A Novel Sepic Based Dual Output DC-DC Converter for Solar Applications

Mahajan Sagar Bhaskar Ranjana
School of Electrical Engineering
VIT University, Chennai
Tamil Nadu –INDIA
sagar25.mahajan@gmail.com

Nandyala SreeramulaReddy
School of Electrical Engineering
VIT University, Chennai
Tamil Nadu –INDIA
ammasreeram@gmail.com

Repalle Kusala Pavan Kumar
School of Electrical Engineering
VIT University, Chennai
Tamil Nadu –INDIA
repallekusalapavan@gmail.com

***Abstract*—This paper presents a sepic based dual output DC-DC converter, which is suitable for solar applications where two output voltages are needed at the same time. The proposed converter topology is the combination of sepic converter and high gain multilevel boost converter. Only one input source and switch is required to obtain two output voltages at the same time. One output voltage is obtained through high gain multilevel boost converter and other output voltage is obtained through sepic converter. Sepic converter operates in two modes, step-up or step-down depending on the duty cycle. The output voltage levels of high gain multilevel boost converter can be increases by adding diodes and capacitors without disturbing main circuit. The converter has been designed for 12V input supply with rated output parameters 180W, 230V and 50W, 36V. Switching frequency of applied gate pulse is 50 KHz with 75% duty cycle. Simulation is carried out using MATLAB/SIMULINK.**

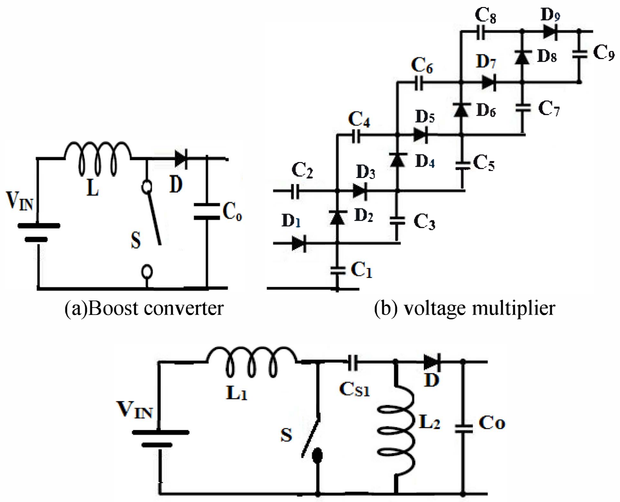
***Keywords*—DC-DC converter; dual output; high gain boost converter; sepic.**

I. INTRODUCTION

Now a day the demand of electricity generation from renewable energy is increasing for domestic to industrial applications. The electricity generated from fossil fuels causes rising of toxic gases in the atmosphere. These fossil fuels are decreasing bit by bit in the environment. Solar energy is one of the most abundant renewable energy resource, eco-friendly, and pollution free. Sunlight is converted into electricity via solar cell using the photovoltaic effect [1]-[3]. For solar energy system installation cost only needed, if once installed it can run for a long duration and it can also save the overall maintenance cost. Solar energy having versatile in nature, it can be used for different power applications from tiny torch to satellite.

Dual converters are useful when dual output voltage levels are required from single input supply voltage [4]-[6]. Flyback converter is capable to produced dual output voltage levels but it required transformer [7]-[9]. The gain of flyback converter is depends upon the turns ratio of transformer. Sepic converter is used for step up and step down application [10]-[11]. High gain multilevel boost converter is used to step up the voltage level with large conversion ratio [12]-[15]. More number of switches and elements are required for generating dual output voltage level from conventional converters. Due to increases in number of switches and elements, converter circuit becomes more expensive and complex.

In this paper, sepic based dual output converter is proposed which is suitable for solar applications. The proposed converter topology is the combination of sepic and high gain multilevel DC-DC boost converter. High gain multilevel DC-DC boost converter combines the conventional boost converter and voltage multiplier functions. The gain of voltage multiplier circuit can be increases by adding diodes and capacitors. Circuit diagram of boost converter, voltage multiplier and sepic converter are depicted in Fig1. The main advantages of proposed circuit topology are (i) dual output (ii) transformer less based design (iii) single switch.



