

A Solar based High Gain Single-Input Dual-Output Boost Converter

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ABSTRACT:In this paper, the proposed SIDO (Single-Input Dual-outputs) DC-DC converter based on coupled inductor. The required controllable high DC voltage and intermediate DC voltage with high voltage gain from low input voltage sources, like renewable energy i.e. PV modules, can be achieved easily from the proposed converter. The high voltage DC bus can be used as the leading power for a DC load and intermediate voltage DC output terminals can charge supplementary power sources like battery modules. This converter operates simply with one power switch. It incorporates the techniques of voltage clamping (VC) and zero current switching (ZCS). The simulation result in PSIM software shows that the aims of high efficiency, high voltage gain, several output voltages with unlike levels, are achieved.

KEYWORDS:Single-Input Dual-Outputs boost converter, coupled inductor, zero current switching (ZCS), voltage clamping, PSIM.

I. INTRODUCTION

Considering the global warming and greenhouse effect because of conventional fuel sources, renewable energy is the solution for saving the environment. The converters with different topologies are used to generate power from renewable energy sources like photovoltaic, wind, fuel cells, etc. Several researchers have work on single-input single-output (SISO) DC-DC converters. Several SISO DC-DC converters with different voltage gains can be combined to obtain the required various output voltages, but it effects in the cost and control scheme of the system. Its control arrangement becomes complicated. This study will motivate to design SIMO converter for improvement of power conversion efficiency, reducing the complexity of the control system and decreasing the manufacturing cost. It also includes the voltage clamping and soft switching techniques to reduce switching losses which help to increase the efficiency.

Patra et al. [2] introduced a Single-Inductor Multiple-Output Switcher with three outputs as a buck, boost, and inverted at the same time. On the other hand, three switches are compulsory for the single output. It results in increases in the switching losses. The design is only appropriate for the low voltage and power application. Due to hard switching, its power conversion ratio is low. Nami et al. [3] suggested DC-DC multi-output boost converter. It can be used for the dissimilar variety of output voltage for low or high applications. Unfortunately, two switches were mandatory for a single output. Its control scheme was complex. Chen et al. [4] had proposed a multiple-output DC-DC converter using shared ZCS lagging leg topology. Though it practices the soft-switching technique to decrease switching losses, the density of electronics component used in circuit increases because of the grouping of three full bridge converters. Therefore, its cost increased and efficiency decreased. Maria et al. [5] summarized new single-input-multiple-output converter topologies.

This paper introduced newly designed coupled inductor based single input multiple outputs DC-DC converter. For high conversion efficiency, high conversion ratio, and different levels of output voltage it utilizes only one power switch. The proportional-integral (PI) control technique is used to monitor the output voltage at high voltage side circuit. This

study is prepared in six sections. After the introduction, Section II explains about photovoltaic cell. Section III explains about the design of SIMO converter. The operating stages of the recommended converter are briefly deliberated in Section IV. Section V delivers the simulations results in PSIM to confirm the usefulness of the suggested converter. Lastly, the paper ends with the conclusions made in Section VI.

II. PHOTOVOLTAIC CELL

A photovoltaic system is made up of several photovoltaic solar cells. An individual small PV cell is capable of generating about 1 or 2 W of power approximately depends of the type of material used. For higher power output, PV cells can be connected together to form higher power modules.

Basically, photovoltaic cells can be represented with a simple electric circuit include a current source, a diode and serial-parallel connected resistances [12]. The equivalent circuit model of the solar cell including current source, diode and resistors is given in Fig. 1. Basically, photovoltaic cells can be represented with a simple electric circuit include a current source, a diode and serial-parallel connected resistances. The equivalent circuit model of the solar cell including current source, diode and resistors is given in Fig. 2

