Design &Simulation of Solar Powered Zeta Converter using Perturb& Observe Method

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Abstract It is very essential to harness solar energy effectively as demand of electrical energy is increasing day by day and resources of fossil fuels are limited. Solar energy is abundantly available hence proper conversion and use is highly required. This paper addresses comparison between various DC-DC Converters and maximum power point tracking (MPPT).For extraction of power from the solar panelmaximum power point trackingalgorithm is used.Comparative analysis is done among Buck-boost converter, Cu'k converter, SEPIC converter and Zeta converter using MPPT.Considering input power, output power, voltage ripple and MPP signal tracking Zeta Converter waveforms are analyzed compare to other three converter waveforms considering the voltage ripple and Maximum Power Point Tracking.Zeta Converter topology is more beneficial as it can be used to maximize the generated solar power by Solar Photovoltaic Panel (SPV).

Keywords—Solar Photovoltaic Module (SPV); Maximum Power Point Tracking (MPPT); Perturb & Observe Method, Voltage Ripple, Zeta Converter

I. Introduction

As the fossil fuel resources are less and can be out of stock any time. Considering the clean energy & green energy concept it is advisable to use solar energy as the renewable energy sources for the generation of electrical energy. Photovoltaic Effect defined as the transformation of solar energy into electrical energy using semiconductor devices such as solar photovoltaic cells (SPV). As the geometrical conditions of India has the waste resources of solar energy.From SPV panel, output can be fed to the DC-DC converter. This DC-DC converter output is fed to the Inverter which supplies the domestic applications. Using SPV, development of Solar Powered Inverter can be done and domestic loads like lighting loads and other small applications can be run. Maximum Power Point Tracking (MPPT) algorithm is used for extraction of maximum power and maximum energy from the Solar panel.

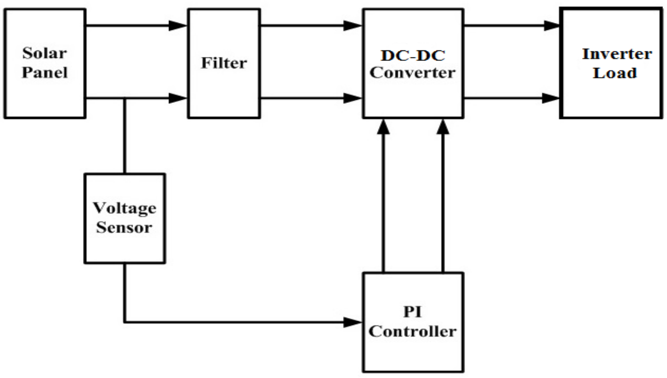


Fig.1 Block Diagram of Solar Powered Converter

II. VARIOUS TOPOLOGY FOR DC-DC CONVERTERS

A. Buck Boost Converter

It can increase or decrease the input voltage (module voltage). Mathematical modelling is less complex as compared to Cuk converter. MPPT implementation using this converter is simpler as compared to Cuk converter. Implementation of this converter into hardware is simpler as compared to Cuk converter. Ripples ininput current and input voltage are higher in comparison with the Boost and Cuk converter. Output current and output voltage are higher as compared to buck and Cukconverter.

B. Cu'k Converter

It can increase or decrease the input voltage (module voltage).Ripples in input current and input voltage are lesser in comparison to buck boost and buck converter (due to presence of an inductor at source side). Ripples in output current and output voltage are lesser in comparison to buck boost and boost converter (due to presence of an inductor at load side).Mathematical modelling is more complex in comparison to buck boost converter.MPPT implementation using this converter is more complex in comparison to buck boost converter. Implementation of this converter in hardware is more complex in comparison to buck boost converter (as two inductors are need to be designed)

C. SEPIC Converter

It has same voltage polarity as the input. Being capital of true shutdown means Switch OFF gives Output voltage 0 V. Ithas pulsating output current. It requirescapacitor of high capacitance and current handling capability is required. Nature wise control of the converter is quite difficult.

D. Zeta Converter

It has lower output voltage and easier compensation. Also, the small ripple level is advantageous. Average steady state time occurred in all three converters are 0.06 ms while SEPIC has 0.08 ms.