(a)Boost converter (b) voltage multiplier

(c) Sepic converter

Fig.1 Circuit diagrams of boost, voltage multiplier and sepic converter

II. CIRCUIT DESCRIPTION

A. Power circuit

Power circuit diagram of proposed sepic based dual output DC-DC converter is depicted in Fig2. In the proposed converter only one input source and switch is required to obtain two output voltages at the same time. One output voltage is obtained through 5-level multilevel boost converter and other output voltage is obtained through sepic converter. Sepic converter operates in two modes, step-up or step-down depending on duty cycle. When duty cycle is less than 0.5, sepic converter is operated in step-down mode. When duty cycle is greater than 0.5, sepic converter is operated in step-up

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mode. The output voltage levels of high gain multilevel boost converter can be increases by adding diodes and capacitors without disturbing main sepic converter circuit.

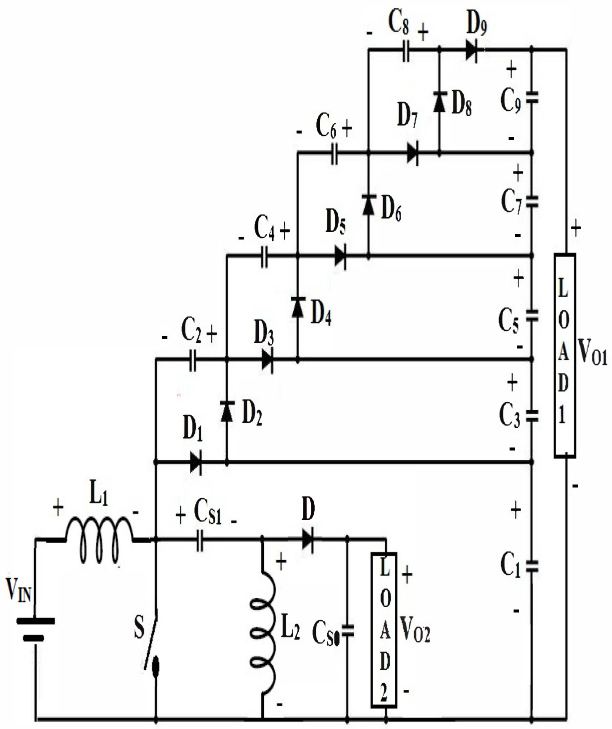


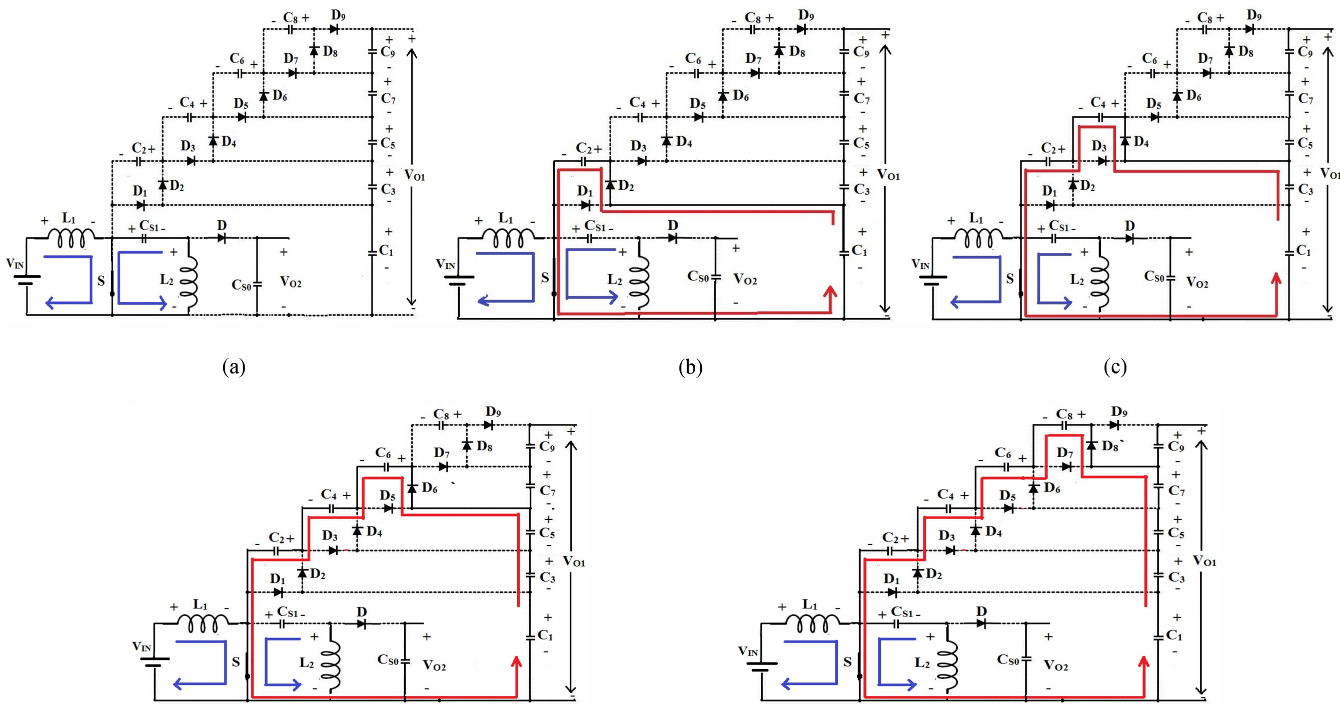
Fig.2 Power circuit diagram of proposed converter

