Design, Simulation of a SEPIC and CUK Converter For Solar Powered Electric Vehicle Battery Charging

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Abstract.

This work focuses on the design comparison and implementation of a Sepic converter and Cuk converter for the solar powered battery charging application. The proposed converter is designed and realized for the given specification using suitable equations. In this project design and comprehensive analysis is carried out for both Sepic converter and Cuk converter with same power rating and operating frequency. Detailed comparison is carried out in terms of battery charging and discharging with constant voltage and current using MATLAB/SIMULINK software.

Index: Sepic converter, Cuk converter, Battery, Charging, Discharging

1. INTRODUCTION

The solar PV array is widely used in both urban and rural areas to generate the electric power from sun. The output power from solar panel is varying and it can be utilized effectively by step up or step down to the required voltage and current for electric vehicle battery charging application.[1,2] PV based solar power has many advantages because it does not require fuel, less noise, low in maintenance, clean and green energy source [3,5]. The output voltage is varying depending on irradiance. Higher the irradiance, greater the output current and the power generation. In this work, PI controller is used for closed loop controller [4]. The two controllers are used like current controller and voltage controller. Using Sepic converter circuit we can control the voltage using PI controller and from current control circuit we can control the current using PI controller [5-8].

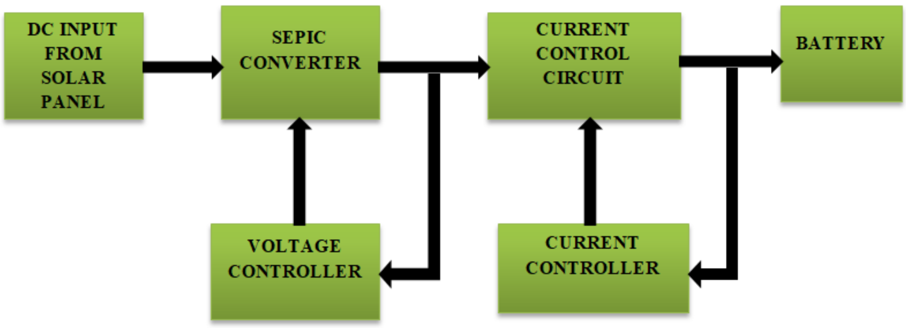

Figure 1.1: Block Diagram for the proposed Sepic converter

The Figure 1.1 shows the block diagram representation for the proposed converter along with the voltage and current controller [1]. From the P V panel solar energy converted into electrical energy. A DC Source from P V Array as an input to the sepic converter. The output of the Sepic converter is connected to current control circuit and output of the current control circuit is connected to the battery [9-13]. The main aim is to battery charging application the output current and voltage should be maintained constant to charge or discharge of the battery.

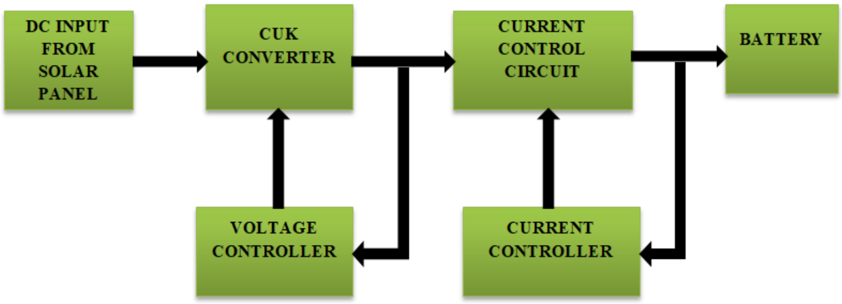

Figure 1.2: Block Diagram for the proposed Sepic converter

The Figure 1.2 shows the block diagram representation for the proposed DC-DC Cuk converter along with the voltage and current controller. A DC Source from P V Array as an input to the Cuk converter. The output of the Cuk converter is connected to current control circuit and output of the current control circuit is connected to the battery. If there is any variation in the output current and voltage, it is sensed by varying duty cycle. Thus output voltage and current is maintained constant. Compare to cuk converter major advantages of Sepic converter is that provide low input current ripple and reduce the harmonics and it also provide lesser electrical stress and higher converter efficiency.

