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Dual Output DC-DC converter Based on CUK and SEPIC

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Abstract: The proposed model of dual output converter is presented based on CUK and SEPIC converters. The dual output of a single input voltage source is useful in various applications, like DC micro grids, Electrical machines, Solar Energy systems. The proposed converter requires less number of inductor and capacitor as it is compared with the separate converter. The proposed converter is useful regarding the different output polarities. In addition, this converter can be used as multiple voltages power supply. The converters analysis is carried out in continuous current mode. The proposed converter is simulated both in open loop and closed loop using MATLAB/SIMULINK model.

Keywords: Dual output, CUK and SEPIC converter, DC Micro grid.

I. INTRODUCTION

In recent days, use of renewable energy such as photovoltaic, wind energy, ocean wave, and fuel cell are more popular. Applying DC-DC converters in these types of applications necessary. Therefore, presenting new DC-DC converter topologies with some advantages such as high voltage gain and reliability are more important. This converter can be applied in multi-voltage DC grid to feed different applications [1]. Furthermore, multi-level voltage is needed in the electrical machine for battery charging and motor drive. Although this topology uses the transformer, it is non-isolated. Besides output magnitudes are equal, as the result, they are not controllable separately. The voltage gains improved by using the transformer. On the other hand, using transformer leads to the cost and volume increment. In [2] a dual output converter is introduced by combining a SEPIC and a multilevel boost converter with high voltage, but output voltage level is not independent in this converter too. In addition, the number of the element increases proportionally to voltage gain improvement. For example, if the boost converter gain promotes five times it has to use 4 pairs of diodes and capacitors. In [3] a dual output converter is introduced based on the SEPIC and traditional buck-boost converter. A multi-output boost converter with diode clamp topology is presented in [4]. The output voltage is divided between different outputs using diode clamp topology in this converter. Therefore, output voltage depends on the load. This dependence leads to some limitation for obtaining different voltages. In [5] a family of the multi-output DC-DC converter is introduced. Most of the proposed topology of this family use active switches to divide voltage to the different outputs. An innovative topology with stepping up and down ability is presented in [6]. In this topology, the output voltage is promoted by means of clamp diodes. So each of the output voltage levels is less and outputs depend on loads proportion. In [7] a dual input single output is introduced which is extracted from traditional boost and buck-boost converters. This converter has better voltage gain rather than the previously mentioned converters. According to the extension of SEPIC converter, another converter is obtained in [8] that has remarkable voltage gain. In this topology firstly the SEPIC converter gain exchange to the traditional boost converter, then it has multiplied to n factor. To implement this theory in the first case single diode and a capacitor has added to SEPIC circuit then some diodes, capacitors, inductors and switches added to the circuit to multiple the voltage gain. The addition of the number of elements in this converter reduces the reliability of this topology. In addition, this converter has single output although it uses bulk capacitors. In this paper, a dual output converter is introduced using traditional SEPIC and CUK converters. In this topology, there are two diodes and two synchronous switches. As this converter is designated based on the CUK and SEPIC converters, it has both topology advantages such as continuous current.

II. PROPOSED SYSTEM

The conventional topology of CUK and SEPIC converters shown in Fig.1. and Fig.2. An innovative topology is obtained of these two converters shown in Fig.3. This topology can give two voltages with different polarity and

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different level. Also, output voltages are controlled using converter switches. In this topology, Q1 and Q2 switches operate synchronously. According to the circuit structure, diode D1 and D2 operate complementarily.