B. *Modes of operation*

The operation of the sepic based dual output DC-DC converter can be divided into two modes, when switch S is turned ON and another when switch S is turned OFF.

In mode 1, switch S is turned ON, the inductors L_1 and L_2 are charges from the input source and capacitor C_{S1} respectively. Capacitor C1 clamps the voltage across capacitor C_2 through D_2 and switch S, when D_2 is forward biased. Voltage $V_{C1}+V_{C3}$ clamp the voltage $V_{C2}+V_{C4}$ through D_4 and switch S, when D_4 is forward biased. Voltage across voltage $V_{C2}+V_{C4}+V_{C6}$ is clamp by voltage $V_{C1}+V_{C3}+V_{C5}$ through D_6 and switch S, when D_6 is forward biased. Similarly voltage $V_{C2}+V_{C4}+V_{C6}+V_{C8}$ is clamp by $V_{C1}+V_{C3}+V_{C5}+V_{C7}$ through D_8 and switch S, when D_8 is forward biased. The current direction and operating modes, when switch is turned ON is shown in Fig.3 (a-e).

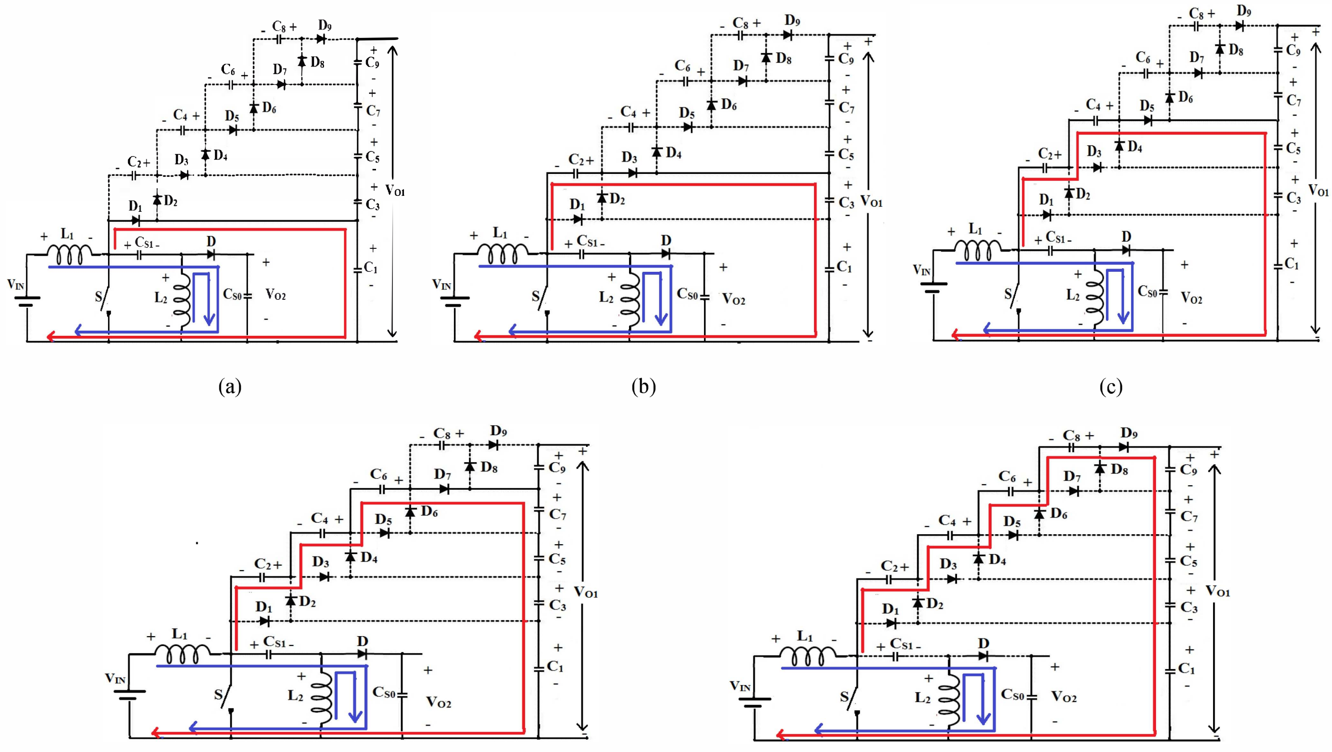
In mode 2, switch S is turned OFF, the inductors L_1 and L_2 are discharges through D and D_1. The inductor current and input voltage charges the capacitors C_1 through D_1. Capacitors of the sepic converter C_{S1} and C_{S0} are charges from input voltage and inductors current through D. when D_3 is forward biased, voltage $V_{IN}+V_{L1}+V_{C2}$ clamps the voltage $V_{C1}+V_{C3}$. Voltage $V_{C1}+V_{C3}+V_{C5}$ is clamp by voltage $V_{IN}+V_{L1}+V_{C2}+V_{C4}$ through D_5, when D_5 is forward biased. When D_7 is forward biased, voltage $V_{IN}+V_{L1}+V_{C2}+V_{C4}+V_{C6}$ is clamp the voltage $V_{C1}+V_{C3}+V_{C5}+V_{C7}$ through D_7. Similarly, when D_9 is forward biased, voltage $V_{C1}+V_{C3}+V_{C5}+V_{C7}+V_{C9}$ is clamp by voltage $V_{IN}+V_{L1}+V_{C2}+V_{C4}+V_{C6}+V_{C8}$ through D_9. The current direction and operating modes, when switch is turned OFF is shown in Fig.4 (a-e).



