DESIGN AND DEVELOPMENT OF DUAL INPUT CUK-ZETA CONVERTER

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ABSTRACT: The history of Dual input DC-DC converter for DC distribution system has the combination of various converters which are the demand for wide range of power supplies. This paper aims at the design and development of dual input Cuk-Zeta converter for the hybrid power systems. The hybrid power systems can transfer energy to the load individually or simultaneously from several renewable energy sources. The uses of DI-DC-DC Converters have the several advantages over the number of single input converters such as reducing the system complexity and cost effectiveness. For different input voltage sources, maintaining the output voltage constant by varying duty ratios of two switches and also with variation of load. The proposed converter is also designed with PID feedback controller to control the gating signal of switches such that maintaining the output voltage constant in variation of input voltage sources. The proposed converter is designed for maintaining the output voltage constant at 24V with high frequency of 10kH. It is simulated in MatLab/Simulink. Efficiency is maintained in the range of 70%-85% with constant output voltage of 24V, ripple voltage of 0.02V and ripple current of 0.0034A.

KEYWORDS: DI-CUK-ZETA converter, PID controller, DC distribution system, Renewable energy sources, Matlab/Simulink.

INTRODUCTION

DC distribution systems are applied in communications power architectures, data centers, and microgrids as they are efficient with renewable sources. The renewable energy sources such as Photovoltaic (PV) energy, hydro-energy, wind energy and batteries maintain continuous transfer energy to the load individually or simultaneously. Conventionally a hybrid power system involves the number of renewable energy sources connected to a common load through a number of single-input converters [1]. The uses of Multiple-Input converters in place of several single input converters have the advantages of reducing the system complexity, passive elements and cost effectiveness over the increase of attention [2].
A systematic approach for synthesizing different Dual Input Converter (DIC) topologies is basically derived from the six basic non-isolated converters such as buck, boost, buck–boost, Cuk, Zeta, and SEPIC converters. Two basic building cells such as pulsating voltage source cell (PVSC) and pulsating current source cells (PCSC) are used for synthesizing the DICs [2]. This paper aims at the design and development of DI-CUK-ZETA converter that provides better efficiency and low ripple content of output voltage and current suitable for dc distribution systems. In the proposed converter, the input dc voltage sources can be either buck or boost and can also transfer energy to the load individually or simultaneously. The combination of proposed converter results an output voltage of positive polarity. The proposed topology is analyzed under steady state operating condition considering the switches to be ideal and its performance parameters are studied under open loop and closed loop scenario with variations in the input voltage. The output voltage is regulated by PWM technique. [3]
PID controller is used as feedback loop for regulating output voltage under variations of source voltage. The controller is tuned by using the Ziegler and Nichols tuning method such that output voltage is maintained constant with improved efficiency and reduced ripple content of output voltage and current.
The block diagram of proposed converter is shown in Fig 1. Two different renewable energy sources such as Source 1 and Source 2 energy sources are fed to the load through the DI-Cuk-Zeta converter. In order to maintain output voltage constant, duty ratios of 2 switches of the converters are varied with variation of input voltage sources and load. The

gating signals of proposed converter are controlled by PID controller which is connected from the load to the switches. With variation of input sources and load, maintaining output voltage constant and improving efficiency.

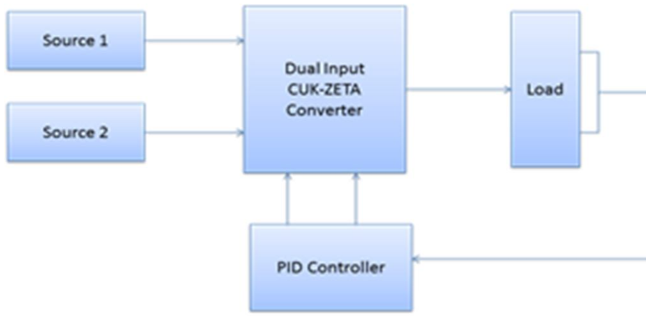

Figure. 1. Block diagram of Dual Input CUK-ZETA converter

ANALYSIS OF DUAL INPUT CUK-ZETA CONVERTER

The circuit diagram of proposed converter is shown in Fig 2. By varying input voltage sources, the output voltage is maintained constant with variation of duty ratios of two switches.

