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Multi Input and Multi Output Zeta Converter for Hybrid Renewable Energy Storage systems

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Abstract: In this paper, multi input multi output (MIMO) Zeta converter is proposed for hybrid renewable energy applications. The Traditional MIMO is modified with Zeta converter for its Continuous output current, high voltage Gain, Buck boost capability & performing higher switching frequencies. Here there are five ports among them three input ports and two output ports. The Inputs are PV, Battery & Super capacitor. The converter is controlled by sliding mode controller (SCM) and it has fast system response and it controls peak overshoot. This converter boosts the PV panel, battery and fuel dc voltage to regulated output dc voltage without any losses. This topology provides a positive output voltage. Modes of operation for multi port zeta converter are explained. To test the effectiveness of the proposed topology, simulation model is developed using MTALB and suitability of the proposed model is tested using experimentation.

Keywords: Zeta Converter, Sliding Mode Control, Multi-Input port and Multi-output port, boost conversion.

I. INTRODUCTION

Nowadays, Global warming is the major Problem faced by the society. In order to cope up with the challenges Renewable energy resources play a key role for the substitute for fossil fuels [1-4]. To obtain a highly reliable renewable energy system, hybrid systems plays important role in composing different renewable energy resources with different input different characteristics to provide intended output. Multiport converters play a key role in composing different input to give the desired output. These converters have low cost, simple structure and fewer components [5]. In [6], working of buck boost converter with multi input configuration is presented, the component count in this converter is less, but the output from this converter is negative. In [9], non-isolated dc-dc step up converter with multi source and single output is analyzed. This topology has properties of the boost and buck and converters.

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This converter required large number of inductors and power semiconductor switches. These will leads to size of this converter are bulky and losses are high. In [10] a multi-output boost converter is analyzed. In this topology, outputs of the boost converters are connected in series. It requires "m+1" switch for "m" outputs. Due to more number of switches, the control becomes complex.

In [11], bidirectional dc-dc converter with single input and multi output configuration is explained. This converter can operate in buck or boost mode. But size of the converter is bulky and it needs complex control techniques. In [12], single stage dc-dc converter with multi input multi output configuration is analyzed. It requires "a+b" power switches for "a" number of input and "b" number of output. This control scheme is very complex. In [13], matrix converter based dc –dc buck boost converter with multi input multi output configuration is presented. Due to increases in number of input sources, this will leads to increases in component i.e., it requires more number of inductor and power switches. It needs "b2" power switches, b number of inductor and dc voltage sources for "a" input and "b" output. Due to more components, topology was more complex. There is also a difference in polarity of the voltage.

The block diagram of Traditional hybrid energy system is given below

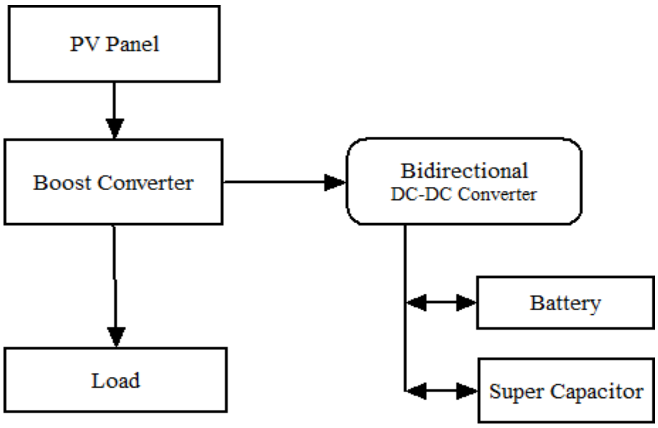

Fig.1. Traditional Energy storage system

The novel topology on multi input multi output system is developed to overcome the problems listed in the above literature and it is shown in the Fig.3. This topology is further modified with zeta converter for its high voltage gain & continuous output current. The block diagram is given below

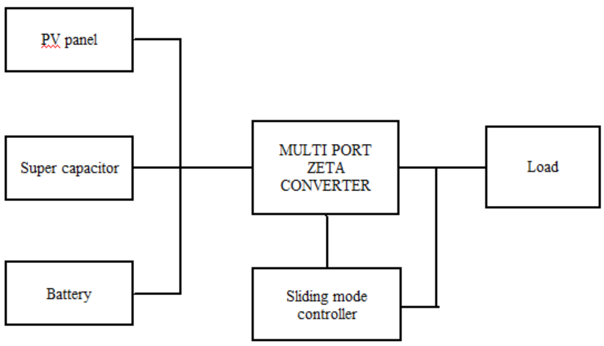

Fig.2. Block Diagram of closed loop control of MIMO zeta dc-dc converter

In this work, a MIMO zeta converter is designed. The different modes of and its working of converter is elaborated with MATLAB simulation and experimental verification. Figure 3 shown the topology of the MIMO zeta dc-dc converter.