(a) (b) (c)

(d) (e)

Fig.3 (a-e) Operating Modes when switch S is ON



(a) (b) (c)

(d) (e)

Fig.4 (a-e) Operating Modes when switch S is OFF

III. Analysis Of Proposed Converter

When switch S is closed, both inductors L1 and L2 will charges from input voltage and capacitor Cs1 respectively.

$$V_{L1} = V_{IN} \tag{1}$$

$$V_{L2} = -V_{CS1} \tag{2}$$

Voltage V_{C2} is charges from voltage V_{C1}

$$V_{C1} = V_{C2} \tag{3}$$

Similarly,

$$V_{C1} + V_{C3} = V_{C2} + V_{C4} \tag{4}$$

$$V_{C1} + V_{C3} + V_{C5} = V_{C2} + V_{C4} + V_{C6} \tag{5}$$

$$V_{C1} + V_{C3} + V_{C5} + V_{C7} = V_{C2} + V_{C4} + V_{C6} + V_{C8} \tag{6}$$

When switch S is open, both inductors will discharges

$$V_{L1} = V_{IN} - V_{CS1} - V_{02} \tag{7}$$

$$V_{L1} = V_{IN} - V_{C1} \tag{8}$$

$$V_{L2} = V_{02} \tag{9}$$

By inductor volt second balance for inductor L1,

$$V_{L1}(D) + V_{L1}(1-D) = 0 \tag{10}$$

From equation (1) and (7)

$$V_{IN}(D) + (V_{IN} - V_{CS1} - V_{02})(1-D) = 0 \tag{11}$$

$$V_{IN} + (-V_{CS1} - V_{02})(1-D) = 0 \tag{12}$$

From equation (1), (8) and (10)

$$V_{IN}(D) + (V_{IN} - V_{C1})(1-D) = 0 \tag{13}$$

$$\frac{V_{C1}}{V_{IN}} = \frac{1}{(1-D)} \tag{14}$$

By inductor volt second balance for inductor L2,

$$V_{L2}(D) + V_{L2}(1-D) = 0 \tag{15}$$

$$-V_{CS1}(D) + V_{02}(1-D) = 0 \tag{16}$$

$$V_{CS1} = \frac{V_{02}(1-D)}{D} \tag{17}$$

Put V_{CS1} in equation (12)

