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Single Input Dual output converter

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Abstract- **A new dc dual output converter topology is proposed. This topology presents a family of single-input–multiple-output (SIMO) dc–dc converter. The proposed system has dual dc output, one step up and one step down output.Compared with separate converters,these topologies utilize a lower number of switches and are more reliable. Simulations shows that this topology exhibit similar dynamic behaviour as individual buck and boost converters. Hence, the control system methodology is the same as that of separate converters. The proposed converter has verygood cross-regulation to step load change as well as dynamic reference changein either output. Operating principle has been experimentally evaluated using 40W prototype. The measured efficiency is around 90%**

***Index Term-DC–DC power converters*, low conduction losses, single-input multiple-output (SIMO), dual output converter (DOC)**

1. INTRODUCTION

The evolution of modern power electronics has witnessed its fast expanding in emerging applications and its indispensable role in processing electric energy. The rapid increase of battery-operated portable applications such as personal digital assistants and mobile phones, minimizing power consumption becomes one of the most important design criteria. Dc to multi output dc converter has been used for many of these applications. Figure. 1(a) shows a representative system, where three different outputs are obtained from single ac input using three separate power converters. This system is too bulky with multiple control circuits and passive components. The proposed system (Figure. 1(b)) gives multiple outputs generated from a single integrated system with reduced number of switches. Due to integrated architecture, all the outputs of the system are regulated using the same set of switches and hence, coordination and control is easier.

A new Ac to dc multi output topology is derived by modify and combining commonly known topologies. Multiple output converters with magnetic coupling and number of secondary winding are discussed in [1]-[4], but precise regulation of each output is difficult due to magnetic coupling. To overcome the drawback of isolated multi output converters non isolated converters are proposed, in which cascaded dc-dc converters are mentioned in [5]. The number of circuit elements used in cascaded stages is more, this can be reduced by using multiplexed converters [6-8], but the control system is complex and depend on various constrains such as cross regulation, operating modes and time multiplexing. A dual output converter based on single switch and coupled inductor [9] has been proposed, from a single input it can provide two different dc output. Integrated multi output converter with simultaneous buck and boost converter is proposed in [10]. The advantages of the system are lower number of switching elements, continuous current at input and step down output, filter requirement is lower, simple control system and precise regulation of both buck and boost output etc

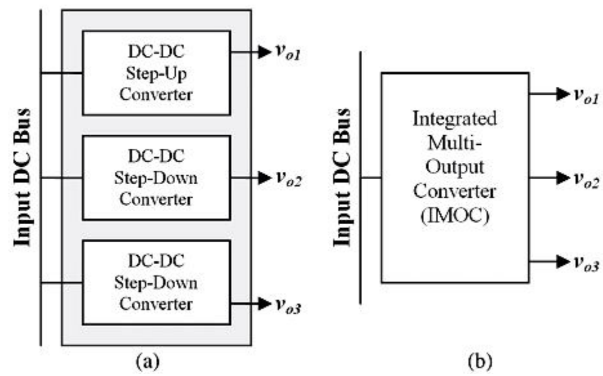

Figure.1.Schematic of power converter with three dc outputs. (a) Separate dc-dc converters for three outputs. (b) Integrated architecture for three outputs.

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The topology has been realized by replacingthe control switch of a boost converter topology by seriesconnected switches and using the resulting switch nodes tosynthesize additional outputs using low-pass filter networks. The step-up and step-down gains achieved are the same asseparate boost and buck converters, respectively. However,
compared with separate converters, the proposedstructure uses a lower number of switching elements. Moreover,the converter has continuous currents both at the input andthe step-down output. Hence, compared with a conventionalbuck or buck–boost converter, the input filter requirement islower.

Present-day power electronic systems require multiple dcoutputs at different voltage levels. Auxiliary circuits are often present in addition to the main power stage, and they should be powered at low voltages, e.g., fuel cell system [11]. The proposed converter can provide a step-up output, which forms the main power stage, along with an auxiliary step-down output. Some potential application areas of the converter are solar battery chargers, dc nanogrids, bias supplies, etc.

