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Hybrid Boost Converter for DC and AC Applications Supplied from Single DC Source

Priyanka G V[1], Hemavathi R[2]

PG Student [POWER ELECTRONICS], Dept. of EE, UVCE, Bangalore, Karnataka, India[1]

Assistant Professor [POWER ELECTRONICS], Dept. of EE, UVCE, Bangalore, Karnataka, India[2]

ABSTRACT: The paper proposes a hybrid converter topology which can supply both dc and ac loads from a single dc input. This topology is derived by replacing the controlled switch of boost converter with a voltage-source-inverter bridge. The resulting hybrid converter will have lesser number of power switches to provide both ac and dc outputs with an increased reliability and will have better power processing density and is suited for systems with simultaneous both ac and dc loads. As it is derived from the conventional boost converter , the proposed converter is called boost-derived hybrid converter (BDHC). A modified unipolar PWM control strategy is explained.

KEYWORDS: Hybrid Boost converter, Voltage Source Inverter (VSI), modified PWM technique.

I.INTRODUCTION

Nano grid structures are small autonomous system formed by integrating various electrical energy sources like solar, wind, fuel cells, biomass etc[1]. These are being incorporated in smart residential electrical power systems. These systems involves different type of loads- DC as well as AC loads which are efficiently interfaced with conventional or non-conventional energy sources using power electronic converters[2]. There are several DC-DC converter configuration which are already proposed such as buck, boost, Cuk and Sepic. A DC-DC converter with a high voltage gain and high power density is desirable in modern residential applications. For example: An application of a hybrid converter used to power an AC fan and a LED lamp both at the same time from a single DC input in a single stage. Normally, a boost converter is used to step up a DC voltage. Inverter section may be either voltage sourced or current sourced[3]. Voltage source inverters are commonly preferred in grid applications.

Conventional designs involve two separate converters, a dc–dc converter (e.g., boost) and a voltage source inverter (VSI), connected either in parallel [as shown in Fig. 1(a)] or in cascade [Fig. 1(b)], supplying dc and ac outputs at Vdcout and Vacout, respectively.

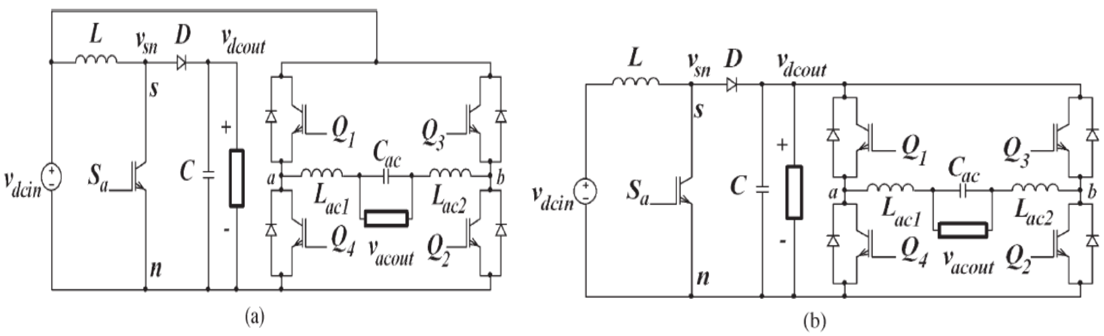

Fig1.Schematic of conventional power converter topologies with simultaneous dc and ac loads.

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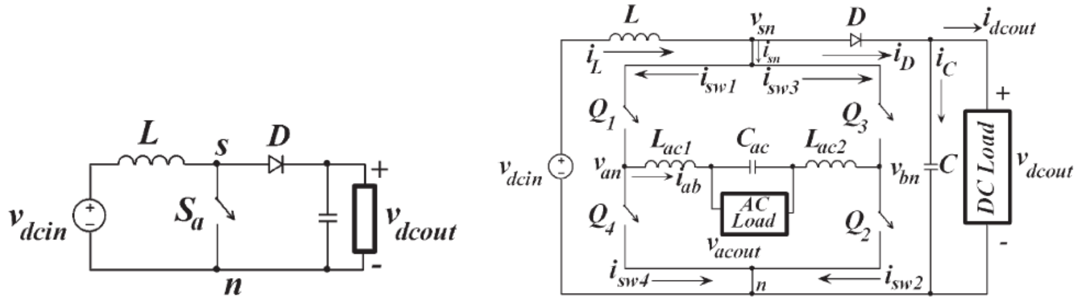
II. PROPOSED HYBRID BOOST CONVERTER