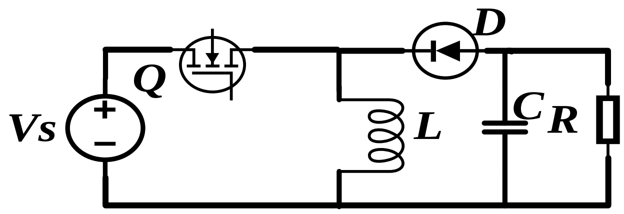


Fig.2 Buck-Boost Converter

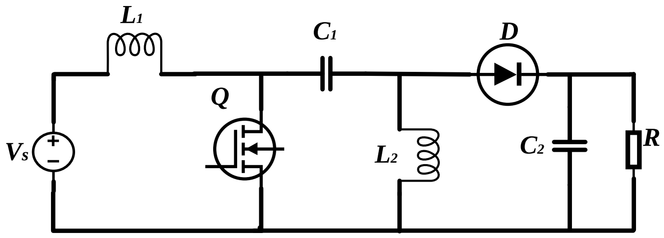


Fig.3 Cu'k Converter

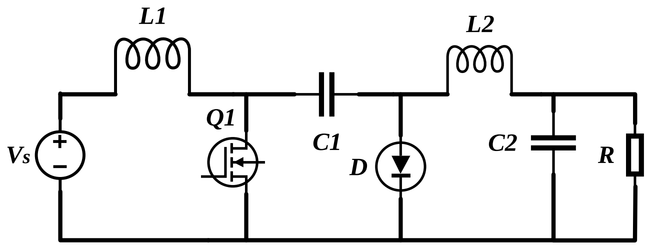


Fig.4 SEPIC Converter

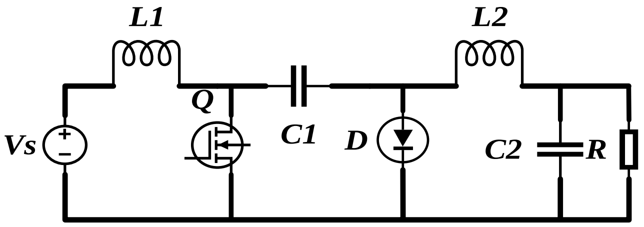


Fig.5 Zeta Converter

III. MPPT and P & O Method

Considering allthe MPPT methods P & O (Perturb & Observe) is the simplest method among them. used for sensing Voltage & current of PV panelare sensed using sensors. So, implementation cost is less & can be implemented easily. Algorithm has less time complexity but reaching close to MPP(Maximum Power Point) it doesn't stop at the MPP and keeps on perturbing on both the directions. Reaching close to the MPP algorithm appropriate error limit is setor need to using a wait function it can end up with increase in time complexity of the algorithm. Algorithm operates periodically by perturbing (incrementation or decrementation) voltage or current of the array terminal and PV output compared with that of the perturbation cycle.