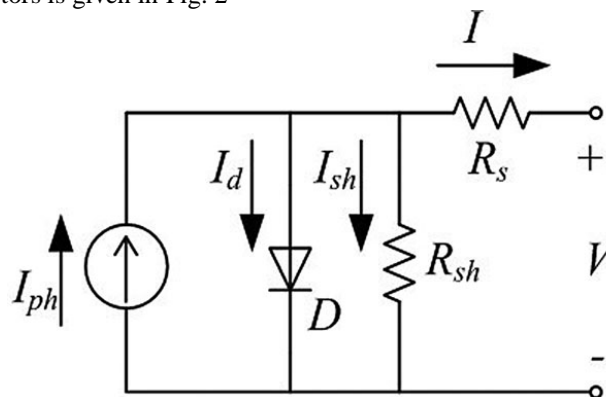


Fig. 1. Equivalent circuit of PV cell [12]

The symbols in Fig. 1 are defined as follows:

I_{ph} : photocurrent;

I_d : current of parallel diode;

I_{sh} : current in shunt resistance;

I : output current = current through series resistance;

V : output voltage;

D : parallel diode;

R_{sh} : shunt resistance;

R_s : series resistance.

The I-V equation [12] of Fig. 2 is given by

$$I = I_{ph} - I_0 \left(e^{\frac{q(V+R_s I)}{AKT}} - 1 \right) - \frac{V + R_s I}{R_{sh}}$$

Where, I_0 is the reverse saturation current of the diode, q is the electron charge (1.602×10^{-19} C), A is the curve fitting factor, K is Boltzmann constant (1.38×10^{-23} J/K).

III. SIDO CONVERTER DESIGN

The suggested converter topology is capable of producing two separate level DC voltages from an only one DC voltage supply source as presented in Fig. 1. The recommended converter configuration is distributed into five sections which include Low Voltage Side Circuit (LVSC), Clamped circuit, Intermediate Voltage Circuit, Auxiliary circuit, High Voltage Side Circuit (HVSC). The primary symbols used in this configuration are precised as follows. V_{in} and I_{in} are the input voltage and input current at the LVSC. V_{O1} and I_{O1} indicate the voltages and currents at auxiliary circuit and V_{O2} (I_{O2}) denote the voltages (currents) for high voltage side. C_{in} is the filtering capacitor at the LVSC. The filtering capacitors on the auxiliary circuit and the HVSC are denoted as C_{O1} , and C_{O2} , respectively. C_1 is the clamped capacitor of the clamped circuit and C_2 is the intermediate voltage capacitor of intermediate voltage circuits. L_1 and L_2 are the separate inductors of primary and secondary side windings of the coupled inductor (CL), respectively. The dots denotes the positive polarity of the coupled inductor. L_{ax} is the inductor in auxiliary circuit. The main power switch symbolized as SW_1 in the LVSC. R_{O1} is the corresponding load in the auxiliary circuit, and the output load is denoted as R_{O2} in the HVSC. The primary and secondary winding currents of CL are represented by i_{L1} and i_{L2} respectively. Current through the auxiliary inductor represented by i_{Lax} . The magnetizing current and leakage current of the primary side of CL denoted as i_{Lm1} and i_{Lk1} .

