Integrated Dual Output Converter with Low Electric Stress on Components

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ABSTRACT

In recent days there is a vast development in the field of power electronic converters. Necessity of multiple level of voltage demand is raised for single supply system. To meet different level of load demand single input and multiple output topologies (SIMO) are created. There are many such converters fall under SIMO converters. The Integrated Dual Output Converter (IDOC) is one among them. The IDOC is a DC-DC converter that performs boost and buck operations simultaneously with a single input. It is basically evolved from boost converter, replacing a single switch by couple of switches. Both the switches are connected in series not only to perform both buck and boost operation but also to provide continuous input current. Main advantage of IDOC over conventional boost and buck converter is the reduced number of switches. Comparisons among another six buck-boost converters and the proposed IDOC converter are presented. It is found that the proposed converter's voltage gain is smaller than the other converters' in step-down mode. Also, based upon the comparisons among the same kind and same number of components, the voltage and current stresses on the power switch of the proposed IDOC converter are less than or equal to those of the comparative converters, and the voltage stress on the charge pump capacitor and the switching device power rating of the proposed IDOC converter are always lower than those of other comparative converters. These advantages make component selection for the proposed converter much easier, and it can be used for industrial application. In order to check the behavior of the converter simulation is carried out in a MATLAB/SIMULINK. The simulation results validated the operation of the converter.

Keywords: Conventional Boost converter; conventional buck converter; Integrated Dual Output Converter (IDOC); Single Input Multi Output converter (SIMO).

1. INTRODUCTION

Demand of integrated converters is increasing day by day over conventional converters. SIMO topology has found much advantage in terms of reduced number of switches and continuous input current. Practical applications of IDOC are electric vehicles [1], LED (Light Emitting Diode) lamps [2], USB (Universal Serial Bus*)* power manager [3] and small projectors and HID devices [4]. In this topology single switch in the conventional boost converter [5] is replaced by dual switches to obtain dual output. During shoot through, both the switches in the same leg can be turned on simultaneously to obtain the boost voltage. Characteristic response is consistent during inherent shoot through period. Fig.1 shows the block 1diagram of the IDOC [6]-[8] converter.

Input inductor current is always continuous not only for boost operation but also during buck mode. This is major advantage over conventional buck and boost converter. According to switching operations converter can be operated in three different modes. By choosing the ripple content of inductor current and capacitor voltage, the size of the passive components can be optimized to get higher efficiency. In this paper IDOC is designed for same input and output power ratings as well as both the conventional buck and boost topologies. All three topologies are simulated using MATLAB/SIMULINK and the hardware prototype model is developed for all three topologies. Also the performance comparison is made to project the advantages of IDOC converter topology.
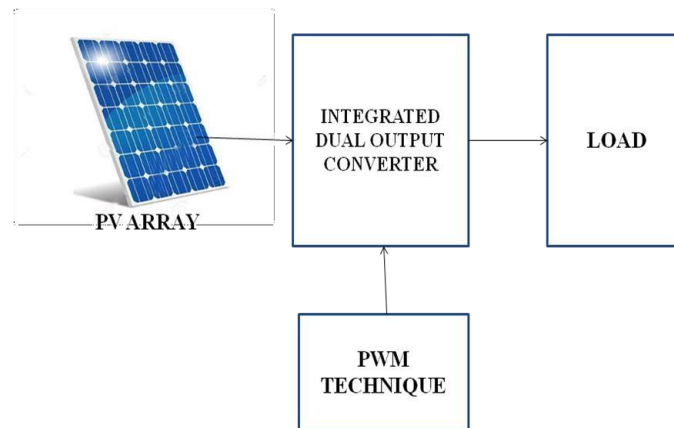
2. BLOCK DIAGRAM

