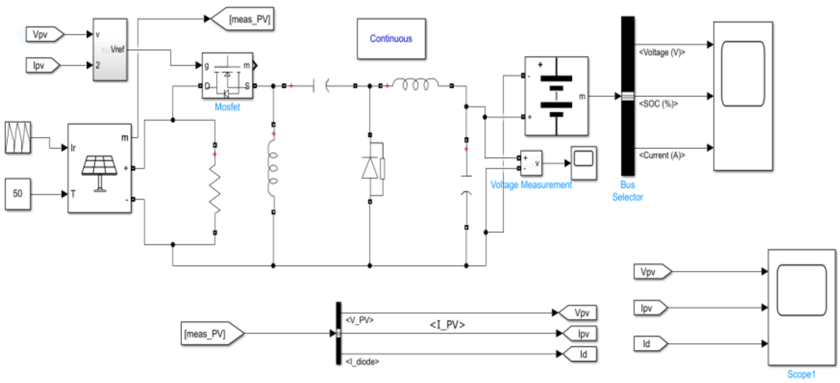

Figure 5. Simulation circuit of Zeta Converter

4. Simulation Results

The parameters used for Solar panel (PV Array) in the simulation are listed in Table 1. By changing irradiance and temperature parameters, voltage and current values obtained are listed in below table.

Table 1: Current and Voltage values by varying irradiance and temperature

Irradiance	Temperature	Voltage	Current
1000	38	295V	2.95A
750	35	172V	1.72A
500	30	168V	1.68A
490	50	164V	1.64A

The figure 6 shows the characteristic graph of PV Array from MATLAB Software.

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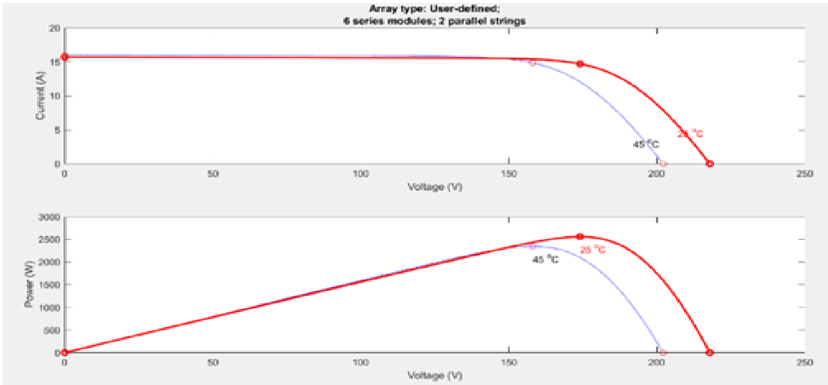

Figure 6: Characteristic of PV Array

The Figure 7 and Figure 8 are graphs of Voltage and Current across PV Array from simulation.

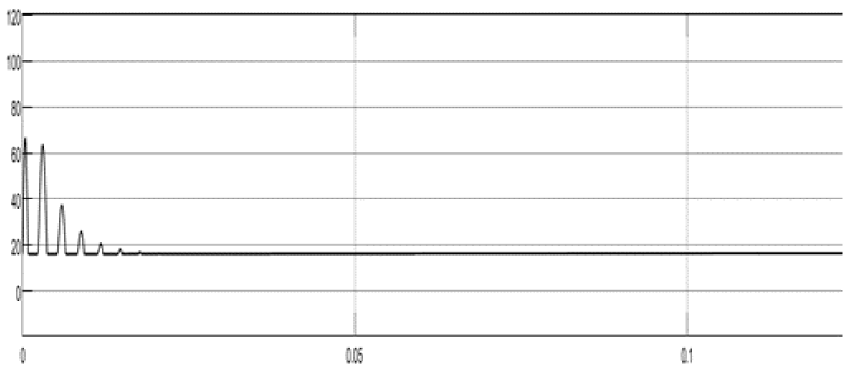

Figure 7: Voltage waveform for PV Array

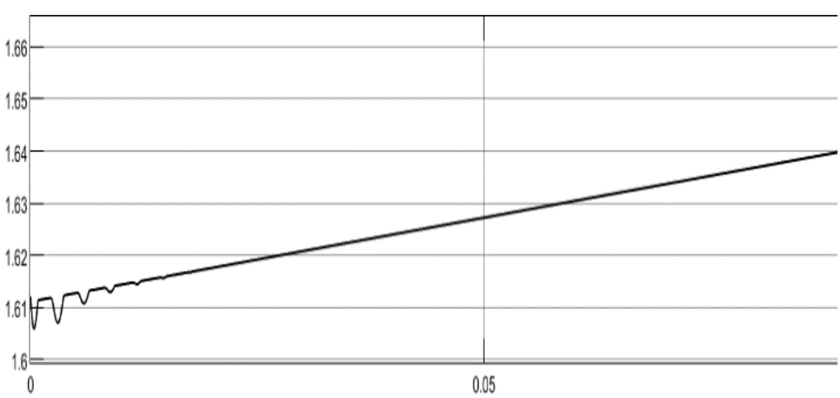

Figure 8: Current waveform for PV Array

The resulted voltage and current waveform across Battery when it is connected to load is shown in Figure 9 and Figure 10.