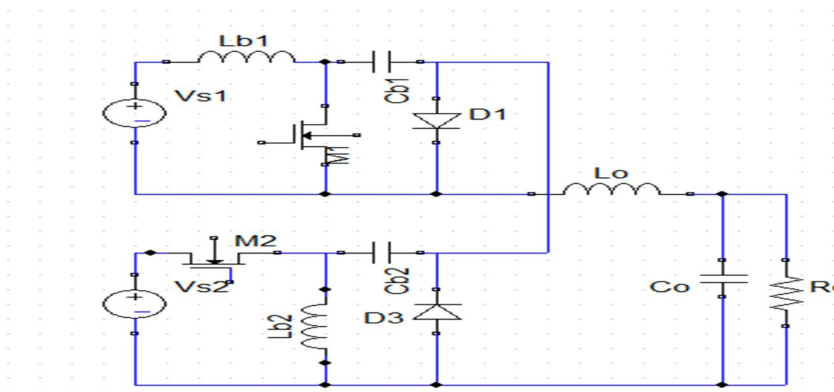

Figure. 2. Circuit diagram of DI-CUK-ZETA converter

MODES OF OPERATION

Mode1: When S1-On and S2-On

Mode2: When S1-On and S2-Off

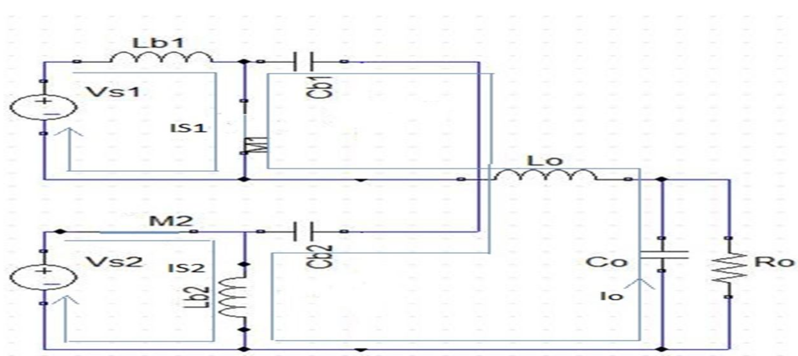

Figure. 3. Circuit diagram in Mode1

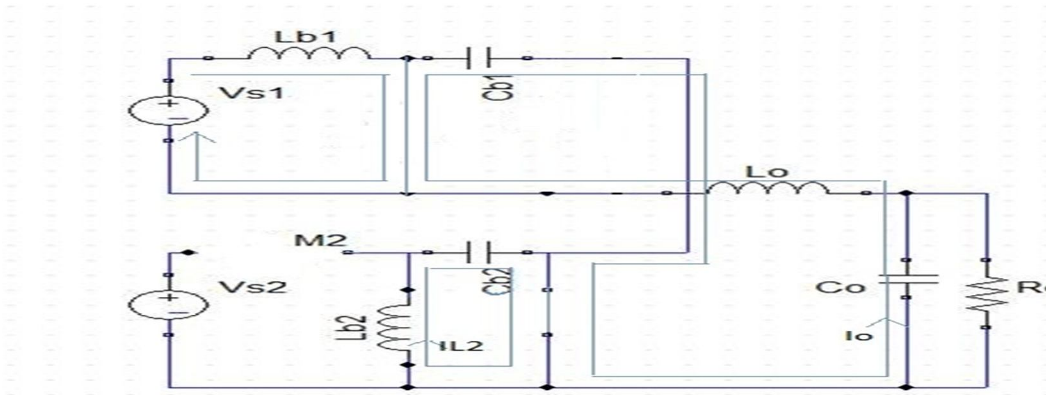

Figure. 4. Circuit diagram in Mode2

Mode3: When S1-Off and S2-Off

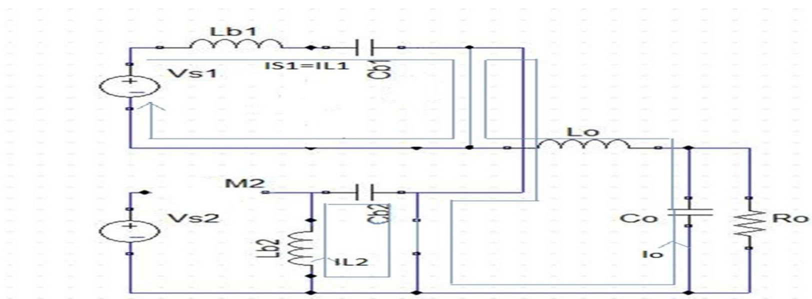

Figure. 5. Circuit diagram in Mode3

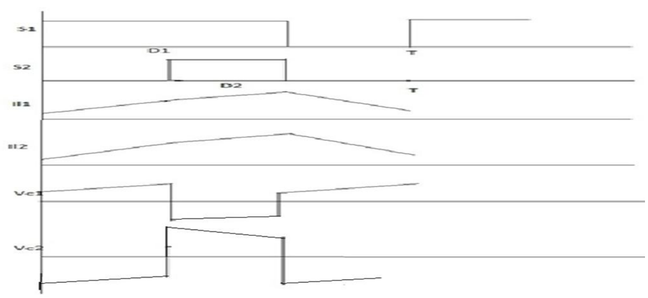

Figure. 6. Waveform of proposed converter

The DI-Cuk-Zeta converter is analyzed in different modes of operation as shown in Fig 3 to Fig 5. Fig 6 shows the waveforms of the DI-Cuk-Zeta converter. S1 conducts for D1T (secs) and after some delay S2 conducts for D2T (secs). Current across inductor L1(Il1) and L2(Il2) flowing from minimum to maximum as shown in the waveform and also show the waveform of voltage across the capacitor C1(Vc1) and C2(Vc2) [4].
From the circuit diagram of DI-CUK-ZETA converter in Fig 2 that operates in different modes. The output voltage is calculated as in equation (1) and designing the inductor value of L1 and L2 in equation (2) and (3) respectively and capacitor value of C1 and C2 in equation (4) and (5) respectively [4].