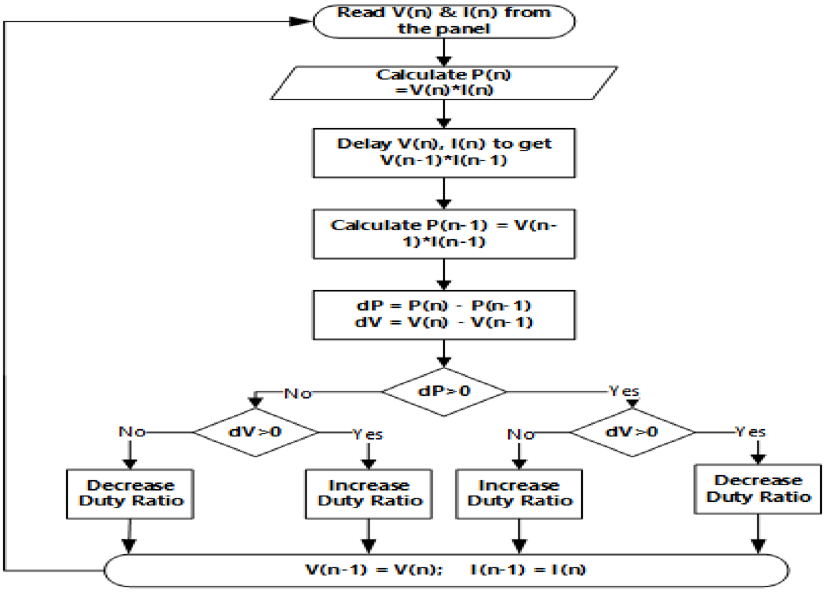


Fig.6 Flow Diagram of Perturb & Observe Method

IV. System Design

TABLE I. SPECIFICATION OF PHOTOVOLTAIC

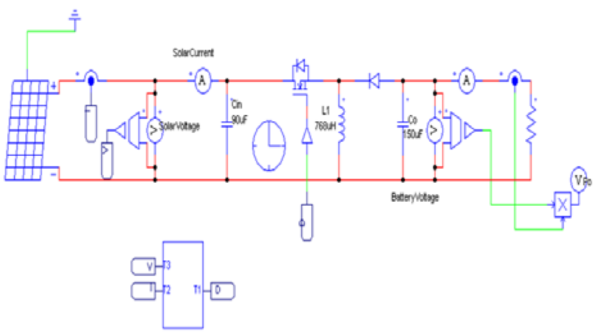
Specification	Value
Number of Solar Cell	72
Maximum Power (P_{max})	80 W
Maximum Voltage (V_{max})	17.5 V
Open Circuit Voltage	20 V
Maximum Current (I_{max})	6 A
Short Circuit Current (I_{sc})	7 A

TABLE II. COMPONENTS PARAMETER ON EACH DC-DC CONVERTER

Component	Buck-Boost	Cu'k	SEPIC	Zeta
Diode	0.6	0.6	0.6	0.6
L_1	768 uH	1.28 mH	1.28 mH	2.4 mH
L_2	-	1.28 mH	1.28 mH	2.4 mH
C_1	150 uF	36 uF	36 uF	18.75 uF
C_2	-	7.81 uF	100 uF	150 uF

V. Simulation Results & Analysis

The simulation of PV fed Converters was done by measuring the voltage ripple occurred at the output side as well as input side. The MPPT circuit for all the four converters Buck-Boost, Cu'k, SEPIC & Zeta are shown in the Fig. 7.



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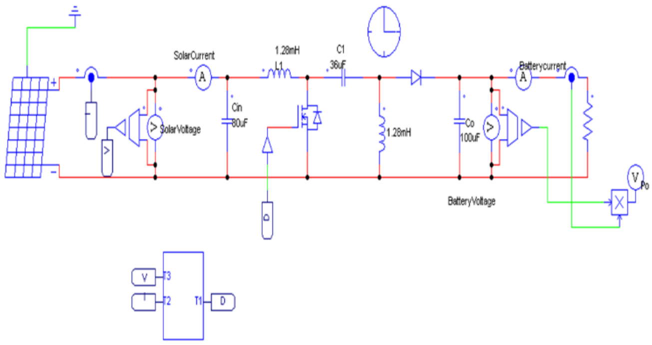

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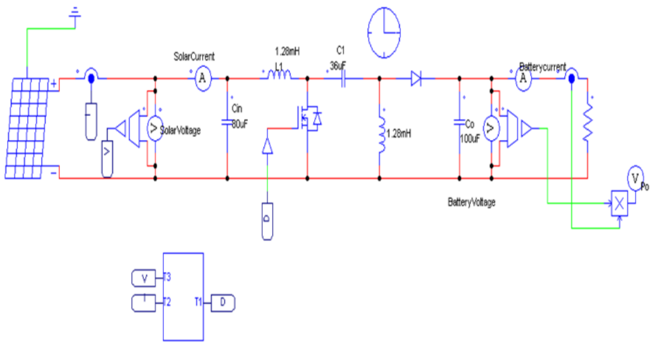

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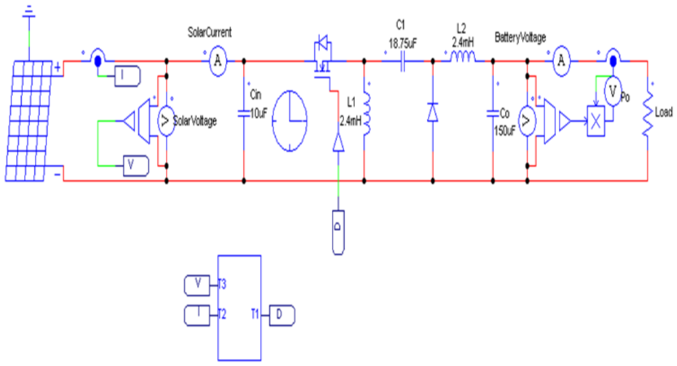