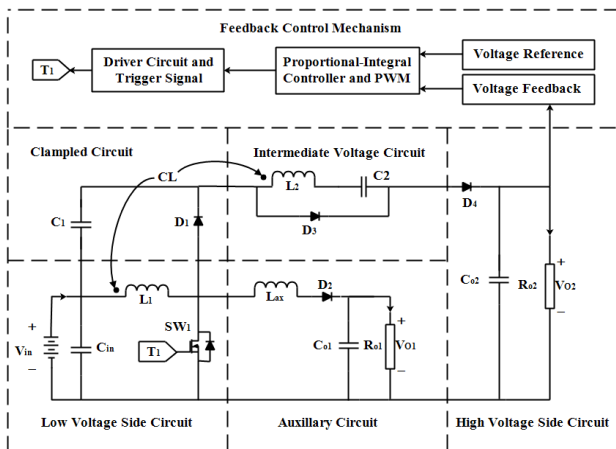


Fig. 2. System configuration of SIMO converter

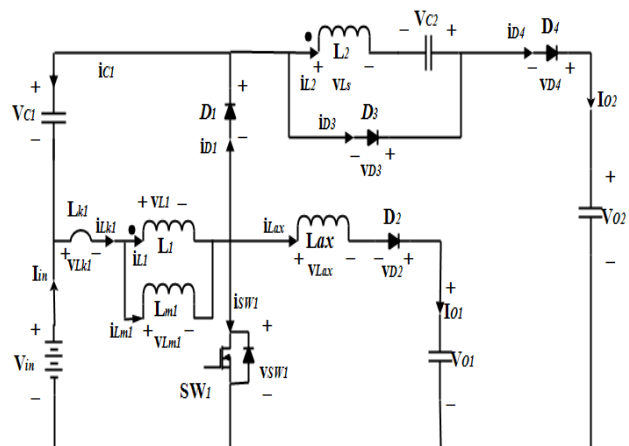


Fig. 3. Equivalent circuit of SIMO converter

Fig. 2 is configured as the equivalent circuit of the proposed system. It shows the appropriate current directions and voltage polarities. The coupled inductor utilized in the converter can be represented as an ideal transformer with a magnetizing inductor as L_{m1} and leakage inductor as L_{k1} , in fig. 2. N and k represent turns ratio and coupling coefficient respectively.

$$N = \frac{N_2}{N_1} \tag{1}$$

$$k = \frac{L_{m1}}{(L_{k1} + L_{m1})} = \frac{L_{m1}}{L_1} \tag{2}$$

Where N_1 and N_2 denote the number of turns of the primary winding and secondary winding of the CL respectively. As the sensitivity of voltage gain is less to the coupling coefficient (k), the k is kept to one in (2) to get $L_{m1}=L_1$. The value of C_1 is carefully chosen in such a manner that it can totally absorb the energy of the leakage inductor [12].

IV. OPERATING STAGES

The six operating stages of proposed converter in single switching cycle are briefly explained as follows.

1. Stage 1 ($t_a - t_b$)

In this stage, main the switch SW1 turned ON for a small fragment of time. D4 gets OFF. Due to the positive polarity of coupled inductor's winding, D3 becomes forward biased. C2 gets charged because i_{L2} flows in the opposite direction. When L_{ax} of the auxiliary circuit entirely discharges its stored energy and D2 becomes reverse biased, this will close stage1.

2. Stage 2 ($t_b - t_c$)

At $t = t_b$, SW1 stays to be in the ON condition. The input power supply charges L1. i_{Lm1} is increasing step by step in an almost linear way. At the same time, v_{L2} charges C2 through D2. Though voltages v_{Lm1} and V_{in} are equal in stage1 and stage2, the ascendant slope of i_{Lk1} , di_{Lk1}/dt at both stage1 and stage2 is dissimilar because of the path of the auxiliary circuit. L_{ax} discharges its stored energy entirely, and D2 goes OFF at the end of stage1, it outcomes at stage2 in the reduction of di_{Lk1}/dt .

3. Stage 3 ($t_c - t_d$)

At $t = t_c$, SW1 is turned OFF. D3 continues to be in conduction because the leakage energy still releasing from the secondary side of CL and releases to C2. When v_{SW1} is greater than V_{C1} , D1 conducts to transfer the energy into C1 through Lk1. At the same time, because of the partial energy of Lk1 is transmitted to L_{ax} , D2 starts conducting. As the i_{Lax} permits through D2, VO1 comes in picture. After totally releasing the leakage energy of secondary side of CL, and D3 goes OFF, this stage ends.

4. Stage 4 ($t_d - t_e$)

At time $t = t_d$, SW1 is insistent in OFF condition. i_{L2} starts flowing in reverse direction because the leakage energy of CL has been entirely discharged from the primary side of Lm1 through the ideal transformer. D4 is in conduction. At the same time, D2 is in conduction because the partial energy of Lk1 continues to transmit to L_{ax} .