Fig 1. Block Diagram of IDOC

To meet the various level of voltage demand, single input and multiple output topologies (SIMO) are developed. Many such converter topologies are available under this category. Integrated Dual Output Converter (IDOC) is one of the single input multi output topologies. IDOC is a DC-DC power converter which performs both buck and boost operations at the same time with a single power supply. IDOC is derived from the conventional boost converter using couple of power switches. With the shoot through phenomenon both the switches in the IDOC can be connected in series and operated to obtain the boost and buck voltage simultaneously. In this paper, the basic operation of IDOC is presented and compared with conventional buck and boost converter.
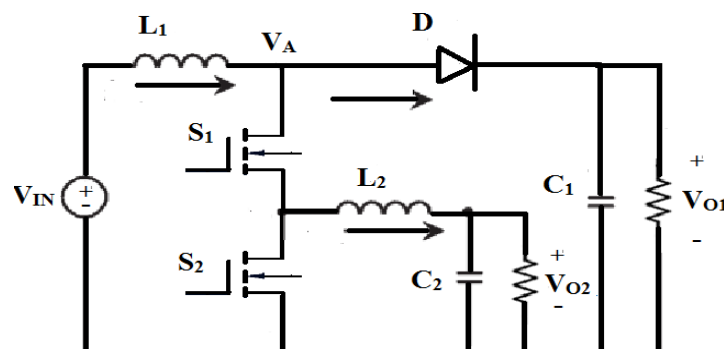
3. CIRCUIT DIAGRAM OF IDOC CONVERTER

Fig 2. IDOC Converter

Fig 2. shows the IDOC power converter topology which includes single DC supply, series connected switches, two inductors and capacitors. To obtain higher output voltages, large capacitors are required to resist the high current which makes the converter more bulky. Also it

can increase the cost of the converter. Dynamic behavior characteristics of IDOC are same as classical buck and boost converters. The converter operation during shoot through is highly reliable, though there are challenges in the power flow of the circuit.

4.PWM CONTROL TECHNIQUE

Pulse width modulation (PWM) has been one of the most conventional modulation techniques for switching dc-dc converters. It compares error signal with sawtooth wave to generate the control pulse. Conventional PWM control technique suffers from slow dynamic response due to smooth error signal variation under step line or load variation. A PWM control (modulation) method for switching dc-dc converters with improved dynamic response in this paper.

4.1 Mode of Operation

The converter can be operated in three different modes. The converter is operated at high switching frequency. Also the inductor is designed to operate in continuous conduction mode.

4.2 Mode 1 Operation of IDOC

During this mode 1operation, both switches S1 and S2 are ON. When the inductor current IL1 is charged up, current through L2 freewheels through switch S2. Diode D is reverse biased. There is no power transferred to the boost load since diode is reverse biased. But there is a current flow through step down load due to L2. Input current remains always continuous for step up and step down loads.
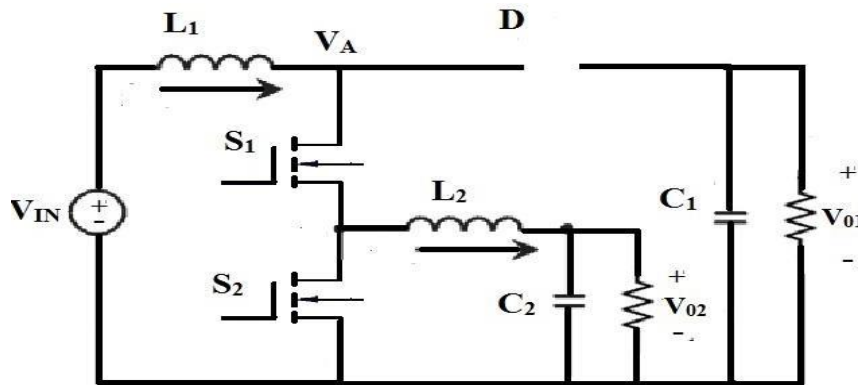

Fig 3. Mode1 Operation of IDOC
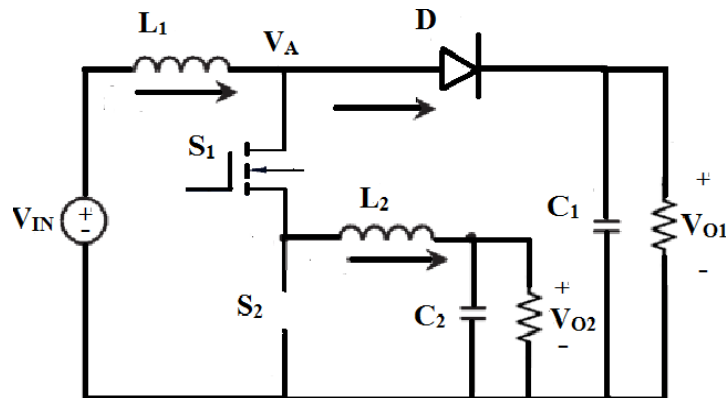
4.3 Mode 2 Operation of IDOC

Fig 4 Mode 2 Operation of IDOC

During mode 2 as shown in Fig.4. S1 is turned on and S2 is turned off. The part of inductor current IL1 flows through diode D and other through buck inductor IL2. At the same time, the buck converter takes energy from the input supply. The total inductor current IL1 is the sum of both the diode current and buck inductor current. Input current gets increased and switch stress is increased due to addition of step down load in the boost converter topology. Thus two switches are connected in series to avoid more stress on the single switch.