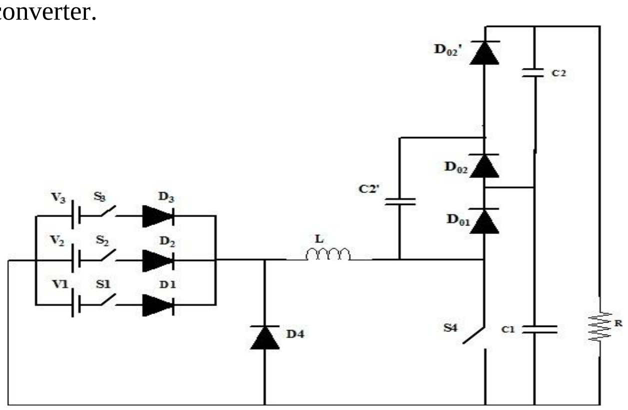

Fig.3. Structure of MIMO Converter

II. MIMO ZETA CONVERTER

This section explains the modes and working of the multi input (three input) multi output (two outputs) zeta dc-dc converter is proposed and it is shown in figure 4. The ripples in the output voltage can be reduced by choosing the suitable inductor and capacitor values. The structure in Fig.3 is modified by replacing the boost converter with zeta converter. The modified structure is given in Fig.4

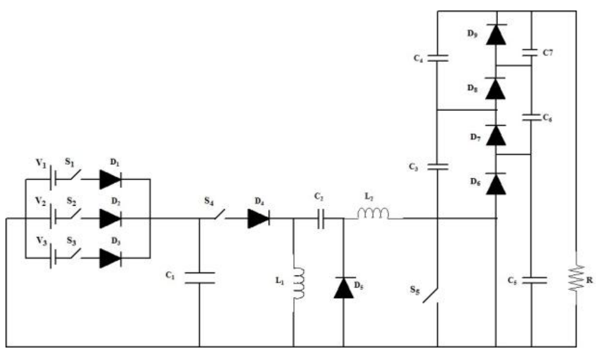

Fig.4. Modified MIMO Zeta Converter

Figure 4 shows the circuit diagram of three input and two output zeta converter. In this circuit, "Vo" denotes the output voltage of the converter and R is known as load resistance. In this circuit "V1","V2" & "V3" known as input voltage of the circuit. Figure 5 shows the switching pattern for S1, S2 and S3 and corresponding duty cycle is denote by D1, D2 and D3 The switches are operated with different duty cycles according with output voltage level.

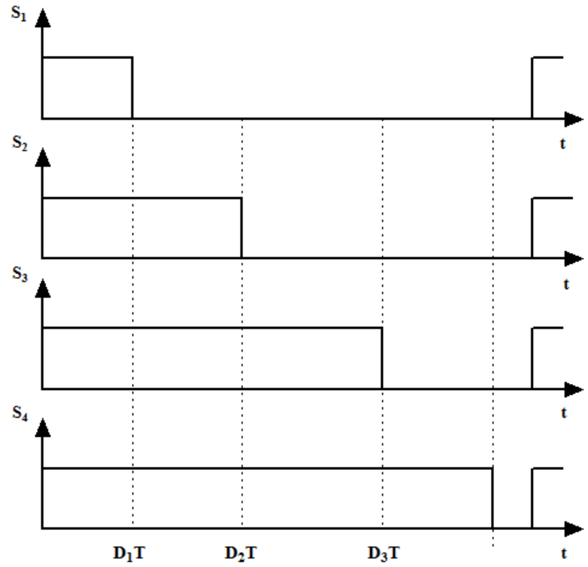

Fig.5. Switching order of the proposed converter

First operating mode ($0 \le t \le D_1 t$)