5. Stage 5 ($t_e - t_f$)

At time $t = t_e$, SW1 is in OFF condition. At $i_{Lk1} = i_{Lax}$, D1 goes to OFF condition. In this stage, V_{in} , L1, and L_{ax} are connected in series to provide the output voltage at the auxiliary circuit through D2. At the same time, the series connection of V_{in} , L2, C1, and C2 helps to discharge the energy through D4 and shows VO2 at high voltage side.

6. Stage 6 ($t_f - t_g$)

At time $t = t_f$, SW1 is stimulated. D2 is in conduction till the i_{Lax} becomes zero. In this stage, V_{in} , C1, L2, and C2 continue to be in series to discharge the energy through D4. To cut off punctually without a reverse-recovery-current (RRC) D1 should be carefully chosen as a low voltage Schottky diode. Furthermore, Lk1 bounds the increasing rate of i_{Lk1} . As a result, SW1 is got ON under the condition of zero current switching. This soft switching technique is useful in reducing the switching loss. When i_{L2} decays to zero, this stage ends. After that, it starts the following switching cycle and repeats the operation in stage1.

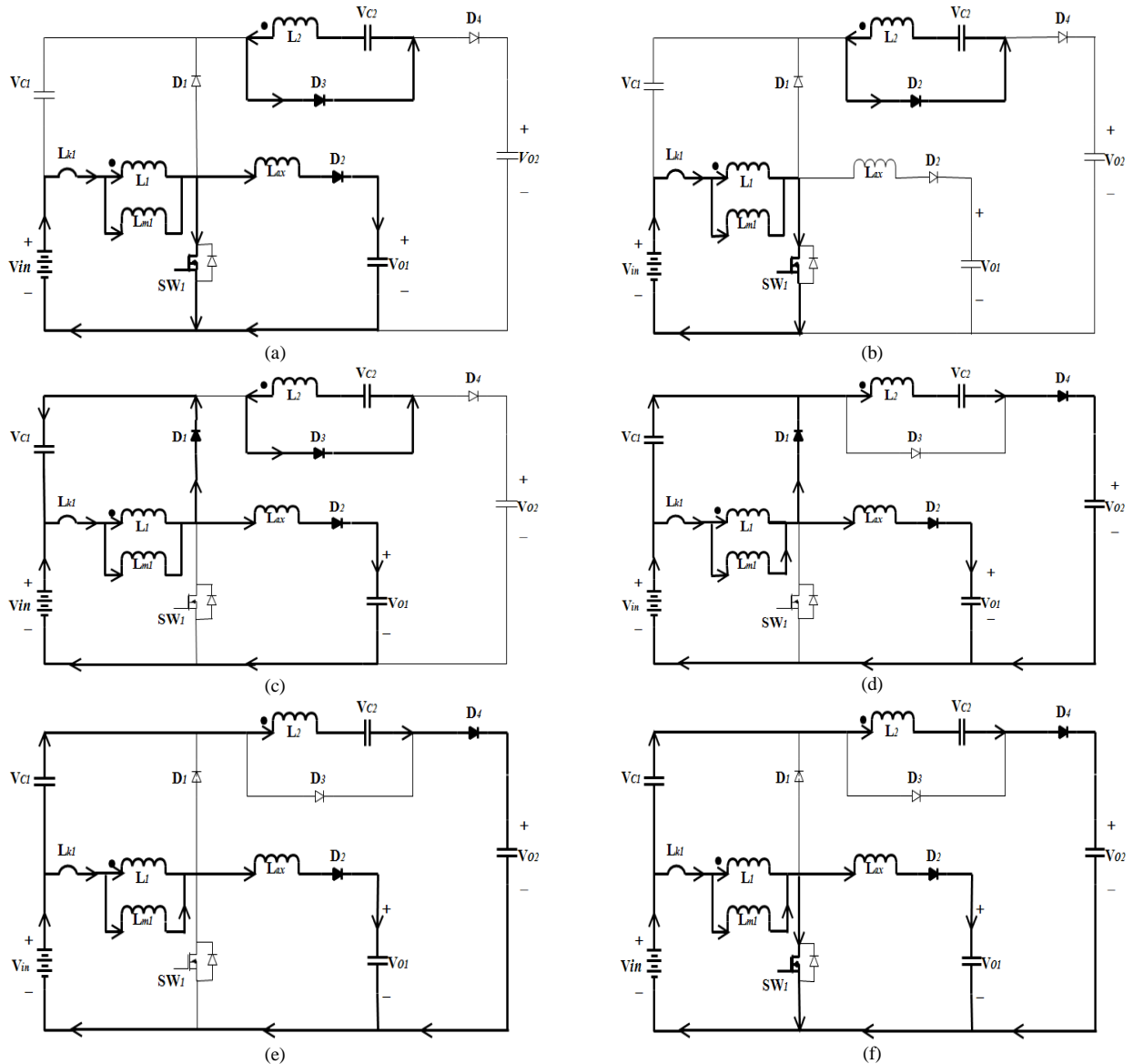