$$Vo = \frac{V1(D1)(1-D2)+V2(D2)(1-D1)}{(1-D1)(1-D2)} \quad (1)$$

$$L1 = \frac{V1*D1}{\Delta Il1*f} \quad (2)$$

$$L2 = \frac{V2*D2}{\Delta Il2*f} \quad (3)$$

$$C1 = \frac{Vo*D1}{R*\Delta Vc1*f} \quad (4)$$

$$C2 = \frac{Vo*D2}{R*\Delta Vc2*f} \quad (5)$$

Specifications and design

The proposed topology is designed for the following specifications.
Two input voltage sources:
Source 1:
Power rating 100W
Voltage range 20-30V
Source 2:
Power rating 100W
Voltage range 15-24V
Vo= 24V; Io= 4A; Po= 100W
Efficiency 70%-85%
Ripple voltage 0.02V
Ripple current 0.0034A
As per the design equations shown in equation (1) to equation (5) the computed values are
D1= 40%
D2= 20%
L1= 4.494mH
L2= 4mH
C1= 64uF
C2= 320uF

SIMULATION AND RESULTS

The proposed DI-CUK-ZETA converter is simulated in MatLab/Simulink with the designed values of L and C components. As per the specification, the output voltage is maintained for 24V at the frequency of 10kH.