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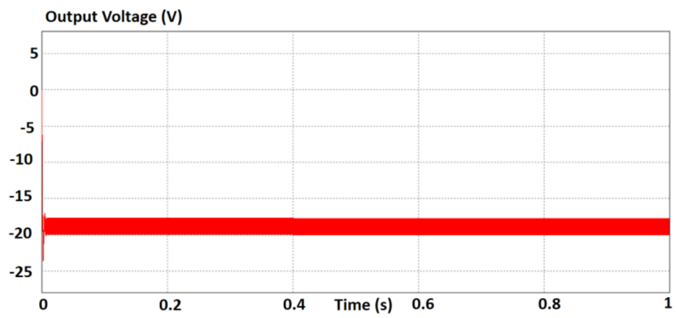
Fig.7 DC-DC Converter Circuit with MPPT for Photovoltaic (a)Buck-Boost, (b) Cu'k, (c) SEPIC& (d) Zeta



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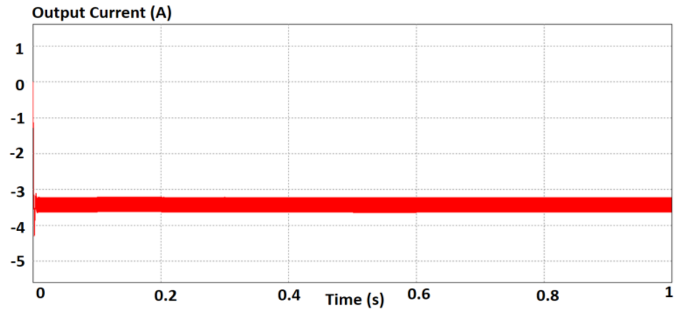

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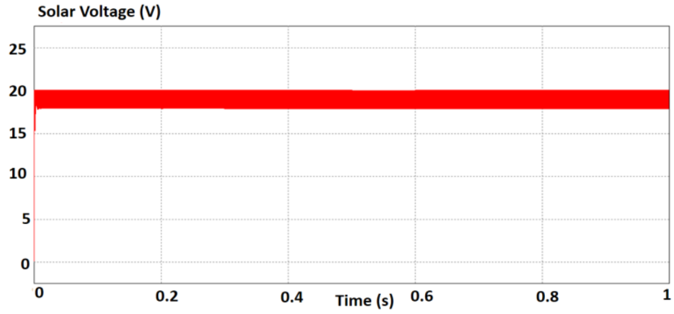

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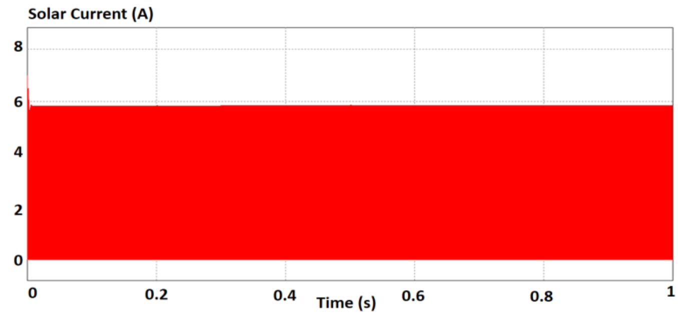

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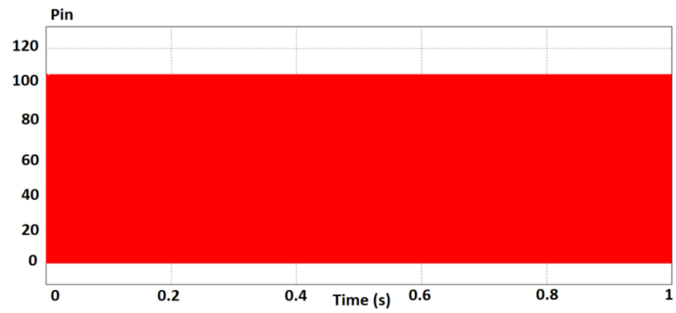

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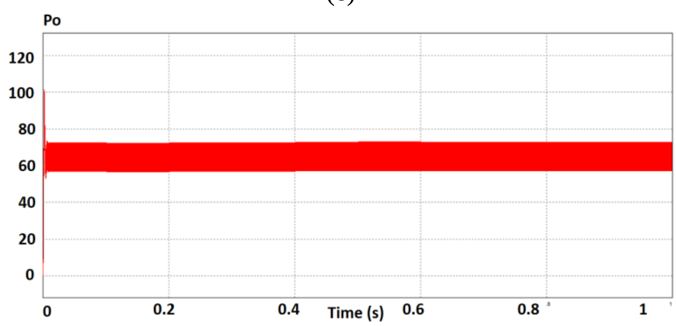