2. PROPOSED PRINCIPLE FOR SYNTHESIS OF DOC

Present-day power electronic systems consists of Auxiliary circuits, which are often present in addition to the main power stage, and they should be powered at low voltages, e.g., fuel cell system, solar battery chargers, dc nanogrids, bias supplies, etc. This paper proposes a Dual output converter with low conduction losses.

A dc–dc architecture that can provide step-up and step-down outputs from a single dc input is used for the dual output part in this paper. The topology is realized by replacing the control switch of a boost converter topology by series connected switches and using the resulting switch nodes to synthesize additional outputs using low-pass filter networks. The dual output circuit is shown in Figure. 3, where inductor *L* and capacitor *C* form the low-pass filter. The boost converter and the buck converter are being integrated in a single topology in this circuit.

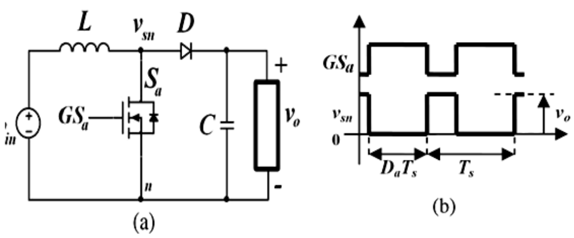

Figure2(a) conventional boost converter and Figure5(b) switch node waveforms corresponding to the gate control signal *GSa*.

Working can be explained with the help of Conventional boost converter. Conventional boost converter with the single control switch *Sa*shows in Figure 2. The switch node voltage *vsn*corresponding to gate signal *GSa*is shown in Figure 5 The switch node voltage is equal to zero when switch *Sa* is turned on ($0 \le t \le Da.Ts$) and is clamped to the boost output voltage (*vo*) when the switch is off (neglecting diode drop) ($Da.Ts \le t \le Ts$).

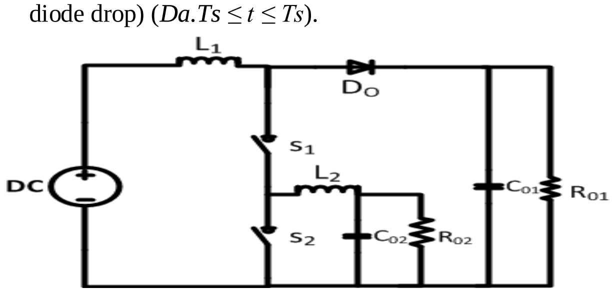

Figure.3 multi output converter

Boost converter circuit when switch *Sa*is replaced by two series connected switches *S*1 and *S*2 shown in Figureure 3. For boost operation (*Da* interval), both switches need to be turned on at the same time. The *Da* interval in Figure 2 can be achieved by turning off either *S*1 or *S*2 or both in Figure 3, and the switch node voltage *vsn*1 is equal to *vo*. If during this interval switches *S*1 and *S*2 are switched in a complementary manner, the switch node *vsn*2 can be used as a buck output with input voltage equal to *vo*.

The proposed modification results in the boost converter and the buck converter being integrated in a single topology. Hence, in this paper, this converter is regarded as IDOC, and the behavioural characteristic of the converter is studied. The same set of switches *S*1 and *S*2 are used to regulate both the outputs.

3. **ANALYSIS OF DOC**

A. Switching Intervals

The schematic of the proposed DOC, having dual dc outputs, is shown in Figure. 3. The converter has been implemented using twobidirectional switches *S*1 and *S*2. These two switches wouldresult in four possible operating states, three of which aredistinct and, thus, results in three different switching intervalsof the converter. These intervals are discussed in the followingsections.