Simulation Of DI-Cuk-Zeta Converter Under Open Loop

The proposed converter is simulated in Matlab/simulink as per the specification under open loop as shown in fig 4. The output voltage is maintained constant at 24V with combinations of different input voltages by varying duty ratio of two switches generated by pulse generator. The resultant waveform of output voltage and output current under open loop is as shown in fig 5 and 6 respectively. The Efficiency, ripple content of output voltage, output current, inductor current and capacitor voltage are tabulated in table 2.

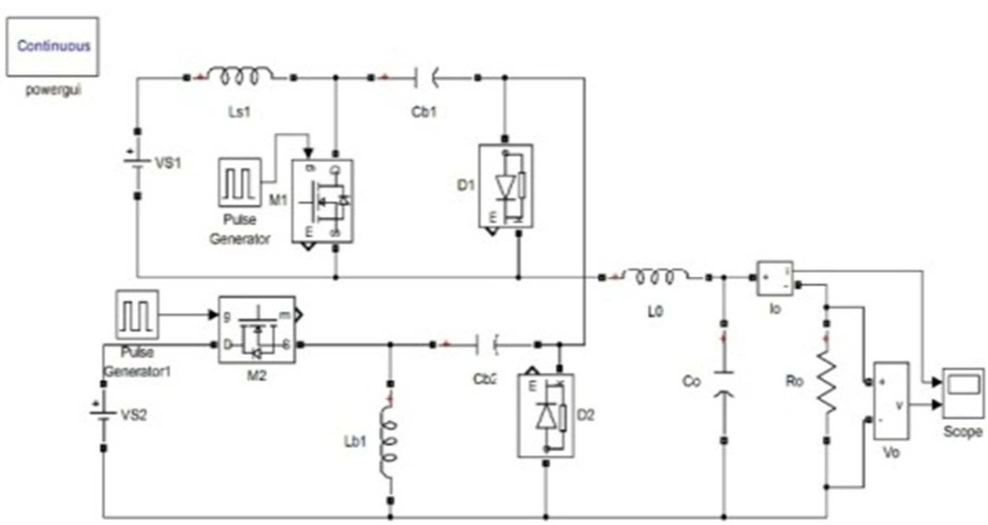

Figure. 4. Simulation Circuit

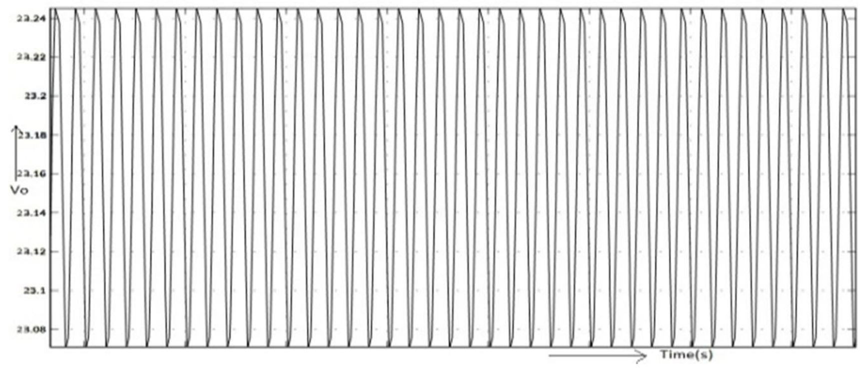

Figure. 5. Simulation Waveform of Output voltage

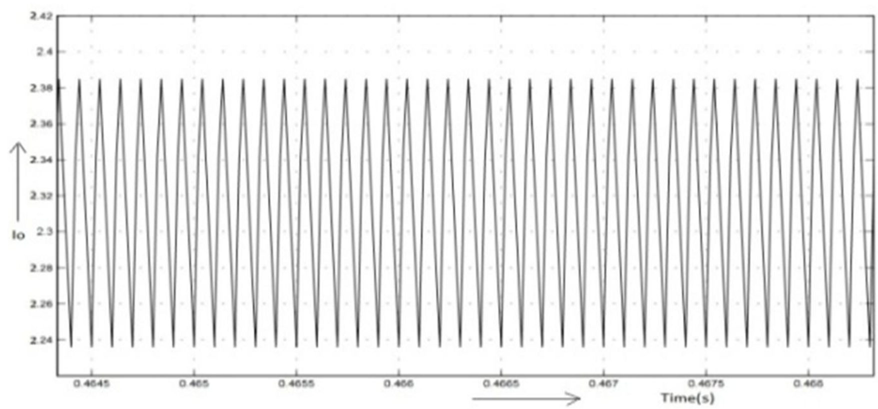

Figure. 6. Simulation Waveform of Output current

Table. 1. Different values of Dula input CUk-Zeta converter under open loop