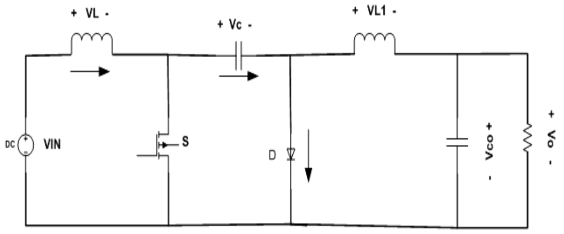

Fig.1.CUK converter

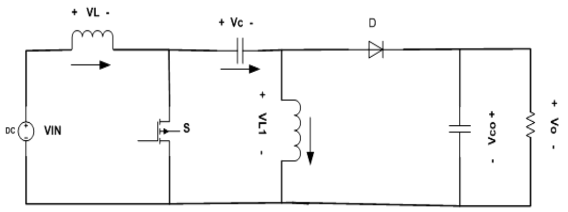

Fig.2. SEPIC converter

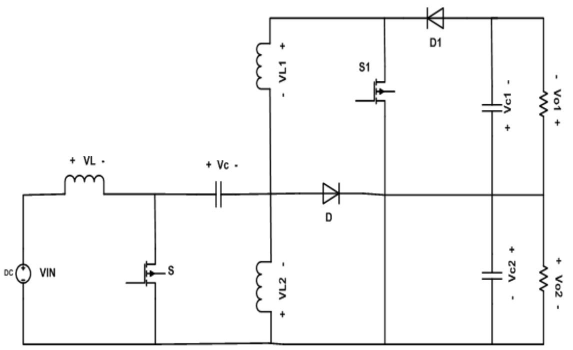

Fig.3.Proposed Dual output SEPIC-CUK converter

A. Operation mode1 (0<t<DT)

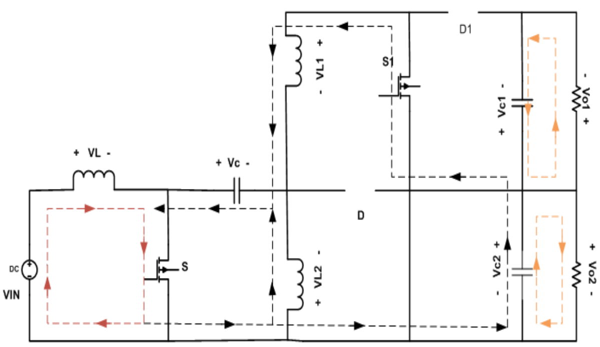

Fig.4.Operating mode when both switches are closed

Durin ON time of gating pulses. Both the switches S and S1 are turned ON. During now, both the diodes are turned OFF due to reverse blocking state. doted lines explain the power path. In this mode L, L1, and L2 charges and capacitors C, C1 and C2 are discharges. The circuit equation are as follows,

$$V_{IN} = V_{IN} \ldots \ldots (1)$$
$$I_C = -I_{L1} - I_{L2} \ldots \ldots (2)$$
$$V_{L1} = V_C + V_{02} \ldots \ldots (3)$$
$$I_{C1} = -\frac{VO1}{R1} \ldots \ldots (4)$$
$$V_{L2} = V_C \ldots \ldots (5)$$
$$I_{C2} = -\frac{VO2}{R2} - I_{L1} \ldots \ldots (6)$$

B. Operation mode2 (when DT<t<T):

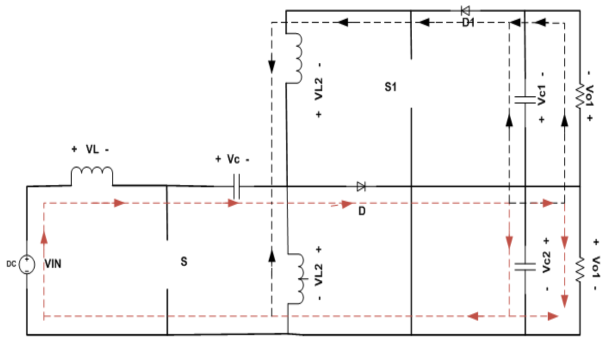

Fig.5. Operating mode when both switches are open

During off period of gate pulse, both the switches S, S1 are turned OFF and Diodes D, D1 are in conducting mode. In this mode inductors L, L1and L2 are discharges and capacitors C, C1 and C2 are in charging mode. The circuit equations are as follows.

$$V_L = V_{IN} - V_C - V_{02} \ldots \ldots (7)$$
$$I_C = -I_L \ldots \ldots (8)$$
$$V_{L1} = V_{01} \ldots \ldots (9)$$
$$I_{C1} = -I_{L1} - \frac{VO1}{R1} \ldots \ldots (10)$$
$$V_{L2} = -V_{02} \ldots \ldots (11)$$
$$I_{C2} = I_L + I_{L2} - \frac{VO2}{R2} \ldots \ldots (12)$$