1. Interval I (t1 to t2)—Both S1 and S2 are on :

Switching interval I is equivalent to thecontrol switch Sa] of a conventional boostconverter being turned "on." Diode D is reverse biased duringthis interval. The inductor current iL1 builds up, while the buck inductor current iL2 freewheels through switch S2. With respect to the waveforms shown in Figure. 7 and considering the dc loads Ro1 and Ro2 at the step-up and step-down terminals, respectively, for a time D1.Ts (where Ts = switching period)

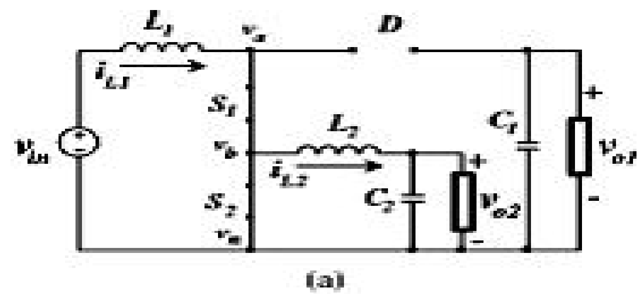

Figure4 equivalent circuits during interval I (**Duty is D**1)

2. Interval II (t0 to t1 and t2 to t3)—S1 is on and S2 is Off

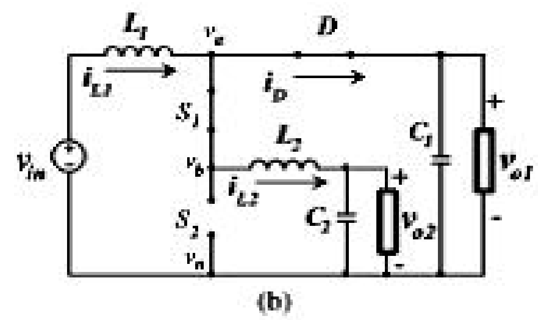

Figure 5 equivalent circuits during interval II (**Duty is D**2)

During this interval, the inductor currentiL1 is distributed into two components: One is flowing throughdiode D, and the other portion is equal to the buck inductorcurrent iL2. The step-down converter draws energy from the source during this interval. Unlike the conventional boost converter, the diode current iDis equal to the difference between the inductor currents iL1 and iL2, and hence, its magnitude decides whether the converter operates in CCM. The switch node voltage (va) is equal to the step-up output voltage vo1. The time duration for interval-II operation is defined to have a duty cycle of D2.

3. Interval III (t3 to t4)— (or Both S1 and S2 are Off)

In this interval, the inductor current iL2 freewheels through switch S2 or through its antiparallel diode (if S2 is not being gated). This interval is thus analogous to the freewheel period associated with conventionalbuck converters, either the lower switch conducts in synchronous switching scheme or the diode conducts.

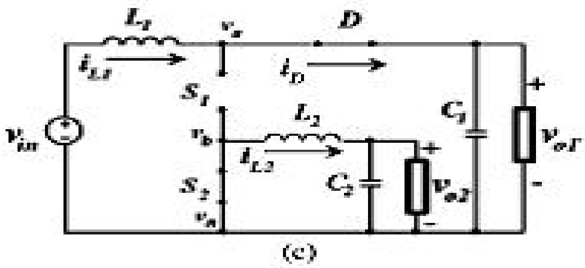

Figure 6 equivalent circuits during interval III

Diode D conducts the inductor current iL1. Hence, both inductors give out their energy to their respective outputs.

B. **steady-State Behavior**

1) Voltage Conversion Ratio: For the purpose of analysis, small ripple approximation for the inductor currents and capacitor voltages has been assumed. Thus, the expressions for the voltage conversions can be derived from (1)-(12), as follows.