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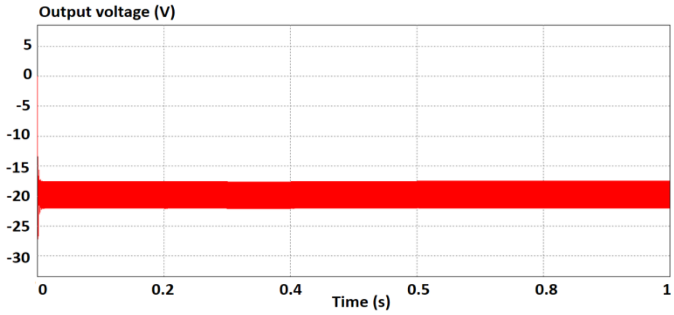
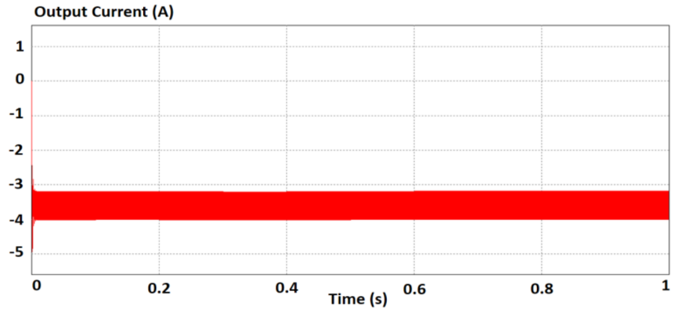
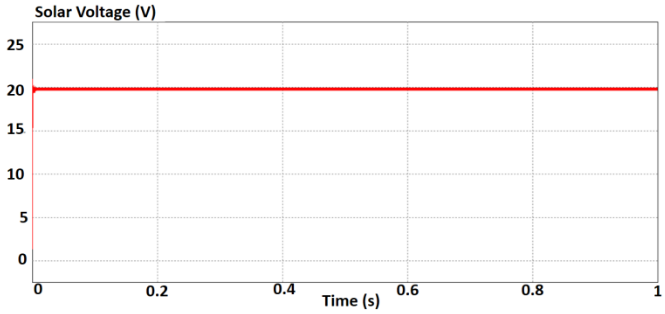
Fig.8Buck-Boost Converter Waveforms (a) Output Voltage,(b) Output Current,(c) Solar Voltage, (d) Solar Current,(e) Input Power to converter & (f) Output Power of converter


Output voltage (V)
5
0
-5
-10
-15
-20
-25
-30
0
0.2
0.4
Time (s)
0.5
0.8
1

(a)


Output Current (A)
1
0
-1
-2
-3
-4
-5
0
0.2
0.4
Time (s)
0.6
0.8
1

(b)


Solar Voltage (V)
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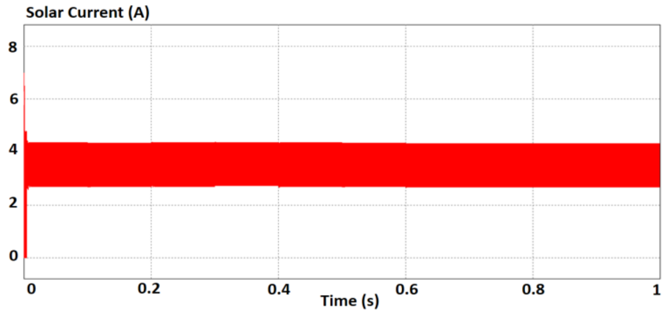
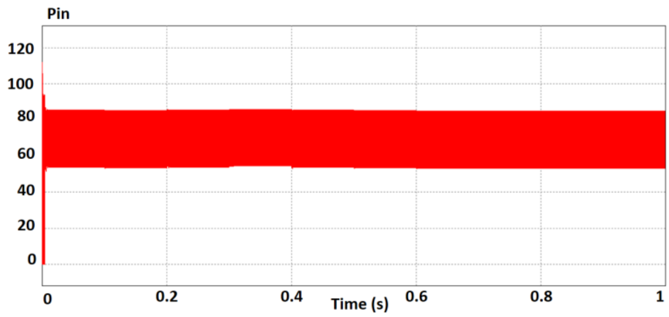
20
15
10
5
0
0
0.2
0.4
Time (s)
0.6
0.8
1