Steady state analysis is done considering all the components are ideal, continuous inductor current. We know that average voltage of an inductor in a period equals zero and average current of a capacitor over a period is zero. T denotes time period and D denotes duty cycle. Equations under steady state are,

$$V_{IN} - V_C - V_{O2} + DV_C + DV_{O2} = 0 \ldots \ldots (13)$$
$$V_{O1} - DV_{O1} + DV_C + DV_{O2} = 0 \ldots \ldots (14)$$
$$-V_{O2} + DV_C + DV_{O2} = 0 \ldots \ldots (15)$$
$$I_L - DI_{L1} - DI_{L2} - DI_L \ldots \ldots (16)$$

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$$-I_{L1}-\frac{VO1}{R1}+DI_{L1}=0 \quad (17)$$

$$I_{L2}+I_L-\frac{V_{O2}}{R_2}-DI_{L1}-DI_{L2}-DI_L=0 \quad (18)$$

DC equations after simplification are as follows,

$$V_C = V_{IN} \quad (19)$$

$$V_{O1} = -\frac{D*V_{IN}}{(1-D)^2} \quad (20)$$

$$V_{O2} = \frac{D*V_{IN}}{(1-D)} \quad (21)$$

III. SIMULATION RESULTS

The proposed converter is modelled in MATLAB/SIMULINK. The model is simulated with the parameter as shown in Table .1. The SIMULINK model of the converter with open loop is shown in Fig.6

Tabe.1. Designed values

Sl. No.	Element	Values
1	Switching frequency	20KHz
2	Duty cycle D	0.7
3	Supply voltage	30V
4	Inductor L	150uH
5	Inductor L_1	1mH
6	Inductor L_2	1mH
7	Capacitor C	220uF
8	Capacitor C_1	4700uF
9	Capacitor C_2	4700uF
10	Resistor R_1	230Ω
11	Resistor R_2	70Ω

The converter is modelled in MATLAB/SIMULINK environment. For simulation of proposed converter, the input is taken as 30V. Table shows the designed values of inductor, capacitor and switching frequency. The switch used here is MOS-FET.

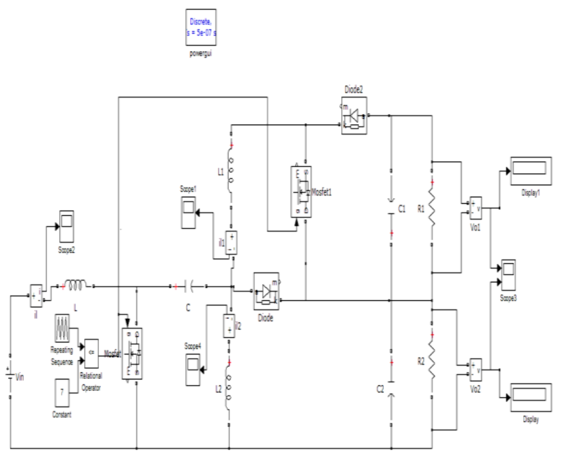

Fig.6. Simulation model of proposed converter without feedback

The switching is done by comparing saw tooth waveforms with a control signal. If the control signal is higher than the repetitive waveform, then signal turns high.

From the simulation result, it can be observed that the CUK converter output is approximately -230V. It can be observed that, from the simulation result SEPIC converter output is approximately 70V.

The Inductor current I_L is equal to the source current, when the switches are closed. From the simulation result, as shown in fig.9,10,11. the inductor current I_L is found to be 10A and inductor currents I_{L1} and I_{L2} are found to be 5.7 and 1.6A respectively.