For inductor L_1, we have

$$(V_{01} + V_{C1}) * D_1 * T + V_{01}(1 - D)T = 0 \quad (1)$$

$$V_{C1} = \frac{V_{in}}{1-D} \quad (2)$$

Hence,

$$\frac{V_{01}}{V_{in}} = \frac{D_1}{(1-D_1)}. \quad (3)$$

Similarly, for inductorL_4, we have

$$(V_{01} - V_{02}) * D_2 + (-V_{02}) * (1 - D_2) = 0. \quad (4)$$

Hence,

$$\frac{V_{02}}{V_{01}} = D_2. \quad (5)$$

Thus,

$$\frac{V_{02}}{V_{in}} = \frac{V_{02}}{V_{01}} * \frac{V_{01}}{V_{in}} = \frac{D_2 * D_1}{1-D_1}. \quad (6)$$

Two dc outputs of dual output bridgeless converter can be regulated using the two control variable $D_1$and D_2. These duty cycles are defined as the time duration for intervals I and II, respectively. The step down output is regulated using switch S_1, when S_2 "off" where as step up output is depend upon the interval when both switches are turned on (depend on duty ratio D_1) . The step up voltage is effectively acts as input to the step down operation.

Voltage conversion ratio in terms of input and load impedance from [15] equation (6)-(9) gives.

$$\frac{V_{01}+V_{02}}{V_{in}} = \sqrt{\frac{R_L}{2R_e}}. \quad (7)$$

Where the quantity Re is defined as the emulated input resistance of the converter and R_L is the equivalent load resistance.

2) Range of output voltages: The duty cycles that control both step-up and step-down voltages have been described in the previous section and illustrated in Figure. 7. Because they share the same switching period, duty cycles D_1 and D_2 should satisfy

$$D_1 + D_2 \leq 1 \quad (8)$$

For any particular value of the duty cycle *D*1, the step-down gain varies within the range

$$0 \leq \frac{V_{02}}{V_{in}} \leq 1 \quad (9)$$

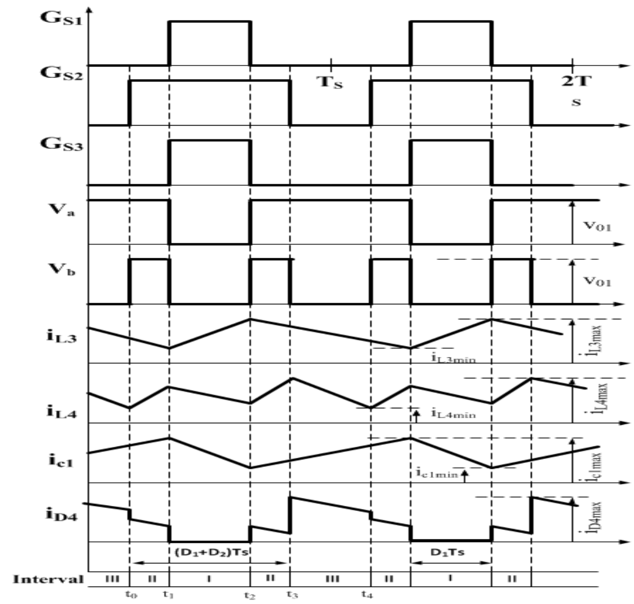

Figure.7. Waveforms of the switch node voltages, the inductor, and diode currents

Thus, the dual output converters can provide step -down output ranges varying from zero to the input voltage. Compared with a conventional buck converter, the dual output converters can provide wide step -down outputs at acceptable duty ratios of switches. This is because the step-down output depends upon both D_1 and D_2, instead of only one duty cycle as in the case of a buck converter. This characteristic has been verified in the experimental section. Similarly, the step-up gain varies between

$$1 \leq \frac{V_{01}}{V_{in}} \leq \frac{D_1}{(1-D_1)}. \quad (10)$$

Thus, the dual output converters preserves the qualities of both buck and boost Converters in an integrated architecture.