V1	V2	D1	D2	V_O	ΔV_O	I_O	ΔI_O	ΔI_{L1}	ΔI_{L2}	ΔV_{C1}	ΔV_{C2}	EFF
30	20	40	20	23.1	0.5	3.84	0.09	0.5	0.39	2.5	0.25	72.5
20	15	49	29	23.1	0.5	3.84	0.08	0.41	0.42	2.9	0.34	74
23	17	46	25	23.1	0.5	3.85	0.08	0.46	0.43	2.7	0.29	73.4
25	18	44	24	23.1	0.5	3.85	0.09	0.41	0.43	2.5	0.29	73.1
28	24	41	19	23.1	0.5	3.86	0.09	0.53	0.48	2.5	0.22	70.1

Simulation Of DI-Cuk-Zeta Converter Under Closed Loop

The proposed converter is simulated in Matlab/simulink as per the specification under closed loop as shown in fig 7. The output voltage is maintained constant at 24V with combinations of different input voltages by proper tuning of PID controller using Zeigler and Nichols tuning method. Simulation of PID controller is shown in fig 8. The resultant waveform of output voltage and output current under closed loop is shown in fig 9 and 10 respectively. The Efficiency, ripple content of output voltage, output current, inductor current and capacitor voltage are tabulated in table 3.

