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HYBRID BUCK-BOOST MULTI OUTPUT QUASI Z-SOURCE CONVERTER WITH DUAL DC AND SINGLE AC OUTPUTS

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Abstract: *This paper presents two hybrid multi output buck-boost quasi z-source converters (q-ZSCs) capable of giving two dc and one ac outputs simultaneously from a single dc input. One dc and the ac outputs of the proposed multi output q-ZSCs have both buck and boost capability and the other dc output has the property of boosting the input voltage, thereby capable of giving a wide range of voltage gain both for dc and ac outputs. The rationale behind proposing two variants of the hybrid multi output q-ZSCs is to have more flexibility on voltage gains as per the load requirements. The proposed converters are derived from the quasi z-source concept and hence inherit all the properties of q-ZSI which realize buck/boost, single- stage inversion, and power conditioning with improved reliability along with inherent shoot-through protection capability. All the three outputs of the proposed converters can be independently controlled making them suitable for various applications. The proposed converters can be utilized for various modern multi output DC-DC and DC-AC power conversion applications such as Renewables and the Uninterrupted Power Supply.*

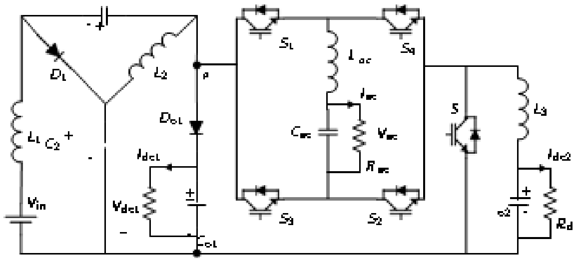
INTRODUCTION

Nowadays, single output converters are not able to meet simultaneous requirements of different types and the voltage level of modern electrical applications such as hybrid electric vehicles, hybrid microgrid, standby power supplies etc. On the other hand, multi output converters are becoming popular because of their ability to supply simultaneous multi outputs, high power density, compact size, and lower cost. Owing to these benefits and demand of multi output converters, lots of researches are being done on them in recent times Lately, various multi output converters are reported in the literature Multi output converters discussed in are predominantly dc/dc converters that only give multiple dc outputs and do not have ac at the output. Literature gives two simultaneous dc and ac outputs and do not have the provisions of multi dc and ac outputs. Moreover, the ac output obtained in the converters reported in the literature is inherently step down. Split source-based hybrid converter topology discussed in gives one ac and one dc outputs. In this case also the ac output is lower than the input voltage. Hybrid multi output converter discussed in gives n-ac and one dc outputs. The hybrid multi output converter discussed in gives one dc with boost capability and the ac outputs are lesser than the input voltage. There are two categories of existing multi output converters 1) converters with multi dc outputs having buck and boost ability and 2) multi output converters giving dc and ac outputs simultaneously with boost dc and buck ac outputs. The conventional multi output converters giving AC as output are derived from the voltage source and current source inverters. Hence, they are prone to electromagnetic interferences (EMI) which may result in shoot through or misgating.

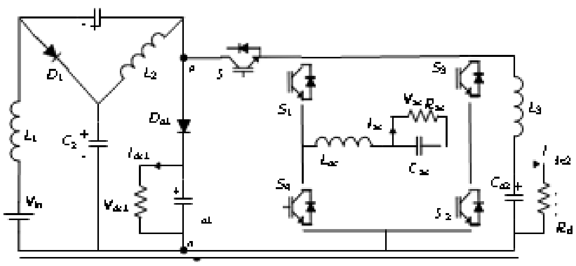
This paper presents two quasi z- source based hybrid buck- boost multi output converters. The proposed multi output qZSC's give three outputs, 1) boost dc, 2) buck-boost dc, and 3ac with buck and boost ability. As the proposed multioutput converters are derived from the quasi impedance network, they inherit all the properties of qZSI.

PROPOSED MULTI OUTPUT QUASI Z-SOURCE CONVERTERS

The circuit diagram of the proposed hybrid multi output q- ZSC Type I and Type II are shown in Fig. 2(a) and Fig 2(b) respectively. Both the converters have been derived from the quasi impedance source network and have the property of giving one boost dc, one buck-boost dc, and one buck-boost ac outputs.