PARAMETERS OF THE DBCC

parameters	Attributes
Input voltage Vin	12 V
Step-up output voltage Vo1	Range : 20- 30 V
Step-down output voltage Vo2	Range : 4 – 8 V
Inductors L1 = L2	15.3 µH
Capacitors C1 = C2	363 µF

4. **SIMULATION AND EXPERIMENTAL RESULTS**

The proposed converter has been simulated using MATLAB for the input and output specification as shown in table I. The simulated results justify the behaviour of the converter. The results shows that the proposed converter can generate step up as well as step down out-puts simultaneously with various duty cycles. The design parameters and specifications are shown in table I.

The Integrated single input multiple output converter works for an input voltage of 12 V DC and generates two output voltages simultaneously. One output with a step-up voltage in the range of 20 to 30 V and other with a step-down voltage in the range of 4 to 8 V. The pulses to the switch MOSFET is generated using PWM pulse generator. The Figure.9 shows the PWM Pulse generation circuit. The two pulses generated have a switching frequency of 10 KHz and have a variable duty cycles. By varying the duty cycles a wide range of step-up as well as step-down voltage gains can be achieved..The measured efficiency is about 90% at full rated load

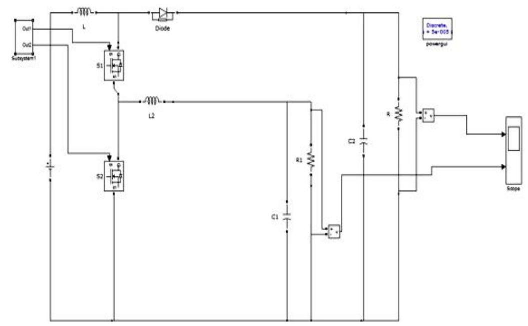

Figure.8.Simulated waveform of proposed converter.

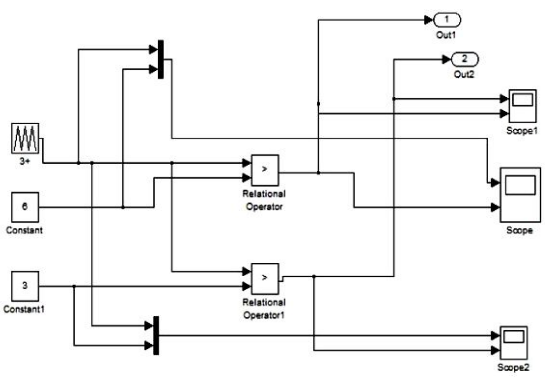

Figure. 9 PWM Generation Circuit

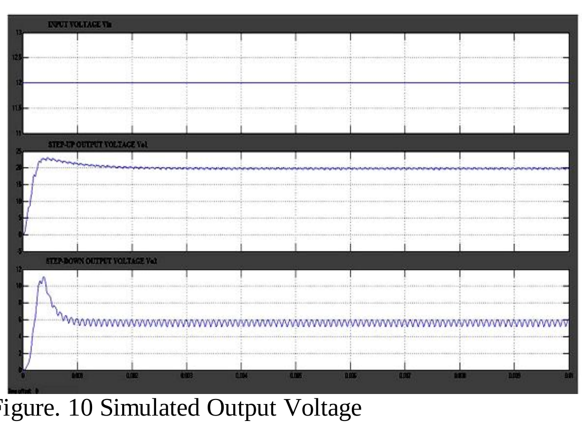

Figure. 10 Simulated Output Voltage

5. CONCLUSION

This paperproposed a Single Input Dual-output dc-dc converter topology with simultaneous step-downas well as step-up outputs. In contrast to a conventional buck converter, the proposed converter has continuous input as well as the step-down output current. The proposed converter can operate at higher frequencies. Thus additional reduction in size and can improve the conversion efficiency. The input filter requirements of the conventional buck and boost converter are reduced.The merits of the converter with respect to shoot-through protection, lesser Billof-Material, and wider output ranges have been discussed. Theconverter behaviour has been verified using a Simulink prototype.

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