During the First operating mode in time interval ($0 \le t \le$ D1t) when switch S5 is on and considering V1>V2>V3 The Source V1 supplies the energy through S1 and Diode D1 , There is positive voltage across the inductance and due this inductor current rises linearly from the initial value Ii. the input voltage is greater than inductor voltage during this mode (V1≥0). The current through the inductor is represented by the following equation,

$$i_L = I_i + \frac{1}{L}\int_0^t V_L \quad (1)$$

Where VL=VL1 + VL2, The above equation is rewritten as

$$i_L = I_i + \frac{V1}{L} t \quad (2)$$

Where $\mathbf{i_L = I_i}$, $\mathbf{V_L = V_{L1} + V_{L2}}$

Second operating mode ($D_1 t \le t \le D_2 t$)

During the Second operating mode in the time interval (D1t $\le$ t $\le$ D2t) when switch S5 is on and considering V2>V3. The Source V2 supplies the energy through S2 and Diode D2 There is positive voltage across the inductor and due to this current rises in the inductor from the initial value Ii1 , the current through the inductor is expressed as,

$$i_L = I_{i1} + \frac{1}{L}\int_{D1t}^{t} V_L \, dt \quad (3)$$

Where $V_L = V_{L1} + V_{L2}$, The above equation is rewritten as

$$i_L = I_{i1} + \frac{V2}{L}(t - D_1 t) \quad (4)$$

Third operating mode ($D_2 t \le t \le D_3 t$)

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During the Third operating mode in the time interval ($D2t \leq t \leq D3t$) when switch S5 is on and considering V2>V3. The Source V3 supplies the energy through S3 and Diode D3 There is positive voltage across the inductor. The current through the inductor rises linearly from the value Ii2 , the inductor current is given by

$$i_L = I_{i2} + \frac{1}{L}\int_{D2t}^{t} V_L \, dt \quad (5)$$

Where $V_L = V_{L1} + V_{L2}$, The above equation is rewritten as

$$i_L = I_{i2} + \frac{V3}{L}(t - D_2 t) \quad (6)$$

III. SIMULATION RESULTS OF MIMO ZETA CONVERTER

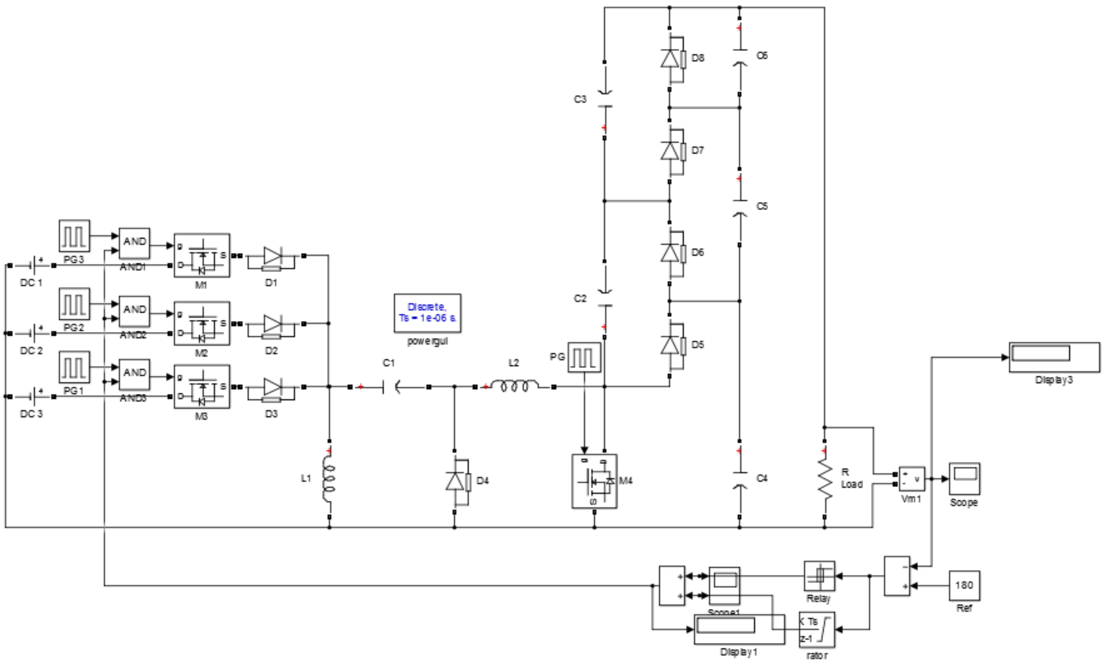

Fig.6. Simulation Circuit of the closed loop control of MIMO zeta dc-dc converter