(a)



(b)

Fig.1 (a) Type I of the proposed multi output hybrid q-ZSC

(b) Type II of the proposed multi output hybrid q-ZSC.

It may be observed from that the inverter bridge and the switch (S) positions are interchanged in Type II as compared to Type I. With this simple modification in proposed Type I converter, the buck/boost range of the ac and dc outputs have increased. It is discussed in detail in the subsequent subsection after the steady state analysis of the proposed Type I converter. The operation of the proposed Type I and Type II converters is similar, therefore a detailed analysis of Type I is discussed in the subsequent subsections and the gain factors of Type II converter is given after that.

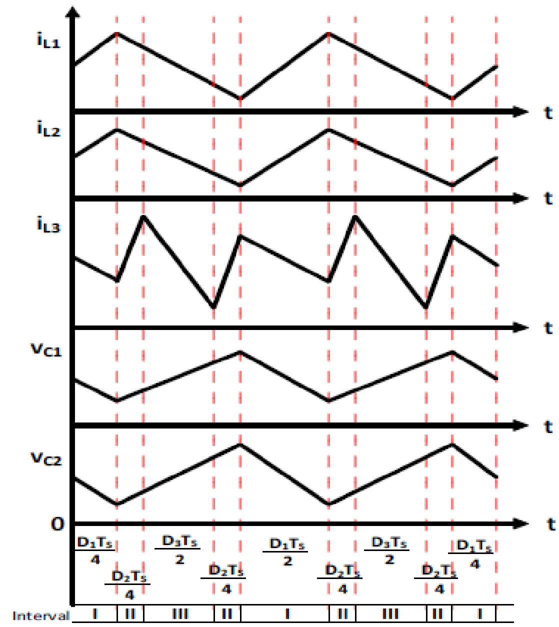


Fig.2. Operational waveforms of inductor currents and capacitor voltages.

The proposed multi output q-ZSC operates in three different intervals. The converter operation in the different intervals is as follows. Complete shoot-through operation (D_1T_s operation- Interval I). In this interval, two switches of the inverter on the same leg and switch (S) are ON. In addition to this, another switch of the remaining leg is also switched ON so as to make the zero stage of the inverter. Diodes D_1, D_{o1} are OFF.

Inductor L_1, L_2 gets charged and capacitor C_1, C_2, C_{o1} and inductor L_3 discharge during this interval. The governing equations during this interval are written as follows.

$V_{L1} = V_{IN} - V_{C2};\ V_{pn} = V_{dc1}$

$V_{L2} = -V_{C1} = V_{C2} - V_{dc1};\ V_{L3} = -V_{dc2}$

$i_{C1} + i_{CO1} = i_{L2} - i_{ac} - i_{dc1};$

$i_{C2} + i_{CO1} = i_{L1} - i_{ac} - i_{dc1}:\ i_{CO2} = i_{L3} - i_{dc2}$

PROPOSED PULSE WIDTH MODULATION TECHNIQUE

Pulse width modulation (PWM) scheme of a converter is pivotal in obtaining the desired outputs. A novel PWM technique is proposed in the paper which is used to operate the proposed converter. The proposed PWM technique is derived from the standard sinusoidal pulse width modulation (SPWM) scheme. The SPWM switching scheme essentially creates two stages of the inverter- power stage and zero stage. The power stages of SPWM are solely responsible for the power quality of the output AC. To ensure the power quality is not degraded, the power stages of the standard SPWM technique has not been disturbed. However, the zero stages may be used to achieve the shoot through intervals. In the proposed converter, the inverter is in shoot through stage in intervals I and II. In SPWM, for modulation index <1, every cycle of carrier triangle wave results in both the power stage and zero stage. However, the length of these stages is not constant in every triangle wave cycle as the reference sinusoidal wave continuously varies with higher time period than the carrier triangular wave. By limiting the value of Modulation Index (M_a) it can be ensured that a minimum length of zero stage ($(D_1+D_2)T_s$) is present in every cycle of the triangle wave. This fixed length zero stage is used in achieving the total shoot through and inverter only shoot through intervals i.e. interval I and II by switching an extra switch in addition to the switches which are already switched ON. Thus, this fixed length zero stages form the intervals Iand