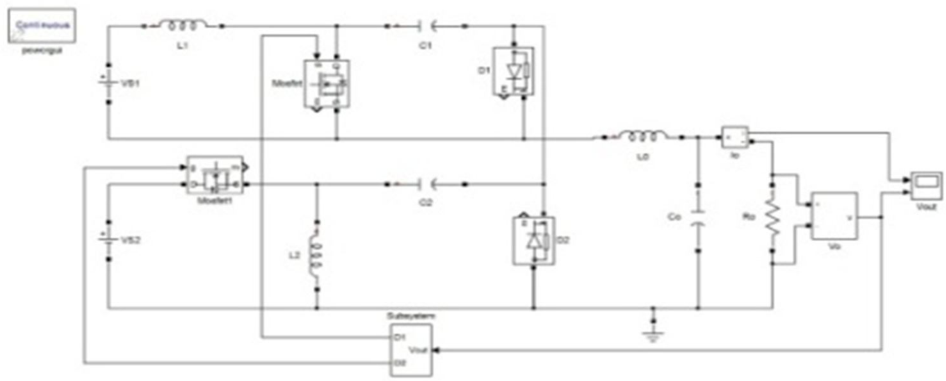

Figure. 7. Simulation Circuit in closed loop

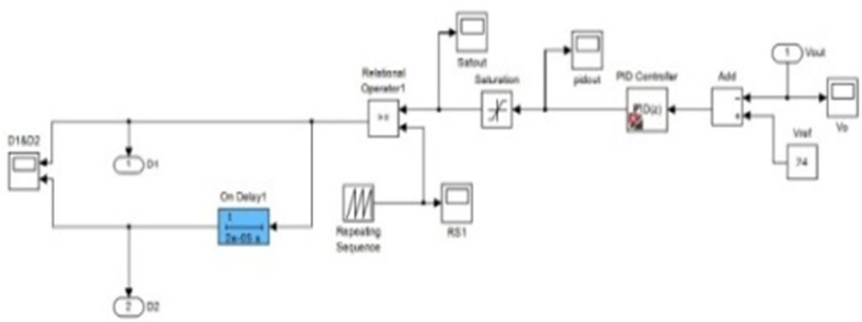

Figure. 8. Simulation of PID controller

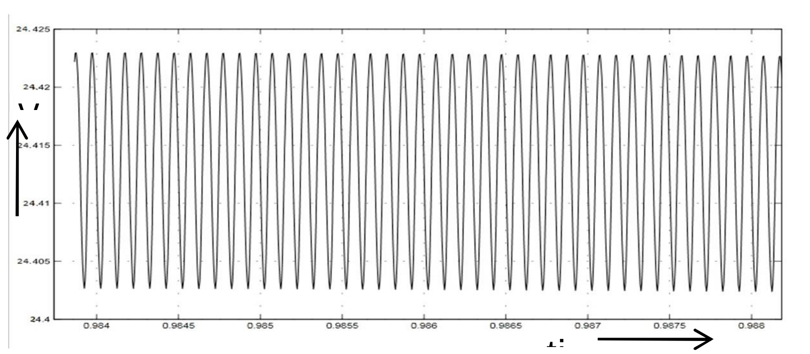

Figure. 9. Waveform of Output voltage

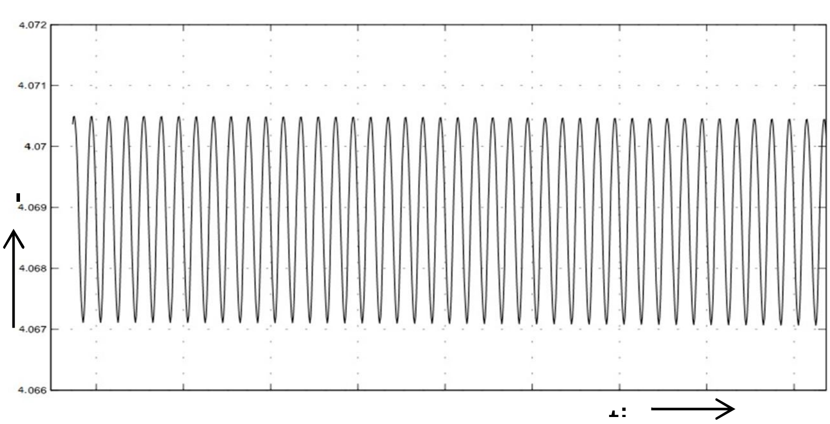

Figure. 10. Waveform of Output current

Table. 2. Different values of Dula input CUk-Zeta converter under closed loop

V1	V2	Vo	ΔVo	Io	ΔIo	ΔIL1	ΔIL2	ΔVc1	ΔVc2	Eff
30	20	24.42	0.02	4.071	0.0034	0.25	0.12	2.6	0.34	71.9
28	18	24.19	0.02	4.032	0.0034	0.26	0.10	2.5	0.32	73.2
26	16	24.13	0.02	4.022	0.0033	0.28	0.1	2.5	0.25	74.7
24	22	24.49	0.02	4.082	0.0033	0.22	0.14	2.4	0.36	70.5
22	15	24.12	0.02	4.0197	0.0028	0.23	0.1	2.6	0.33	74.4

CONCLUSION

The Dual input CUK-ZETA converter is designed for DC distribution systems to transfer energy to the load individually or simultaneously. The proposed topology is analyzed and designed under open loop and closed loop as per the specification. From the result, the range of input voltage from 30V to 22V of source 1 and from 20V to 15V of source 2 is varied and the output voltage is maintained almost constant at 24V. From the table, the efficiency is in the range of 70%-75%, ripple voltage is 0.02V and ripple current is 0.0034A.

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