In this paper, Design Simulation Comparative Study and Implementation of Sepic and Cuk converter for solar Powered Electric Vehicle Battery Charging Application. The work carried out is presented as follows: Section 1 gives introduction for the work carried out in this paper. Section 2 describes the analysis and operation, design details of the Sepic and Cuk converter. Section 3 describes the simulation results and comparison of Sepic and Cuk converter. And the paper is concluded with the conclusion and followed by references.

2 OPERATION AND DESIGN PROCEDURE

1.1. Sepic Converter Circuit Diagram

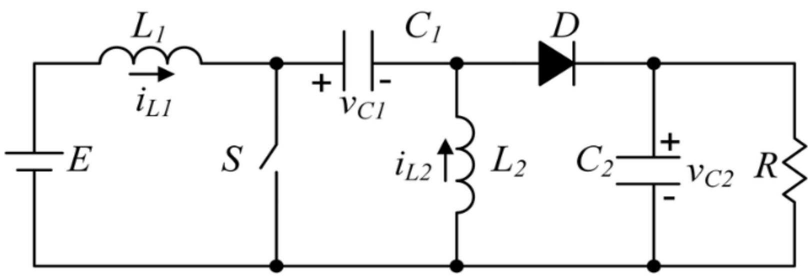

Figure 2.1: Circuit Diagram for the Sepic Converter

The DC-DC Converter is shown in Figure 2.1 works under two modes of operation which are switch S is closed and open. All DC-DC Converters operates simultaneously on and off of a switch generally with a high frequency pulse for a Sepic converter Inductor-1 is charged by the solar panel as input voltage and Inductor-2 is charged by Capacitor-1, if the Diode is off output is maintained constant by Capacitor-2 or output of the Sepic controlled by the duty cycle of the control switch for the closed loop.

2.1.1 Design details of Sepic converter and Cuk converter

Duty cycle calculation

$$D = \frac{V_{out} + V_d}{V_{in} + V_{out} + V_d} \tag{1}$$

$$D_{max} = \frac{40 + 0.5}{25 + 40 + 0.5} = 0.6183 = 61.8\%$$

$$D_{min} = \frac{40 + 0.5}{50 + 40 + 0.5} = 0.447 = 44.7\%$$

Inductor selection

$$L = \frac{V_{in} \times D}{F \times \Delta I_0} \tag{2}$$

$$L = \frac{25 \times 0.6183}{50 \times 10^3 \times 0.5} = 618.3 \times 10^{-6} H$$

Capacitor selection

$$C = \frac{D \times V_{out}}{R \times \Delta V_o \times F} \tag{3}$$

$$C = \frac{0.6183 \times 40}{5 \times 0.5 \times 50 \times 10^3} = 197.85 \times 10^{-6} F$$

Table 1: Specification of Sepic converter and Cuk converter

Parameter	Valve
V_{in}	25-50V
V_{out}	40V
f	50kHz
Dmin	0.447
Dmax	0.618
L1, L2	618.3µH
C1, C2	197.85µF

Abbreviations:

V_{in}: Input voltage
V_{out}: Output Voltage
Dmin: Minimum Duty Cycle
Dmax: Maximum Duty Cycle
F: Switching frequency
ΔV_o: Voltage Ripple
C: Capacitance
ΔI_0: Current Ripple
L: Inductance