The MATLAB software used to simulate the Three Input - two output zeta converter and the simulation results are obtained. Sliding mode controller is implemented for getting desired reference voltage settings [14-28]. Modified MIMO zeta converter parameters are shown in Table I.

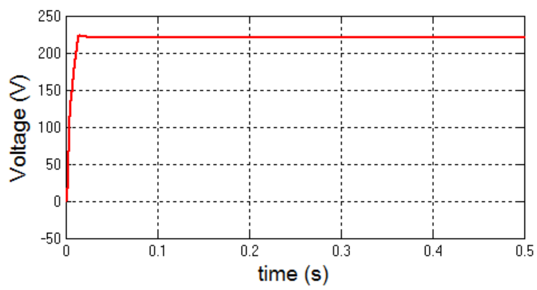

Fig.7. Zeta output voltage

Table-I: Parameters of the proposed Converter

Specifications	Value
First Supply Voltage (V1)	60 V
Second Supply Voltage (V2)	40 V
Third Supply Voltage (V3)	20 V
Inductor (L1)	400 mH
Inductor (L2)	400 mH
Capacitors	2μF
Duty Cycle of Switch (S1)	0.9
Duty Cycle of Switch (S2)	0.6
Duty Cycle of Switch (S3)	0.3
Load Resistor	1000Ω
Switching Frequency	200 KHz

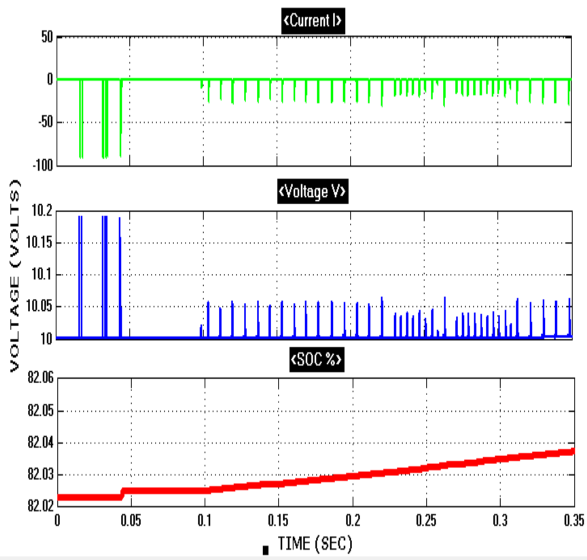

Fig.8. Discharging and Charging characteristics of Battery

The Output voltage obtained by this three input two output zeta converter is 220 V. sliding mode controlled modified MIMO zeta converter is operated in closed loop manner. This control gives the continues output with hybrid input supply system i.e., due to solar PV, battery and super capacitor with different modes of operation and this converter gives continues output from the system.

The Voltage, Current and SOC of battery Charging and discharging is given in Figure 8. The Voltage , Current and SOC of Super capacitor Charging and discharging is given Figure 9.