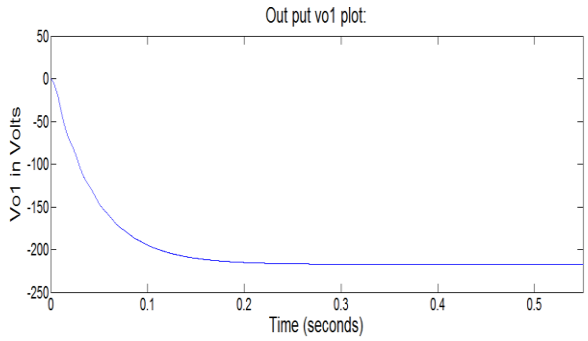

Fig.7. Output voltage V_{o1}

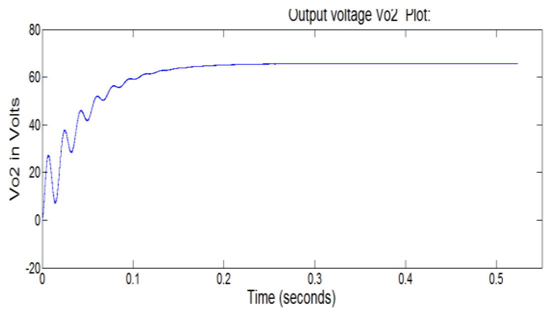

Fig.8. Output voltage V_{o2}

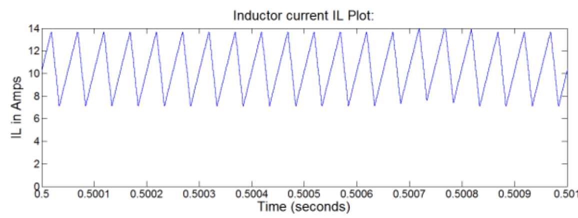

Fig.9. Inductor current I_L

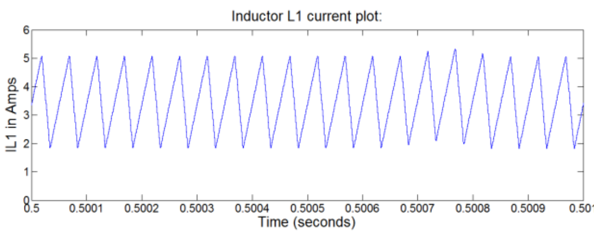

Fig.10. Inductor current I_{L1}

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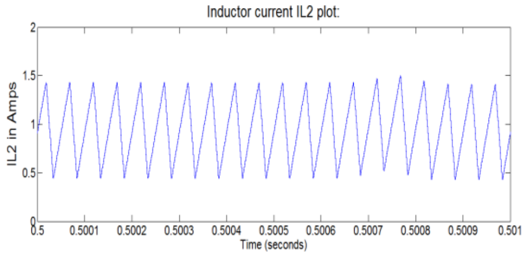