4.4 Mode 3 Operation of IDOC

In mode 3, S1 is OFF and S2 is ON, inductor current IL2 freewheels through switch S2. This interval is similar to free wheel period of conventional buck converter. During this mode, inductor L1 and inductor L2 gets discharged.
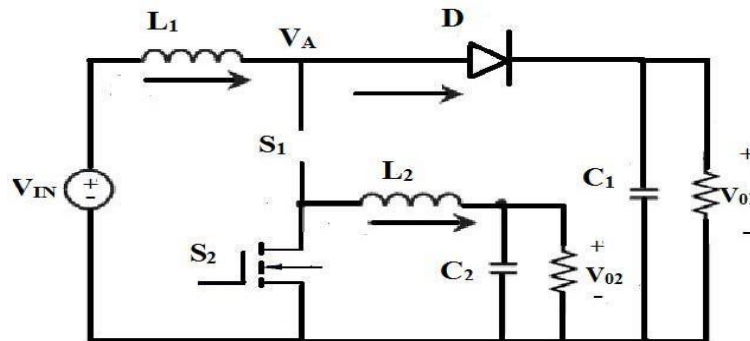

Fig 5 Mode 3 Operation of IDOC

5. VOLTAGE STRESS ANALYSIS ON SEMICONDUCTOR COMPONENTS

The voltage stresses on power switch S and the diodes (D) can also be obtained as follows.

$$V_{01}/V_{in} = 1/(1 - D_1) \tag{1}$$
$$V_{02}/V_{in} = D_2/(1 - D1) \tag{2}$$

Where,

V_{01} = Output voltage of boost Converter V_{02} = Output Voltage of buck Converter
V_{in} = Input Voltage of IDOC Converter
D_1 = Duty cycle of boost Converter D_2 = Duty cycle of buck Converter

Duty cycle of first switch is given by the addition of boost duty cycle (D1) and buck duty cycle(D2). The addition of both duty cycles should be less than one.

Table 1. Design Parameters of IDOC Converter

Parameter	Rating
Input Voltage V_{in}	30 Volts
Buck Output Voltage(V_{buck})	18 Volts
Boost Output Voltage (V_{boost})	55 Volts
Switching Frequency, Fs	100 KHZ
Duty Ratio of Switch S 1	0.7
Duty Ratio of Switch S 2	0.28
Inductor L1	95.7 µH
Inductor L2	45.6 µH
Capacitor C1	9.7µH
Capacitor C2	7.3 µH

6. SIMULATION FOR IDOC CONVERTER

The simulation is carried out in MATLAB/SIMULINK software. The simulation results of IDOC is evaluated and compared with conventional boost and buck converter simultaneously. The input voltage of 30V is provided with high frequency.

Integrated Dual Output Converter (IDOC) is one of the single input multi output topologies. IDOC is a DC-DC power converter which performs both buck and boost operations. simulations are performed using MATLAB SIMULINK platform. simulation results of the IDOC converter are presented in the following.