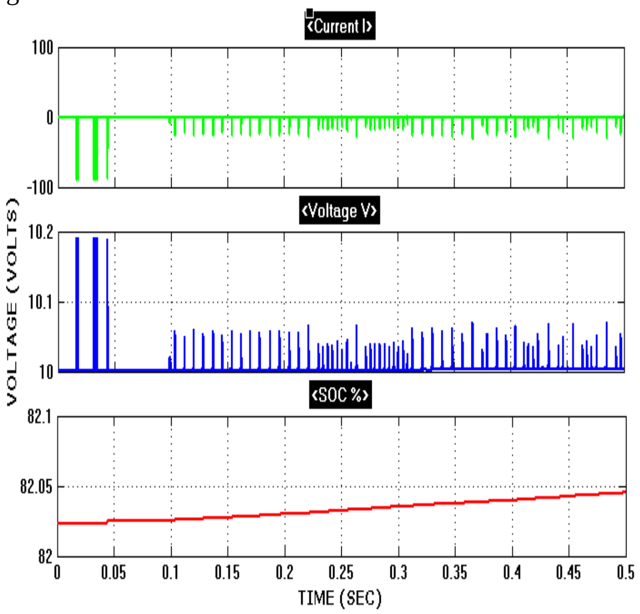

Fig. 9. Discharging and charging characteristics of Super Capacitor

Table-II: Comparison of MIMO with Zeta Converter

MIMO CONVERTER	ZETA CONVERTER
Multi input multi output DC to DC Boost converters are used to get maximum output voltage of 100V	Zeta converter maximum output voltage is 210 V
MIMO Ripple voltage is greater than zeta converter	Ripple voltage is low
Peak voltage is high	Peak voltage low
MIMO converter is using PID controller it is very slowly operation	Zeta converter's using (SMC) controller it is very fast operation.

IV. EXPERIMENTAL RESULTS OF MIMO ZETA CONVERTER

The experimental setup for proposed model is developed and tested for different operating conditions. Figure 10 shows the experimental setup for the proposed system. Input voltage from the different sources is 12 volts and 48 volts is obtained in the output terminal of the converter. Figure 11 shows the output voltage of the converter measured in the digital storage oscilloscope.

Table-III: Parameters of Hardware

s.no	Component	Description	Quantity
1	PV Panel	100 Watts. 12V	1
2	Battery	12 V, 5Ah	1
3	Super capacitor	2.1mF	1
4	Inductance	400 µH	2
5	Micro controller	PIC 16F877A	1

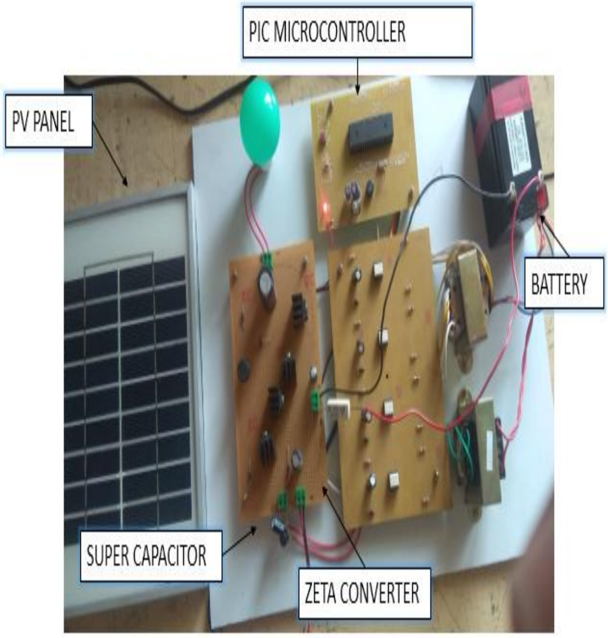

Fig.10. Experimental setup for the proposed system

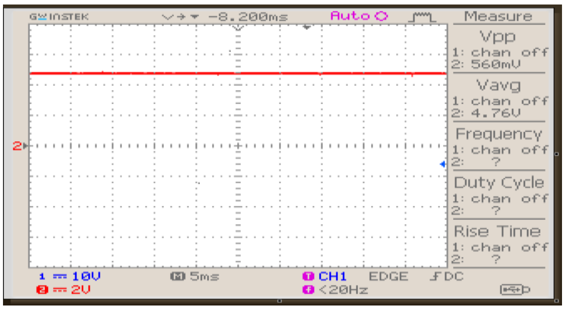

Fig.11. Hardware output of zeta converter

V. CONCLUSION

This paper presented the operation and working of the modified multi input and multi output zeta converter for hybrid renewable application. This converter is operated in high frequencies in order to get high voltage gain in the output of the converter system. The continues current is obtained by this modified MIMO zeta converter structure. The different modes of operation of proposed converter are explained. Simulation results are obtained for the converter by using MATLAB with three different sources such as Solar PV, Super capacitor and Battery. The output voltage obtained can be used for Electric vehicles, DC Charging stations & DC grids. Effectiveness of the proposed model is verified by experimentation and experimental results are presented for checking the suitability of the converter.

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