1.2. Cuk Converter Circuit Diagram

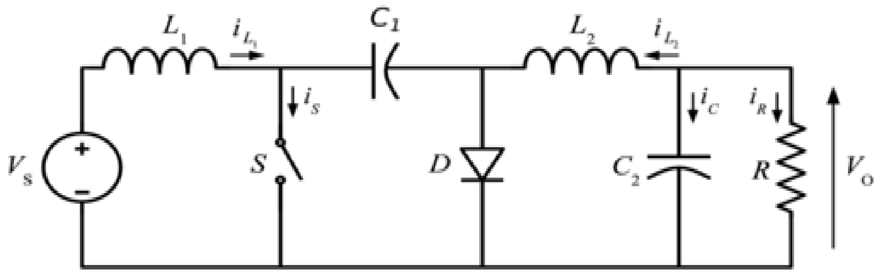

Figure 2.2: Circuit Diagram for the Cuk converter

The DC-DC Converter is shown in Figure 2.2 the cuk converter is a like a buck boost converter with inverted output voltage with lower and higher valve of input voltage from solar panel. In Cuk converter consists of a total six components L1, L2, C1, C2, Diode and the Mosfet Switch. When Switch is on source will charge the inductor that flow of current is observed from L1 to the Mosfet and buck to source and inductor L1 get charged and small amount of voltage in capacitor C1.When Switch is off and inductor L1 is dissipated the stored energy by reversing the positive the flow of current path when the switch is open is inductor L1 to capacitor C1 and diode and return to the source and disadvantages of using Cuk converter is high stress across the switch and inverted output voltage and capacitor is off large size.

Table2: Battery specification

Battery	Lithium ion
Charging voltage	25V
Charging Current	5A
Discharging Voltage	25V
Discharging Current	5A
Initial SOC	45%
Battery response Time	1S
Rated capacity	5Ah

2. SIMULATION RESULTS AND COMPARISON OF SEPIC AND CUK CONVERTERS

3.1 DC-DC Sepic Converter Mat lab Simulation.

To compare both sepic converter and cuk converter same specifications are considered and the simulation model is built in Mat lab / simulation software. The simulation circuit for sepic converter and across battery constant voltage and constant current waveforms. Li-Ion battery of 25V, Initial state of charge (SOC) of the battery is considered to be 45% and rated capacity of 5Ah.

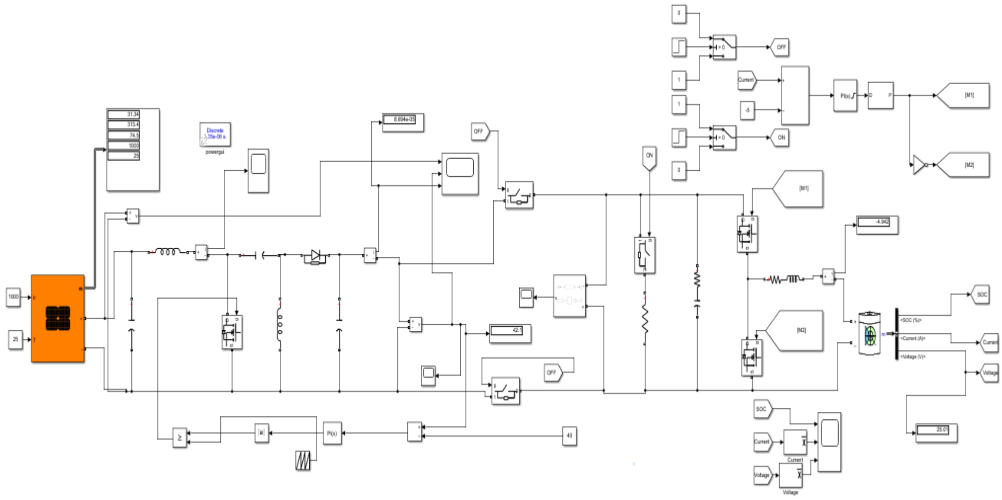

Figure 3.1: Sepic converter with current control circuit

The Figure 3.1 depicts the simulation circuit for Sepic converter. Constant DC Output voltage and current of 25V and 5A is achieved to charge and discharge of the battery of electric vehicle irrespective of power generated from the P V array.