6.1 Simulation – Boost Converter

MATLAB/SIMULINK is used for simulating the circuit. Simulation results of Integrated Dual Output Converter (IDOC) are analyzed and compared with conventional boost and buck converter. Fig.6.1 shows the simulated results of boost part of IDOC converter and Fig 6. shows the buck part of IDOC converter.
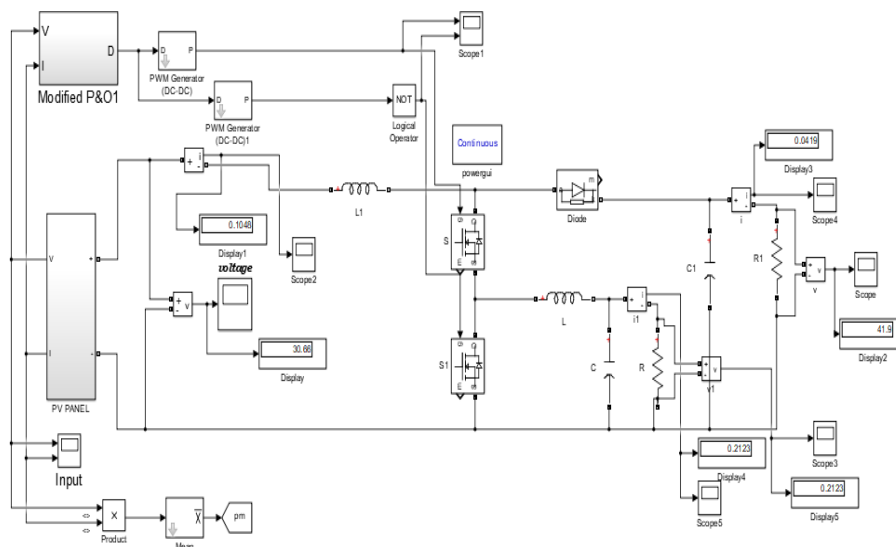

Fig 6. IDOC Of Dc To Dc Converter – Boost Converter
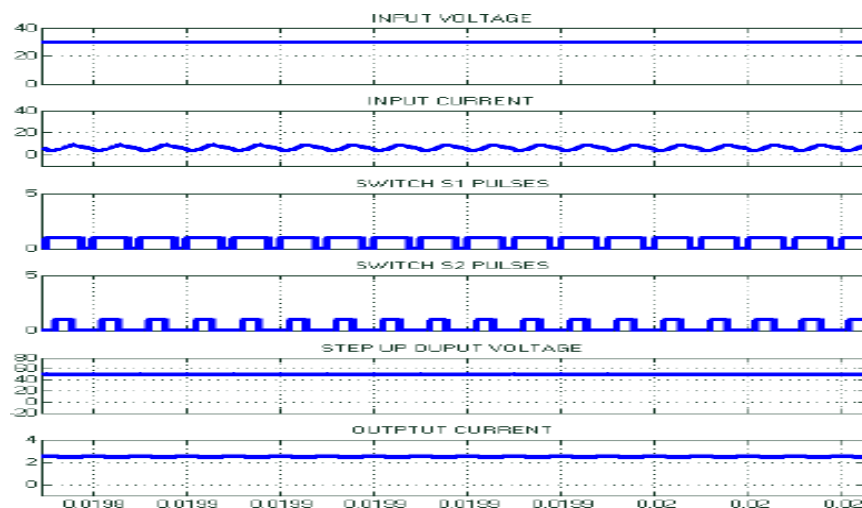
6.2 Output Waveform – Step Up Load

Fig 7 Waveform across step up load

7. SIMULATION – BUCK CONVERTER

MATLAB/SIMULINK is used for simulating the circuit. Simulation results of Integrated Dual Output Converter (IDOC) are analyzed for buck converter.

Fig 8. IDOC of DC to DC Converter – Buck Converter

7.1 OUTPUT WAVEFORM – STEP DOWN LOAD

Fig.7 and Fig.8 show the simulated waveforms of step up and step down converters respectively. For the input of 30 V, duty cycle of 0.70, step up voltage of 50.51 is obtained. For the same input and duty cycle of 0.286,IDOC gives the step down voltage of 17.92V.

Fig 9. Waveform Across Step Down Load

The input current is noted as 6.42A.The output currents of 2.5A and 3.5A are obtained through step up and step down loads respectively. The step up and step down resistive load is 20Ω and 5Ω respectively.