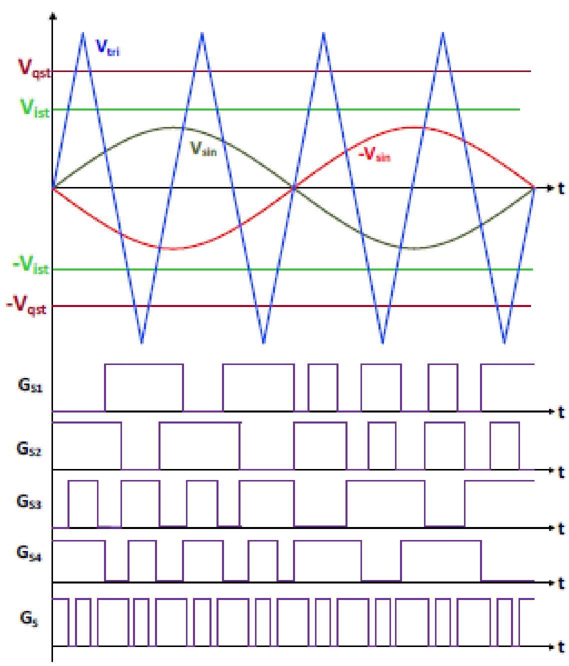


Fig. 3. Switching signals of the proposed pulse width modulation technique.

From the inverter point of view, shoot through interval is same as the zero stage. After subtracting the fixed length zero stages from the continuously varying zero stages, the resultant is also continuously varying zero stages with less time than that of the original ones. These resultant continuously varying zero stages along with the continuously varying power stage combined form the interval III operation of the proposed converter. Due to the varying zero stage and power stage in each and every triangular wave, the pulses are periodical with the low frequency, i.e., 50 Hz rather than the triangular wave frequency. In the zero stage of the inverter, either the upper set of switches (S1, S4) or the lower set of switches (S2, S3) of the inverter are switched ON. To achieve the shoot though of the inverter in intervals I and II, one of the remaining two switches is forced is switched ON in addition to the above set of switches.

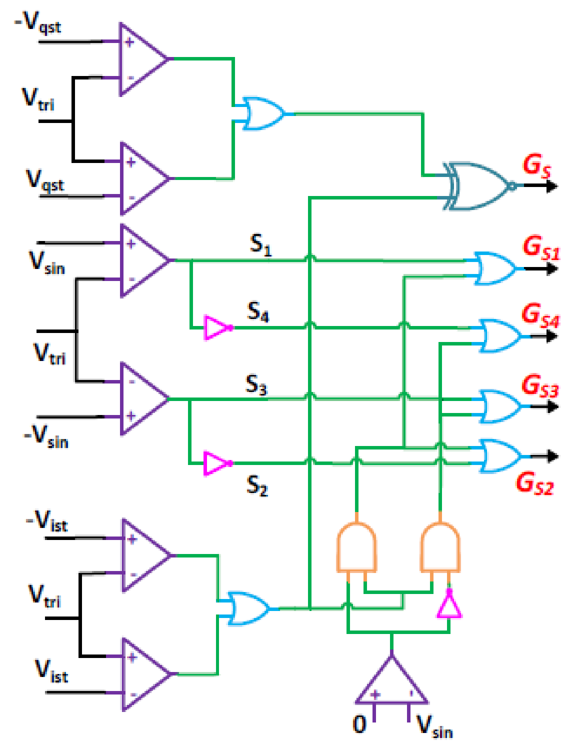


Fig. 4. Logic for pulse generation.

When the reference sine wave is positive, S3 is switched ON when the lower set of switches of the inverter are ON and S4 is forced switched ON when the upper set of switches of the inverter are ON. Similarly, when the reference sine wave is negative, either of the switches S1 or S2 is switched ON depending on PWM logic.