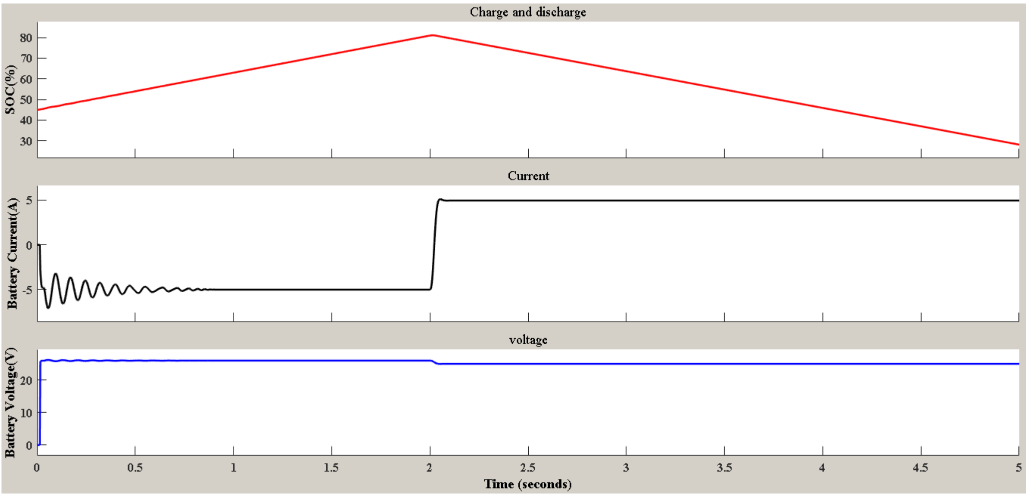

Figure 3.2: State of charge, Output voltage, Output current across the battery

The Figure 3.2 depicts the graph for State of charge, battery current and voltage with 2sec Battery will charge and 3 Sec battery will Discharge with Maintain the constant voltage of24V and constant current of 5A across the Battery using sepic converter.

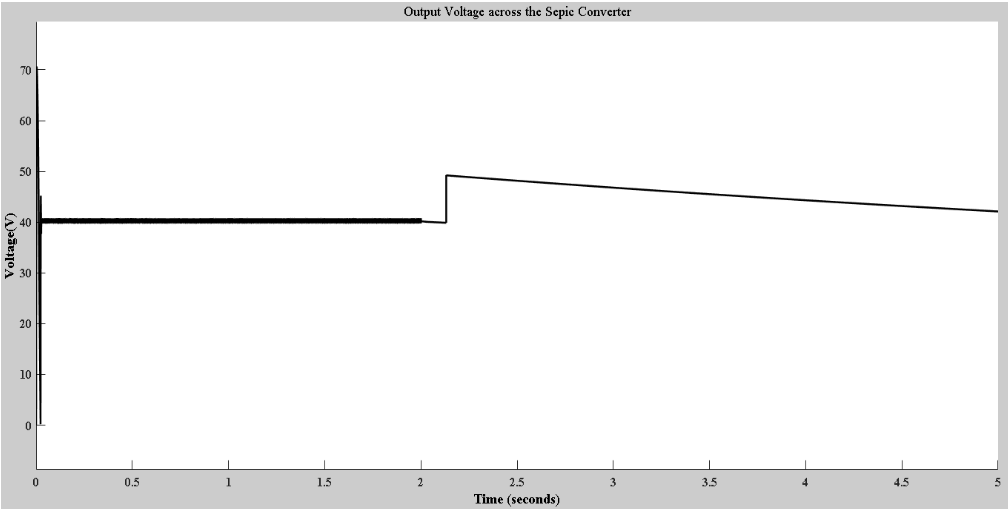

Figure 3.3: Output voltage across the sepic converter

The Figure 3.3 depicts the graph for Output voltage across the Sepic converter in which variation in input voltage the output voltage remains constant with less voltage fluctuation.