Fig. 4. Operating stages of the proposed converter:- (a) Stage 1 (ta-tb) (b) Stage 2 (tb-tc) (c) Stage 3 (tc-td) (d) Stage 4 (td-te) (e) Stage 5 (te-tf) (f) Stage 6 (tf-tg)

V. SIMULATION RESULTS

Fig. 4 displays the simulation model for the suggested converter. The proposed SIMO converter is simulated in PSIM software with DC battery at LVSC and to get controllable VO2 at 200V, PI controller is used.. A SIMO converter with the following parameters is simulated to confirm the results. Vref is considered as 200V.

TABLE I. SIMULATION PARAMETERS FOR SIMO CONVERTER

Parameters	Symbols	Values
Input voltage (LVSC)	V_{in}	12V
Desired output voltage (HVSC)	V_{O2}	200V
Auxiliary output voltage (Aux. circuit)	V_{O1}	28V
Switching frequency	f_{sw}	100kHz
Couple inductor	L_1	3 μ H
	L_2	75 μ H
Auxiliary inductor	L_{ax}	2 μ H
Clamped Capacitor	C_1	85 μ F
Intermediate voltage capacitor	C_2	10 μ F
Filter capacitors	C_{O1}	100 μ F
	C_{O2}	20 μ F

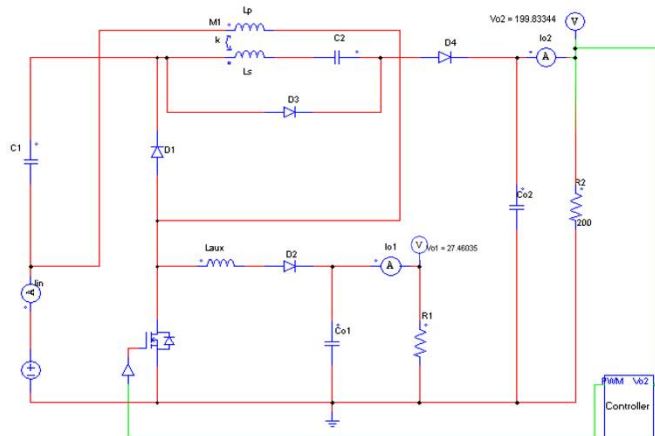
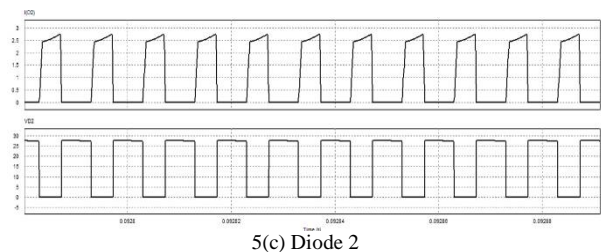
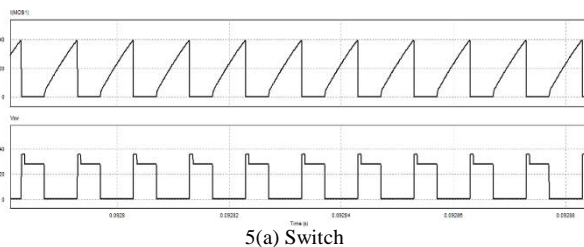


Fig. 5. Simulation model of SIMO converter

The simulation results for 200W output power are shown in fig. 5.