STEADY STATE PERFORMANCE OF PROPOSED MULTI OUTPUT QZSC

The gating pulses of the proposed converter switches S1, S2, S3, S4 respectively. The gating pulses on the left side of the dotted black line indicates the PWM when the reference signal $V_{sin}>0$ where the switches S3 and S4 are switched ON during the zero states to get the shoot through stage. The gating pulses on the right side of the black line indicate the PWM when the reference signal $V_{sin}<0$ where the switches S1 and S2 are switched ON during the dead states to get the shoot through stage.

EXPERIMENTAL VERIFICATION

The proposed multi output q-ZSC is validated on a 310 W scaled-down prototype. Table I lists the parameters along with their attributes. Detailed steady state experimental results of the proposed multi output q-ZSC are discussed in subsequent subsections.

TABLE I

Table of components and their parameters

Component	Part No/Value
IGBT	IKW30N65ES5
Diode	40EPF06
L_1, L_2	PCV-2-564-08L, 560μH, 0.09 Ω
L_3	2.25m, 0.08Ω
C_1	150 μF, 0.04Ω
C_2	100 μF, 0.05Ω
C_{O1}	13.6 μF, 0.05Ω
C_{O2}	13.6 μF, 0.02Ω
V_{in}	48V
D_1	0.3
D_2	0.2
M_a	0.432

APPLICATIONS OF THE PROPOSED CONVERTER

The proposed buck-boost multi output q-ZSC is able to give two dc outputs with boost and buck-boost capabilities and one ac output with buck-boost capability. It possesses high power density and can be applied to modern electrical applications such as renewables and uninterruptible power supplies (UPS) for households. The details of the proposed q-ZSC for renewables and UPS applications along with the specification justification are given as follows.

Renewables: For the input voltage range of (>72 DC) generated from the renewable sources, the proposed multi out q-ZSC gives V_{dc1}= 380 V and V_{dc2}= 48 V (two DC outputs) and V_{ac}=110 V (rms). For an input voltage of 84 V, the above voltages are generated for D_1=0.39, D_2=0.133 and M_a=0.43. It may be noticed that 110 V(rms) AC is a standard AC voltage used for commercial and households, 380 V DC can be used as standard DC bus voltage and 48 V DC is a standard DC voltage used for many custom DC appliances.

Uninterruptible Power Supplies: The proposed q-ZSC can also be applied for uninterruptible power supplies for households. One practical scenario is that, if the proposed q- ZSC is operated with 24 V input voltage, for D_1 =0.25, D_2= 0.104, M_a=0.646, the output voltages would be V_{dc1}=48 V, V_{dc2}=5 V and V_{ac}= 22 V AC. 48 V and 5 V DC can be used directly for custom appliances and with the help of small line frequency transformer, 22 V(rms) ac can be upgraded to 110 V (rms) AC for its practical uses. It is important to note that the proposed converter can operate for a range of input DC voltage levels for the above applications. As per the constraints the non-idealities of components, the input voltage can be decided as per the requirement of the application.

CONCLUSION

In this paper, two hybrid multi output buck-boost q-ZSCs capable of giving two dc and one ac outputs simultaneously have been presented. The proposed q-ZSCs have the capability to give both buck and boost ac as well as buck and boost dc outputs, unlike the conventional multi output converters. Owing to the buck-boost capability of the outputs, the proposed q- ZSCs give a wide range of voltage gain for both ac and dc outputs. The outputs of the proposed q-ZSC can be independently regulated making it suitable for various multi output DC-DC and DC-AC power conversion for modern applications such as renewable and uninterruptible power supplies. It is important to mention that the rationale behind proposing two variants of the proposed concept is to give extra flexibility in voltage gain as per the load requirement. Moreover, as the proposed q-ZSCs have been derived from quasi z source concept, they inherit all the characteristics of the qZSIs such as inherent shoot-through protection and improved reliability in contrast to the VSI derived conventional multi output topologies. The proposed hybrid multi output q- ZSC has been validated experimentally on a 310 W prototype for open loop as well as closed loop operation.

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