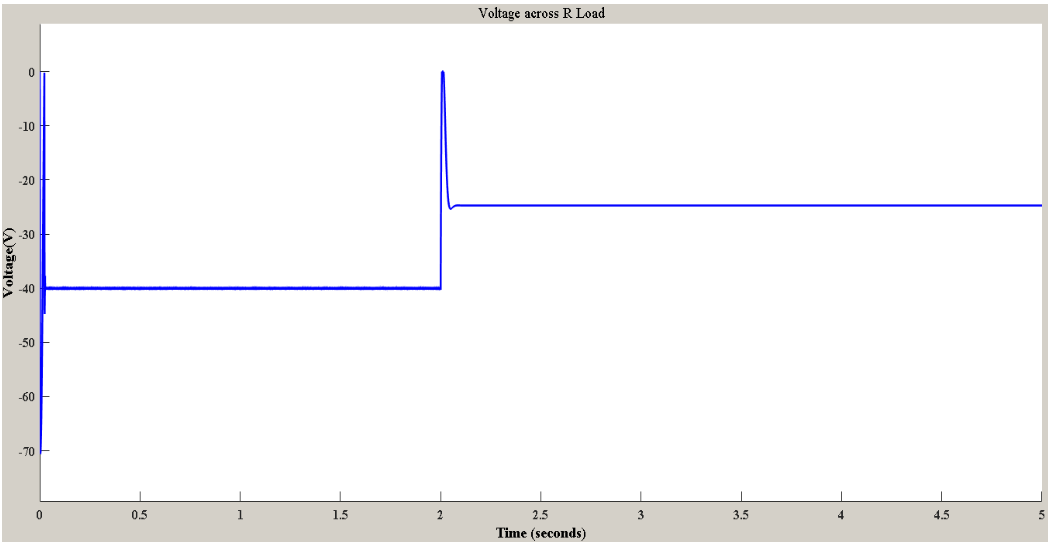

Figure 3.4: Charging and discharging Output voltage across the R load

The Figure 3.4 depicts the graph of Charging and discharging Output voltage across the R load, when charging voltage should be 40V and when Discharging Voltage should be 24V.

3.2 DC-DC Cuk Converter Mat lab Simulation.

The Figure 3.5 depicts the simulation circuit for Cuk converter and across battery constant voltage and constant current waveforms. Li-Ion battery of 25V, Initial state of charge (SOC) of the battery is considered to be 45% and rated capacity of 5Ah.