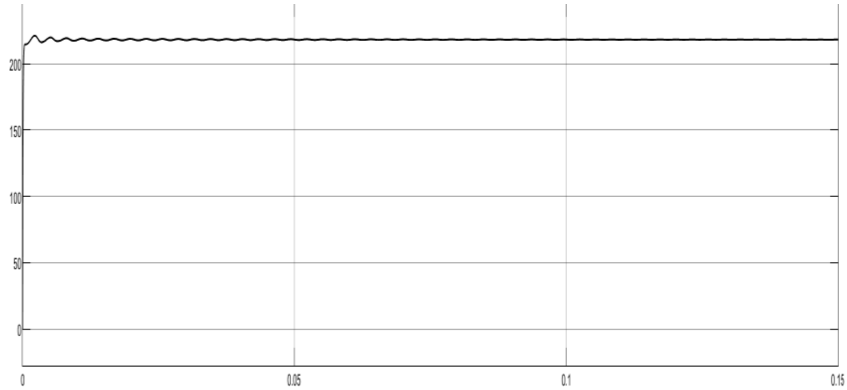

Figure 9: Voltage waveform across Battery

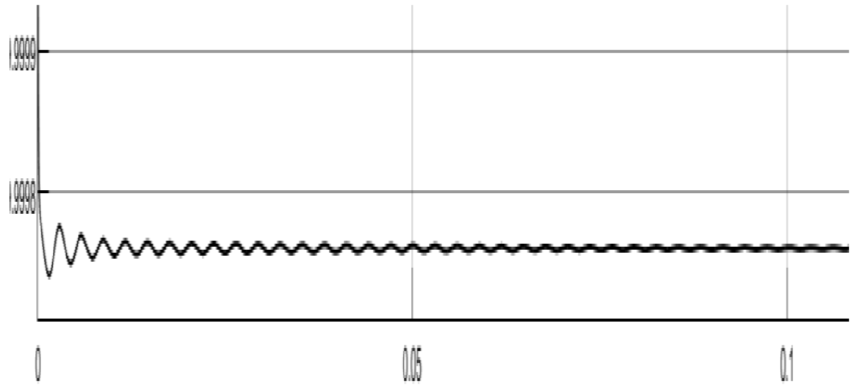

Figure 10: Current Graph flowing through the Battery

From Figure 9 and 10 represents the simulation results across battery.The Output Voltage, Current and State of Charge across battery is 232V,0.9A and 99.9.

5. Hardware Implementation

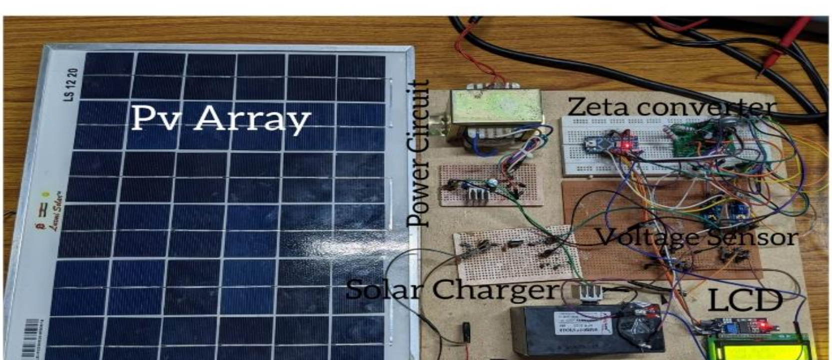

Figure 11. Hardware setup of prototype Zeta Converter

The hardware of this project comprises of a Zeta converter, PV Array, Solar charge controller, Regulated power supply, Arduino Nano, 2 Voltage sensors and rechargeable battery.

Figure 11 represents the hardware of the project and Figure 12 shows the output values that is displayed on lcd screen.

Figure 12. Output values at display

The Voltage across Zeta Converter is 11.73V and the Output Voltage across battery is maintained at 13.07V constant for charging the battery. Values of different components used in designing the Zeta Converter hardware are listed in Table 2

Table 2 : List of Hardware components used for designing Zeta Converter

Component Name	**Parameter**
PV Array	12V,4W,0.4A.
Regulated Power Supply	12V
Rechargeable battery	15V,5W.0.9A.
Resistor	100KΩ
Inductor	100mH
Capacitor	200µF

6. HARDWARE DESCRIPTION

PV Panel is made of Polycrystalline material and ratings are 12V, 4W, 0.4A. IRF744N MOSFET is triggered through Arduino nano.Arduino Nano is programmed to use Perturbation and Observation Method to control the charging of battery. The battery is made of Lead-Acid battery which is rechargeable battery and rating of 15V,1.3Ah. The ratings of inductors and capacitors are 100mH and 200µF.The regulated power supply is of 12V.The solar charge controller is made of voltage regulator (7812), inductor, capacitor and resistor. The ratings of inductor, capacitor and resistor are 5mH, 22µF and 100 Ω.

7. CONCLUSION

This paper consists of Zeta Converter fed through PV Array. The Simulation of this project is done in MATLAB Software. In hardware the Zeta Converter is fed through PV Array, the Converter triggered by a code through Arduino nano. Thus, the battery gets charged. The Output of Zeta Converter and Battery are sensed by the Voltage sensors which are display on LCD. As the Solar energy is not available all the time due to weather conditions Zeta Converter is fed through Regulated Power Supply.

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