8. COMPARISONS BETWEEN CONVENTIONAL BUCK BOOST CONVERTER AND IDOC CONVERTER

comparisons of electric stresses among different converters. Note that the comparisons are only done based on those topologies having the same kind and the same number of components as the proposed IDOC converter.
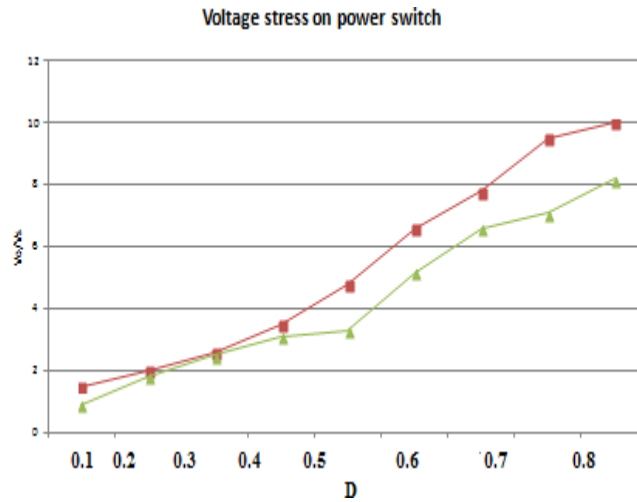
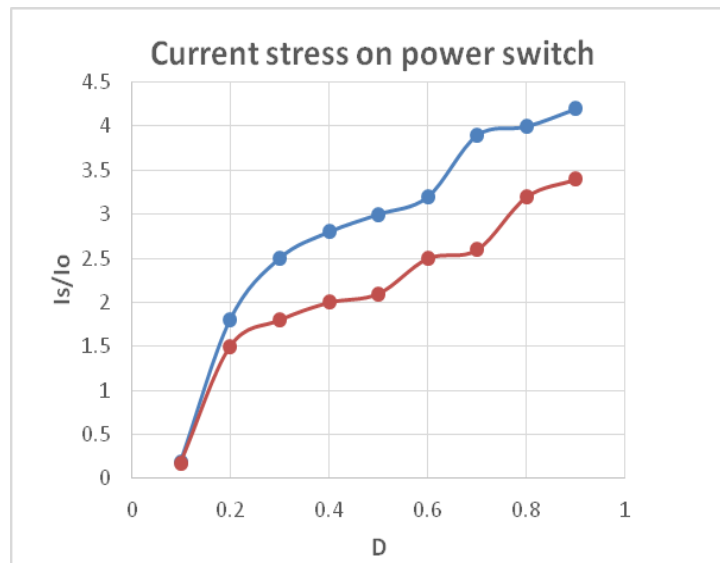

Fig 10. Voltage stress on power switch S.

Fig 11. Current stress on power switch S.

If we assume that there is no power loss in the system, that is, T hat the input power is transferred to the output load totally, which can be described as *Pin=P0*, then Vi_n I_{in} $=V_0$ I_0.
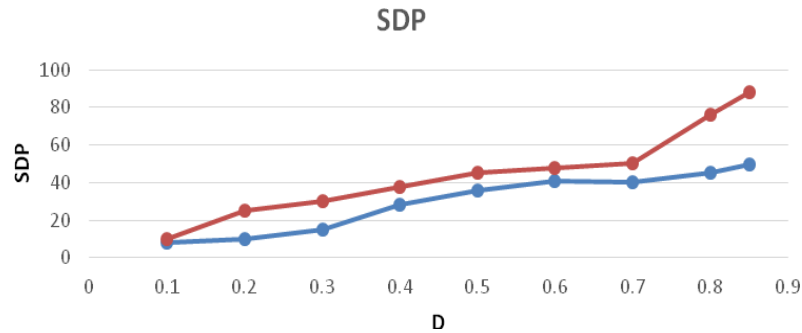
Fig 12. Switching Device Power Rating (SDP)

The total switching device power rating (*SDP*) is the sum of the product of the voltage stress *Vsi* and the average current stress *Isi* on each semiconductor device, which could be a cost. estimation of the DC–DC converter system and show the comprehensive electric stress effect of all active devices.

9.CONCULUSION

Analysis, simulation and comparisons among the buck-boost converter and the proposed idoc converter prove the following:

(1) The proposed IDOC converter's step-down gain is the minimum one.

(2) Based on comparisons among the same kind and same number of components, the proposed converter's current and voltage stresses on the power switch are less than or equal to those of comparative converters, and the current stress on inductor *L2*, the voltage stress on the charge pump capacitor, and the *SDP* of the proposed converter are always smaller than those of comparative converters under the same duty cycle.

(3) The efficiency of the proposed buck-boost converter is highest among those converters having the same number of elements in the MATLAB simulation in both step-down and step-up modes.

(4) The proposed IDOC converter has good dynamic response with load variation. Accordingly, the proposed IDOC converter can achieve very low voltage gain without extremely small duty cycle, and, owing to its low electric stress and small *SDP*, component selection for the proposed converter is much easier.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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