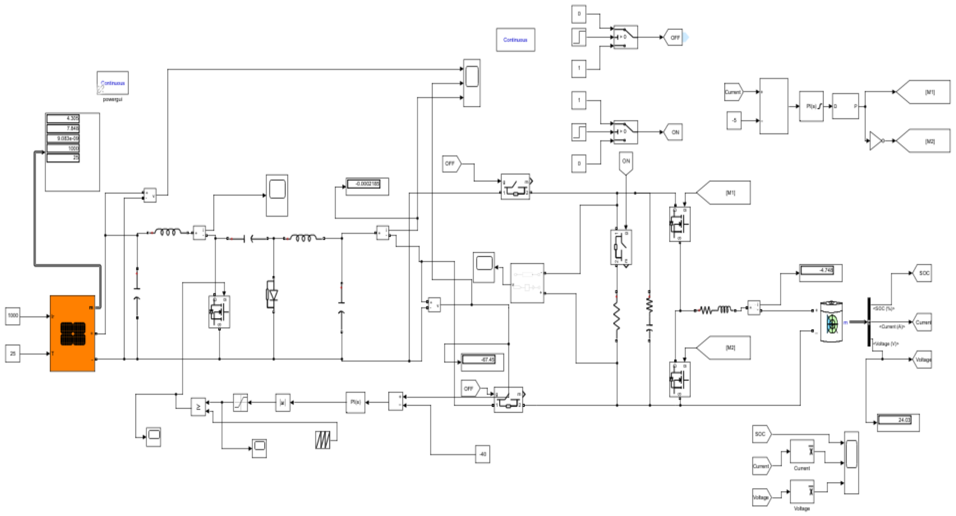

Figure 3.5: Sepic converter with current control circuit

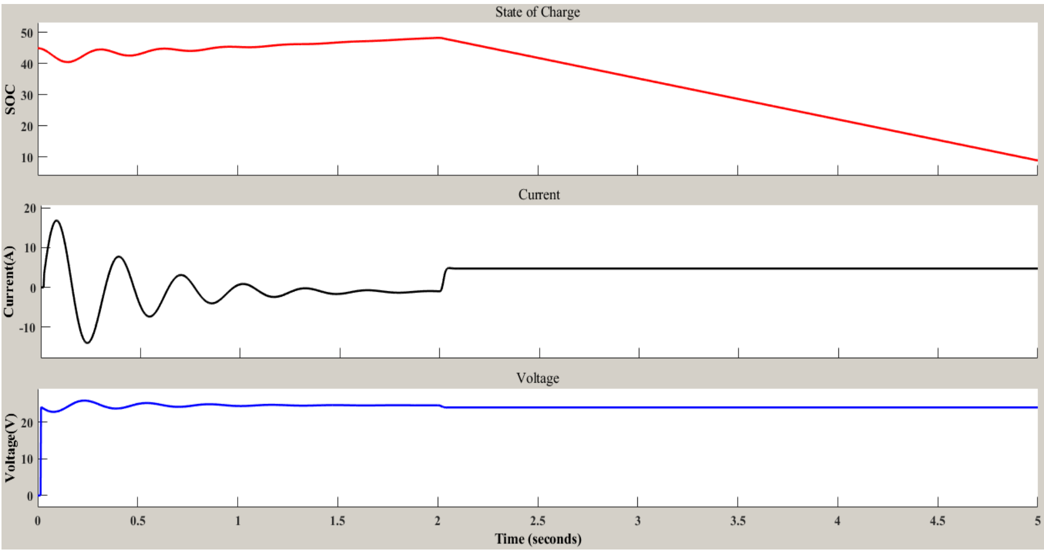

Figure 3.6: State of charge, Output voltage, Output current across the battery

The Figure 3.6 depicts the graph for State of charge, battery current and voltage with 2min Battery will charge and 3min battery will Discharge with Maintain the constant voltage of 24V and constant current of 5A across the Battery using Cuk converter.

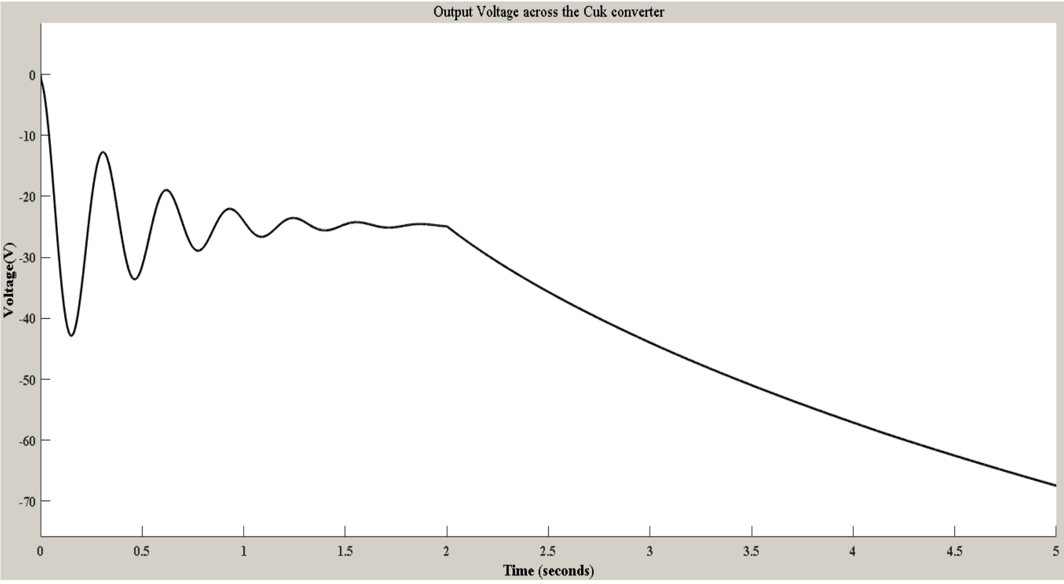

Figure 3.7: Output voltage across R Load of the Cuk converter

The Figure 3.7 depicts the graph of Charging and discharging Output voltage across the R load of the cuk converter as more ripple voltage compare to Sepic converter.