Fig.11. Inductor current I_{L2}

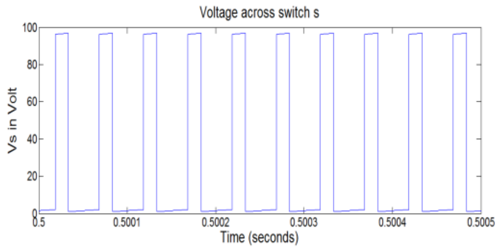

Fig.12. Voltage across switch V_{Sw}

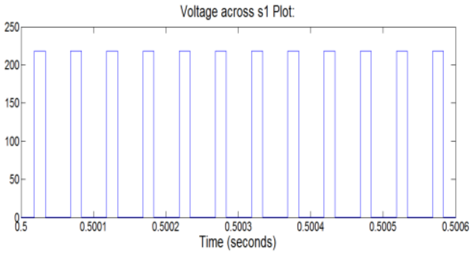

Fig.13. Voltage across switch V_{SW1}

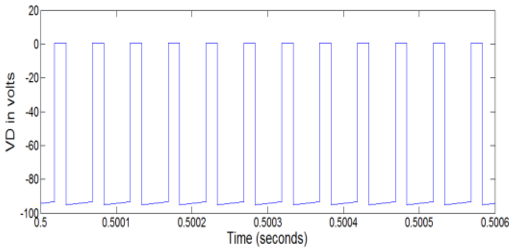

Fig.14. Voltage across Diode V_D

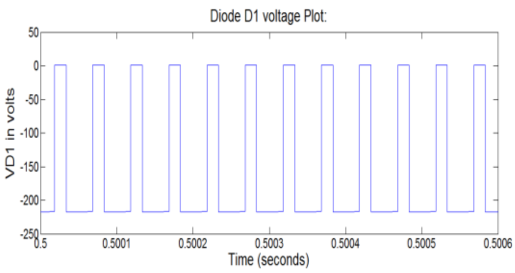

Fig.15. Voltage across Diode V_{D2}

In order to automatically achieve and maintain the desired output condition, closed loop system is designed. The output condition is compared with the actual condition. It is done by generating an error signal which is the difference between the output and reference input. The error signal which is the difference between the input signal and the feedback signal is fed to the controller so as to reduce the system error and bring the output of the system back to the desired value as shown in Table.2. In this design, the controller used is PID controller and it is tuned by trial and error method.

Table.2. Output for various input voltages

V_{IN} in Volts	V_{out}	
	V_{o1} in Volts	V_{o2} in Volts
28	-229	66
29	-228	67
30	-230	68
31	-228.6	68.58
32	-229.4	69.6

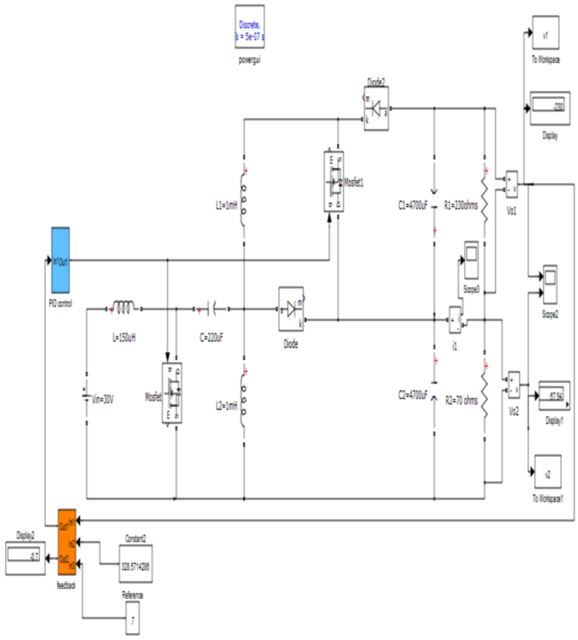
Fig.16. Simulation model of proposed converter with feedback

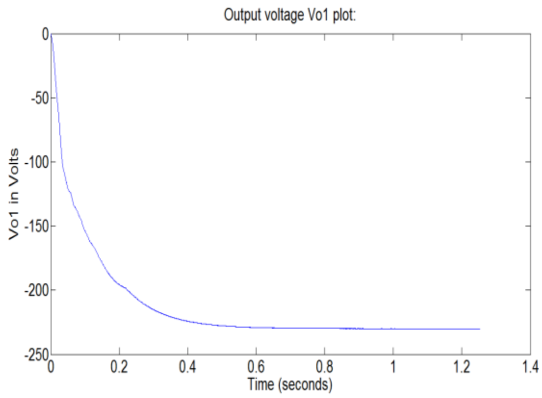

Fig.17. Output voltage with feedback V_{o1} for V_{IN}=30V

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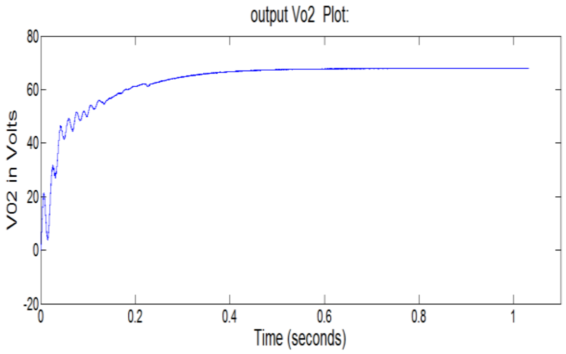

Fig.18.Output voltage with feedback V_{o2} for V_{IN}=30V

IV. CONCLUSION

A Dual output converter has introduced by combining conventional CUK and SEPIC converter. Steady state analysis of the proposed converter is carried out completely. Open loop and closed loop simulation are done using MATLAB/SIMULINK tool. From the simulation, it is verified that the both the output remains approximately constant even for ±10% variation in input voltage.

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BIOGRAPHIES

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