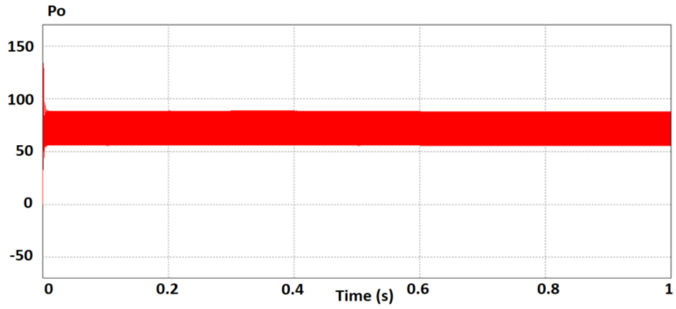
(c)


Solar Current (A)
8
6
4
2
0
0
0.2
0.4
Time (s)
0.6
0.8
1

(d)

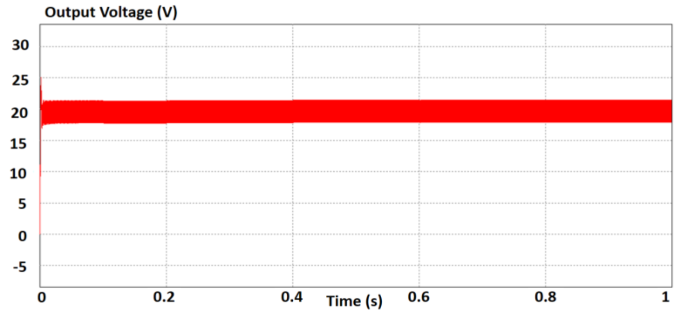

Pin
120
100
80
60
40
20
0
0
0.2
0.4
Time (s)
0.6
0.8
1

(e)

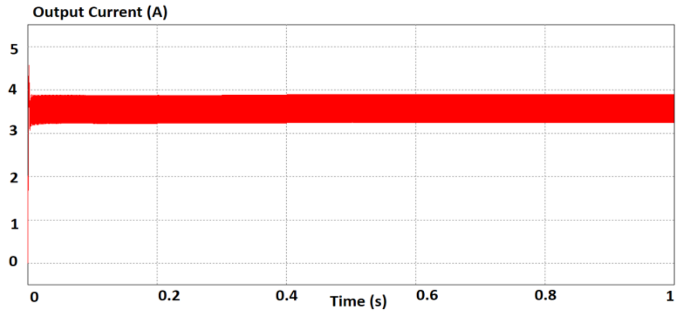


(f)

Fig.9Cu’k Converter Waveforms (a) Output Voltage, (b) Output Current, (c) Solar Voltage (d) Solar Current,(e) Input Power to converter & (f) Output Power of converter



(a)



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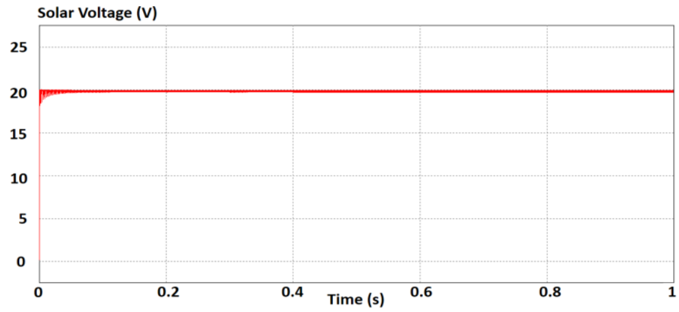

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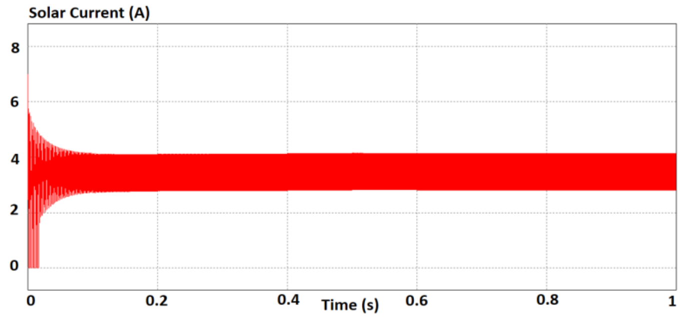