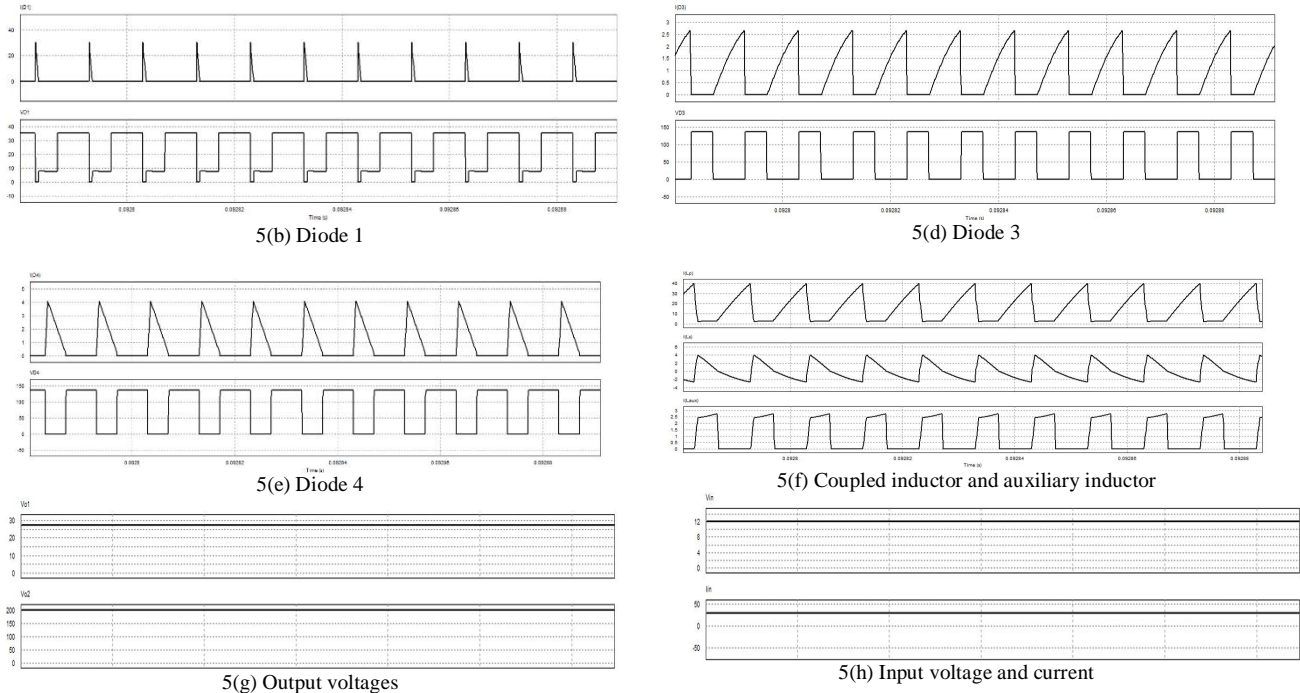


Fig. 6. Outputs for 200W Output Power

VI. CONCLUSION

The proposed Single-Input Dual-Output (SIDO) converter uses only single DC voltage supply to generate two boosted outputs. The coupled inductor helps to achieve a high voltage gain. The simulation results illustrate that the efficiency of the converter is approximately 95%. This type of converter is appropriate for the shared ground application. However, not suitable for the active DC-AC multilevel inverters. This limitation can be taken as upcoming research work. The use of a single switch with zero current switching technique decreases the switching losses that helps to achieve high efficiency objective. The use of coupled inductor helps to manage the essential high voltage gain. The stray energy of the circuit can be reused with help of clamped capacitor.

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