$$V_{IN} - (V_{02}(1-D)/D + V_{02})(1-D) = 0 \tag{18}$$

$$\frac{V_{02}}{V_{IN}} = \frac{D}{1-D} \tag{19}$$

Voltages across all multiplier capacitors are equal

$$V_{01} = V_{C1} + V_{C3} + V_{C5} + V_{C7} + V_{C9} \tag{20}$$

$$V_{01} = 5V_{C1} \tag{21}$$

Thus, the conversion ratio for proposed converter is

$$\frac{V_{01}}{V_{IN}} = \frac{5}{1-D} \tag{22}$$

$$\frac{V_{02}}{V_{IN}} = \frac{D}{1-D} \tag{23}$$

For N-level boost converter voltage gain is

$$G_{01} = \frac{N}{(1-D)} \tag{24}$$

For sepic converter voltage gain is

$$G_{O2} = \frac{D}{(1-D)} \tag{25}$$

Thus, voltage gain for is depends upon duty cycle and the number of levels present in multiplier and voltage gain for load2 depends upon duty cycle only.

IV. Simulation Results

The proposed converter is designed for 12V input supply with rated output parameters 180 W, 230 V and 50 W, 36 V. Switching frequency of applied gate pulse is 50 KHz with 75% duty cycle. Simulation results of proposed converter are verified through MATLAB/SIMULINK. Table I shows the specification of proposed converter.

Table I. Specification of converter

No	Parameter	value
1	Input voltage	12 V
2	Output voltage (V_{01}) and(V_{02})	230V and 36V
3	Power (P_{01}) and(P_{02})	180W and 50W
4	Inductor (L_1) and (L_2)	700 µH
5	capacitors	220 µF
6	Switching frequency	50 KHz
7	Duty cycle	75%
8	Number of Level in boost converter	5 level

Graph of voltage gain versus duty cycle is shown in Fig5. Output voltage and output current waveform for load1 is shown in Fig6. Output voltage and output current waveform for load2 is shown in Fig7. Voltage stress across switch is 48 V which is shown in Fig8. Output power waveform for load1 and load2 is shown in Fig9. The current waveform through inductors with applied gate pulse is shown in Fig10. It is observed that the ripple in inductors current waveform is 0.3A. The voltage at output capacitors node is shown in Fig11.