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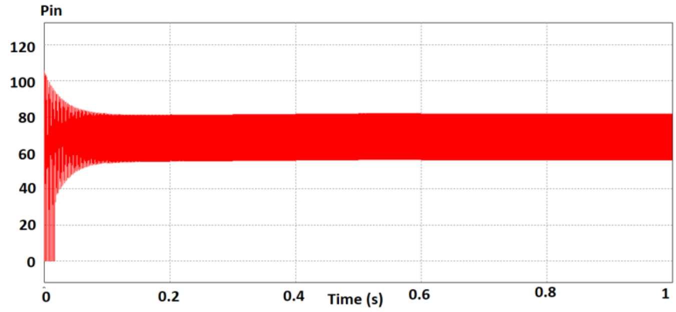
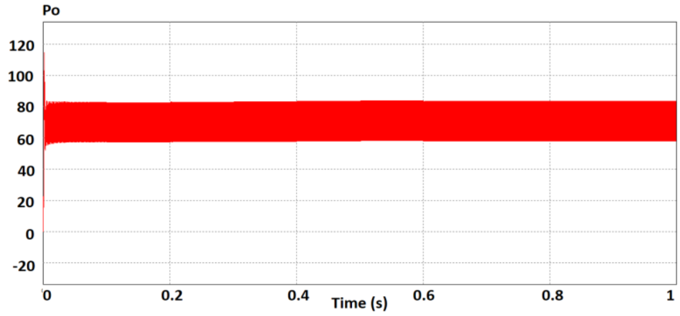
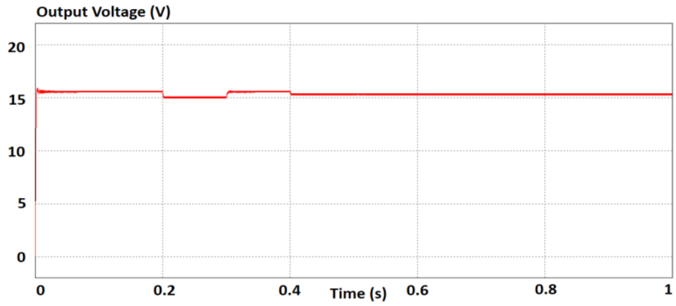


(e)

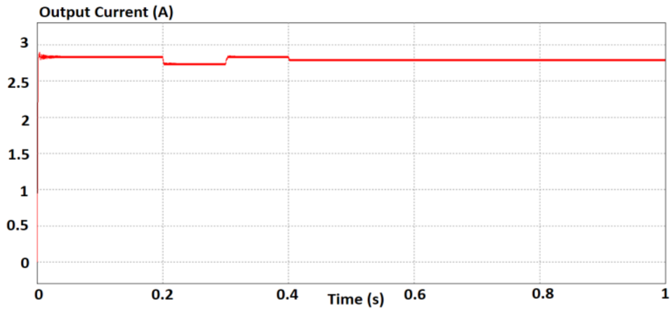


(f)

Fig. 10SEPIC Converter Waveforms (a) Output Voltage, (b) Output Current, (c) Solar Voltage, (d) Solar Current, (e) Input Power to converter & (f) Output Power of converter



(a)



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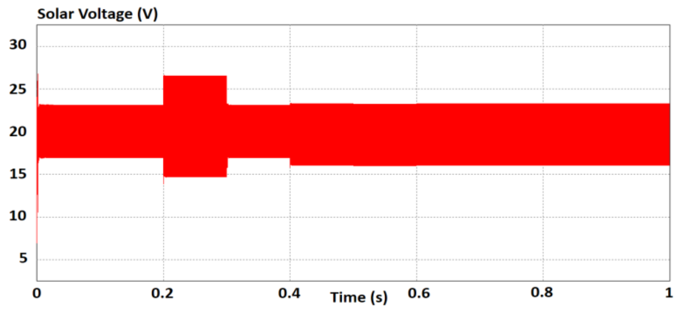

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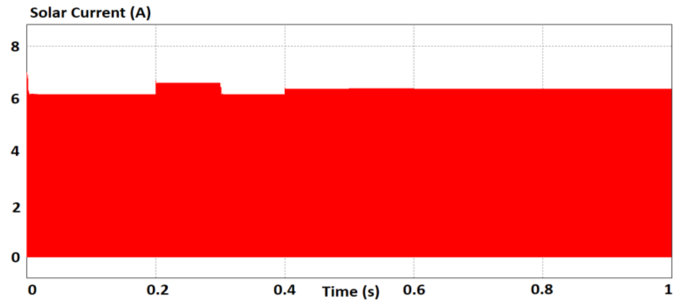
ISSN (Print) : 2319-8613
ISSN (Online) : 0975-4024