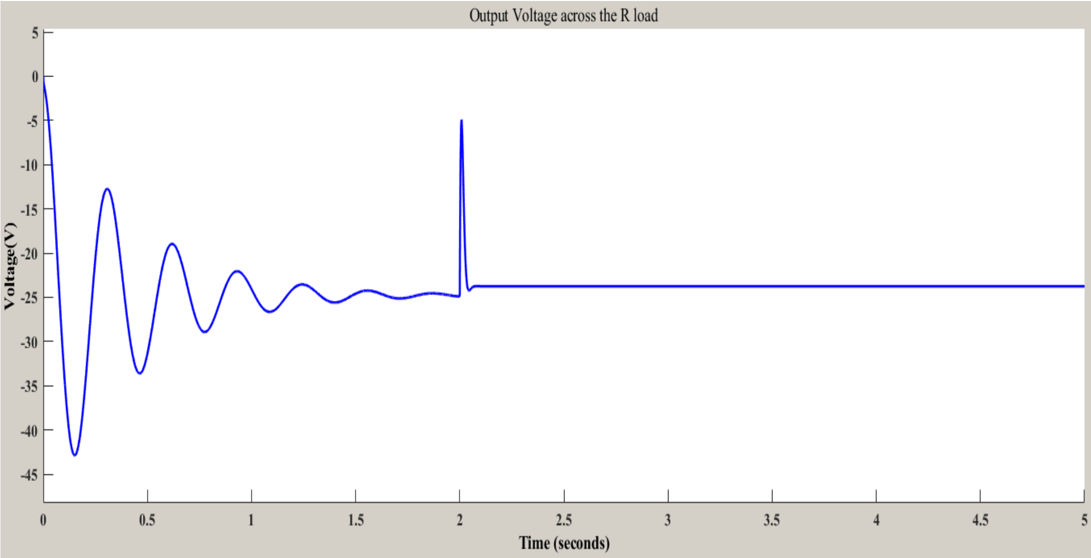

Figure 3.8: Charging and discharging Output voltage across the R load

The Figure 3.8 depicts the graph of Charging and discharging Output voltage across the R load, when charging voltage should be 40V and when Discharging Voltage should be 24V.

Table 3 the comparison between Sepic and cuk converter

SL.NO	TOPOLOGY	PARAMETERS			
		Input Voltage from Solar panel (V)	Output Voltage of sepic converter (V)	Output Voltage across the Battery(V)	Output Current across the Battery(V)
1	SEPIC CONVERTER	31.34	40.02	25.02	4.9
		39.64	39.73	25.12	5.2
		47.19	40.12	24.89	5.23
		55.39	40.16	25.10	5.26
2	CUK CONVERTER	31.34	-41.02	25.10	5.6
		39.64	-42.12	26.12	5.9
		47.19	-40.04	24.01	5.25
		55.39	-40.39	26.10	4.98

Finally two converters such as Sepic and Cuk converter are simulated in Mat lab simulation software. By varying the input voltage from solar panel by changing Parallel strings and Series-connected modules per string in PV array. The performance parameters such as output voltage across the converter, output voltage and current across the battery obtained for sepic and cuk converter, due to less output voltage ripple in sepic converter, non-inverted output voltage, less total harmonics, less electrical stress and hence given higher efficiency in sepic converter compared with cuk converter.

3. CONCLUSION

The Sepic DC-DC Converter and Cuk DC-DC Converter for Solar powered electric vehicle battery charging application is designed and simulated using MATLAB Simulink software. Simulation model also provided a closed loop control for sepic and a cuk converter which maintains a constant 24V output voltage and constant 5A output current across the battery. The comparison of sepic converter and cuk converter with the same specification in terms of switching frequency, charge, and discharge of the battery is carried out. Further, from the simulation results it is found that sepic converter has less fluctuation in output voltage and current across the battery when charging and discharging.

4. REFERENCES

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