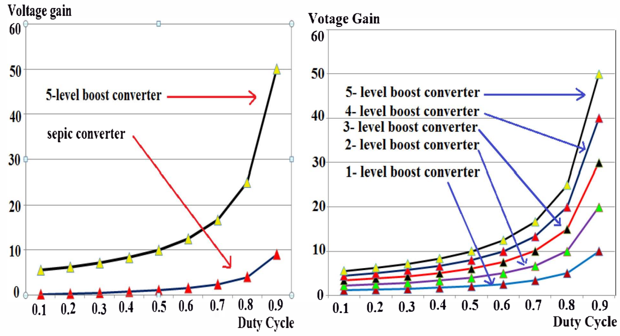


Fig.5 Graph of voltage gain Vs duty cycle

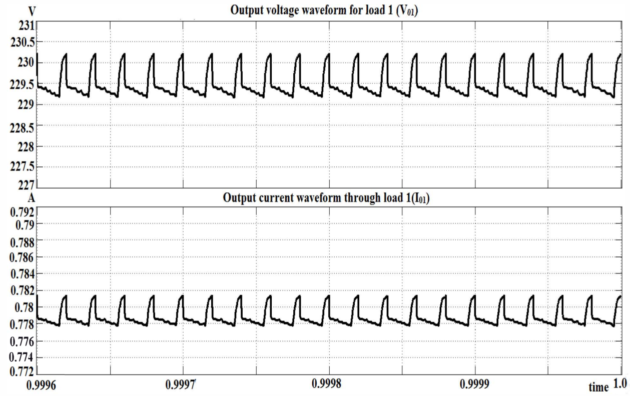


Fig.6 Output voltage and current waveform for load1

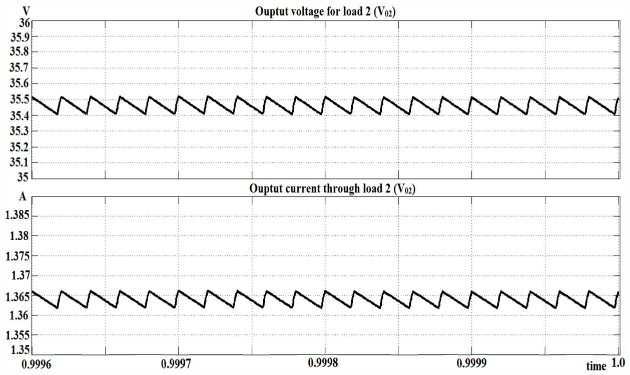


Fig.7 Output voltage and current waveform for load2

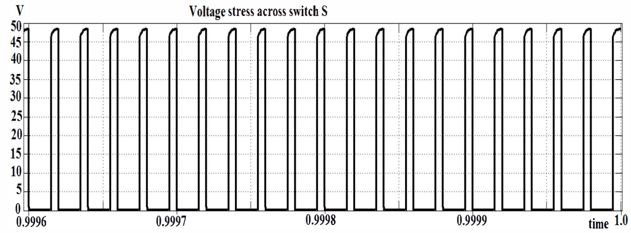


Fig.8 Voltage stress across switch S

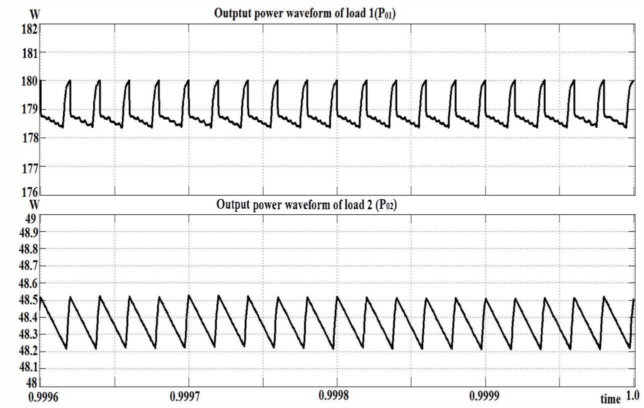


Fig.9 Output power waveform for load1 and load2

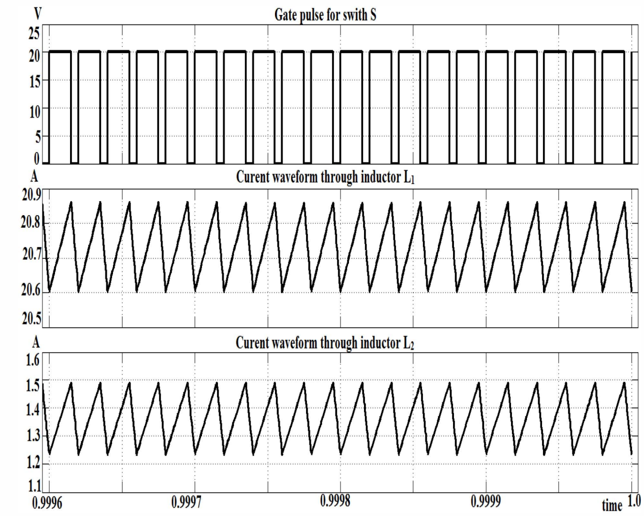


Fig.10 Inductors current waveform with gate pulse

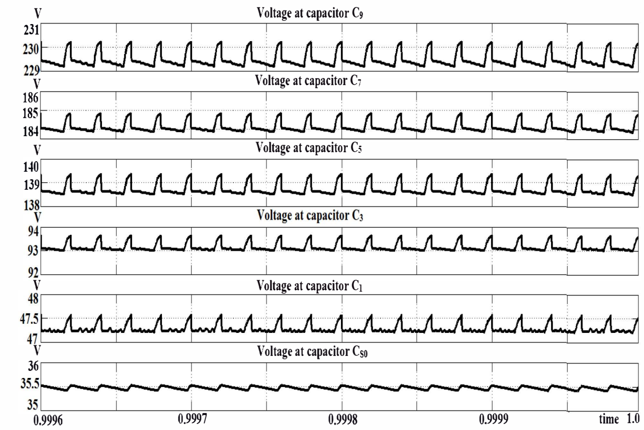


Fig.11 Voltage waveforms at output capacitors node

V. CONCLUSION

The proposed sepic based dual output DC-DC converter is designed for solar application where two output voltages is needed at the same time. The converter was designed to supply 230V at 180W for load1 and 36V at 50W from supply input 12V. The proposed converter is designed by the combination of sepic converter and five level multilevel boost converters. Voltage gain for load1 is depends upon duty cycle and the number of levels present in multiplier and voltage gain for load2 depends upon duty cycle only. The proposed converter simulation results are verified by using MATLAB/SIMULINK. The simulation results show that the proposed converter is suitable for solar application where two output voltages are needed at the same time.

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