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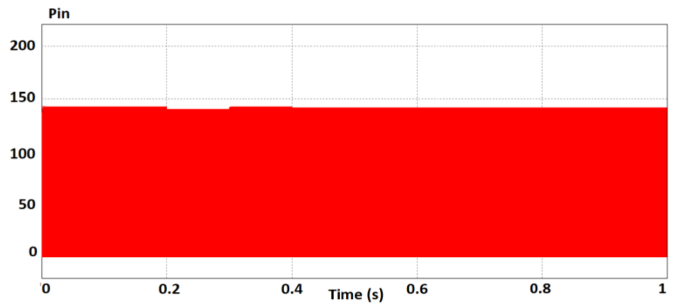

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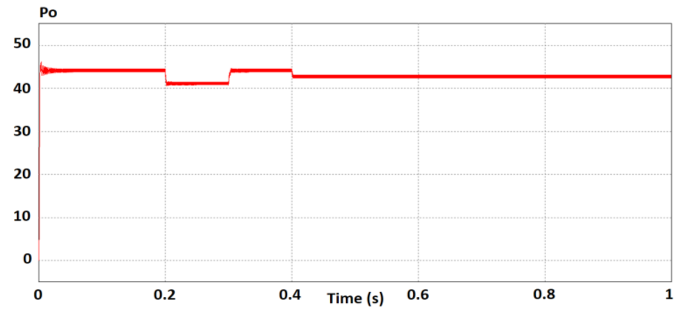

(f)

Fig.11 Zeta Converter Waveforms (a) Output Voltage, (b) Output Current, (c) Solar Voltage, (d) Solar Current, (e) Input Power to converter & (f) Output Power of converter

VI. Comparative Analysis of Various Converters

Simulation Results are shown in the Fig. 8, 9, 10& 11 for all the four converters. From Fig.11 it is observed that P & O MPPT can work well as compare to other converters and also it is trying to achieve the MPP signal in the Zeta Converter.From that we observe that the Zeta Converter is best to achieve the MPP using P & O algorithm and it also works very nicely to achieve MPP. The Voltage Ripple in Zeta is very less as compare to other converters. The lowest voltage ripple which observed in the simulation of Zeta Converter is shown in the Fig.12.Also from the waveforms of all the converters it can be observed that the Buck-Boost & Cu'k Converters gives inverted polarity of the output signal from the input signal, while the SEPIC& Zeta converters gives the same polarity of the output signal from the input signal.The parameters for the simulated Zeta converters are given below in the Table III.

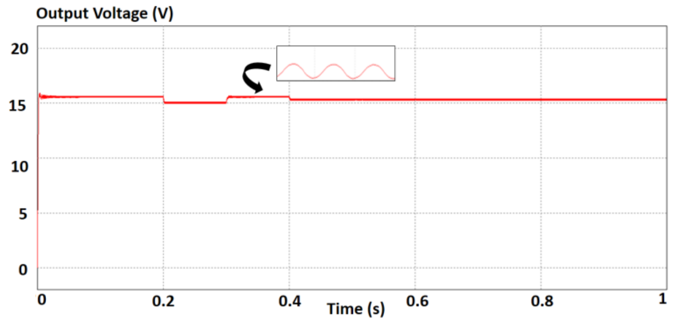

Fig. 12 Output Voltage Ripple of Zeta Converter

TABLE III. PARAMETERS FOR THE SIMULATED ZETA CONVERTER

Zeta Converter Parameters	Value
Output Voltage	15.8 V
Output Current	2.83 A
Average Voltage	15.5 V
RMS value of Voltage	15.5 V
Input Power	52.3 W
Output Power	43.1 W
% V_{ripple}	0.8 %
Efficiency	81%

VII.Conclusion

From the comparative simulation of all the four converters the waveforms for the output voltage and current observed that the voltage Buck-Boost& Cu'k have the output voltage and current signal inverted from the input signal. While, SEPIC & Zeta has output voltage and current same as the input signal.Also, it is observed that the Zeta converter topology has minimum ripple level across the load as compare to other converters. The MPPT signal tracked best in Zeta Topology. It is advantageous to have small voltage ripple level in terms of tracking Maximum Power from the photovoltaic.The percentage voltage ripple is 0.8% which is advantageous for tracking maximum power from PV array. The Zeta converter provides a stiff DC output across the load&comparing all the four converters it is observed that the Zeta Converter is best for extracting the maximum power from the PV array.

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