The proposed hybrid converter is realized by replacing the controlled power switch with an single phase or three phase voltage source inverter (VSI) bridge fig 2. The proposed circuit modification is applied to a boost converter.
The Boost operation of the proposed converter can be realized by turning on both switches of any particular leg (S1-S4 or S3-S2) simultaneously and the converter is said to be in shoot through mode. During inverter operation, circuit has the same states as a conventional voltage source inverter (VSI).



(a) (b)

Fig. 2. (a) Conventional boost converter. (b) Proposed BDHC (Sa is replaced with a single-phase voltage bridge network).

III. OPERATION OF HYBRID BOOST CONVERTER

The switch realization for the bridge can be done by using bidirectional switches either MOSFETs with antiparallel diodes or IGBTs.
The Hybrid Boost converter has three distinct switching intervals as following:
i. Shoot-through interval
ii. Power interval
iii. Zero interval

i)Shoot-through interval:
The shoot-through interval occurs when both the switches (either S1-S4 or S3-S2) of any particular leg are turned on at the same time. The duration of the shoot-through interval decides the boost converter duty cycle Dst. The diode D is reverse biased during this period. The inverter output current circulates within the bridge network switches.

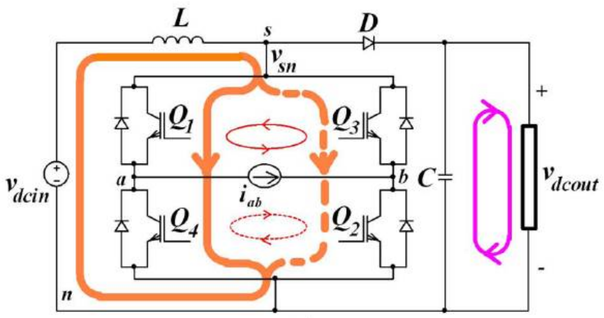


Fig 3: shoot through interval with current flow direction

ii) Power interval:
The power interval occurs when the inverter current enters or leaves the bridge network at the switch node ‘s’. The diode D conducts during this period and the voltage at the switch node (Vsn) is equal to the Vdcout (neglecting the diode voltage drop). In this interval, either S1-S2 or S3-S4 is turned on.

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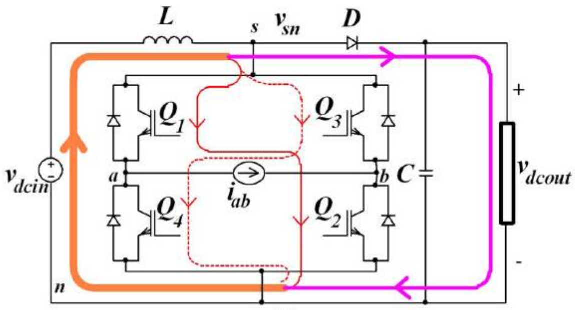

Fig 4: power interval with current flow direction

iii)Zero interval:

The zero interval occurs when the inverter current circulates among the bridge network switches and is not sourced or sunk. The diode D conducts during this interval.

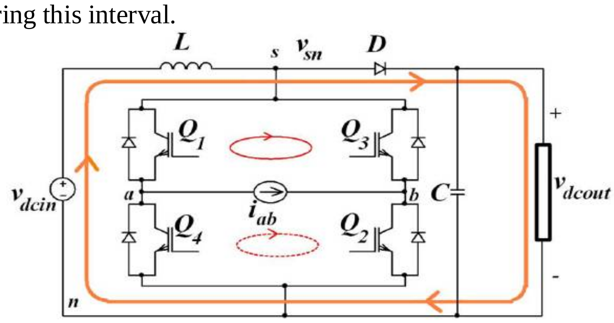

Fig 5: zero interval with current flow direction

IV. CONTROL STRATEGY

Modified Unipolar PWM Control Strategy for Hybrid Converter:

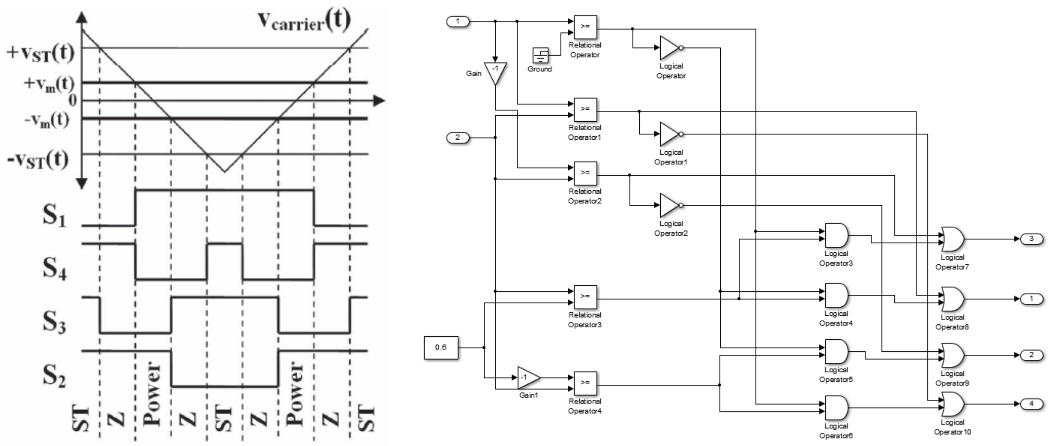

Fig 6: Generation of gate pulse for a positive value of reference signal and Simulink model for PWM generation circuit

The controlling pulses for the switches of the hybrid boost converter can be generated by summing the pulses generated for the boost converter and voltage source converter. The switching pulses for boost operation are generated by comparing the carrier (triangular) and dc reference Vst. For voltage source inverter bridge operation carrier (triangular) and the sine reference Vm are compared. For the proposed hybrid converter pulses generated for boost operation and VSI are combined using OR gate for all the four power switches[2].

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In this scheme, the shoot-through is realized by gating-on both the switches of a single leg at the same time. The switching strategy involves turning on only one leg at a time in order to achieve shoot-through. Another alternative is to turn on all the switches during shoot-through.

The reference signals to the PWM generation circuit are Vm(t) and Vst (t). The signals S1–S4 are provided to the gates of the controlled switches. Vst(t), a dc signal, controls the shoot-through period, and hence, the duty ratio (Dst) for the dc output of the boost converter and Vm(t) controls the modulation index (Ma) for the inverter. The nature of the gate signals for a positive value of reference signal Vm(t) has been shown in Fig. 6.

V. ADVANTAGES OF BDHC

1) Provides inherent shoot through protection.
2) The use of separate dead time is not necessary as it has the special properties of the inherent shoot through capability. The delay time provided by the dead time circuit is to avoid conduction overlap of switching devices.
3) The total number of power semiconductor devices used in the circuit are reduced.
4) The circuit is capable of supplying both AC and DC loads simultaneously thereby multi output behavior is achieved by the hybrid converter.
5) Achieves high voltage gain because of the less voltage stress on switches.

VI. SIMULATION STUDIES AND RESULTS

A list of parameters and there values for prototype is given in below table.

Parameter		Attributes
Power rating ($P_{dc} + P_{ac}$)		500 W + 90 W
Input voltage (V_{dcin})		48 V
Output	(Vdcout)	100 V
Voltage	(Vacout)	30 V
DC Load (R_{dc})		20 Ω
AC Load (R_{ac})		10 Ω
Switching Frequency		10 KHz
Input Inductor (L)		5 mH
DC Capacitor (C)		1 mF
AC Filter Inductor (L1 & L2)		500 µH (each)
AC Filter Capacitor (C_{ac})		10 µF

close loop hybrid boost converter :

In closed loop hybrid converter , a PI controller is used which compares the reference voltage and measured voltage and takes the corrective action for occurred error. The controller part of closed loop BDHC is shown in fig 7. PI controller sends the corrective signal to the PWM generation circuit and control the pulses to get the desired result .

Vin=48volts, Vdc=73volts, Vac=38volts, freq=50 Hz, switching freq=10K Hz with D=0.47 and M=0.5

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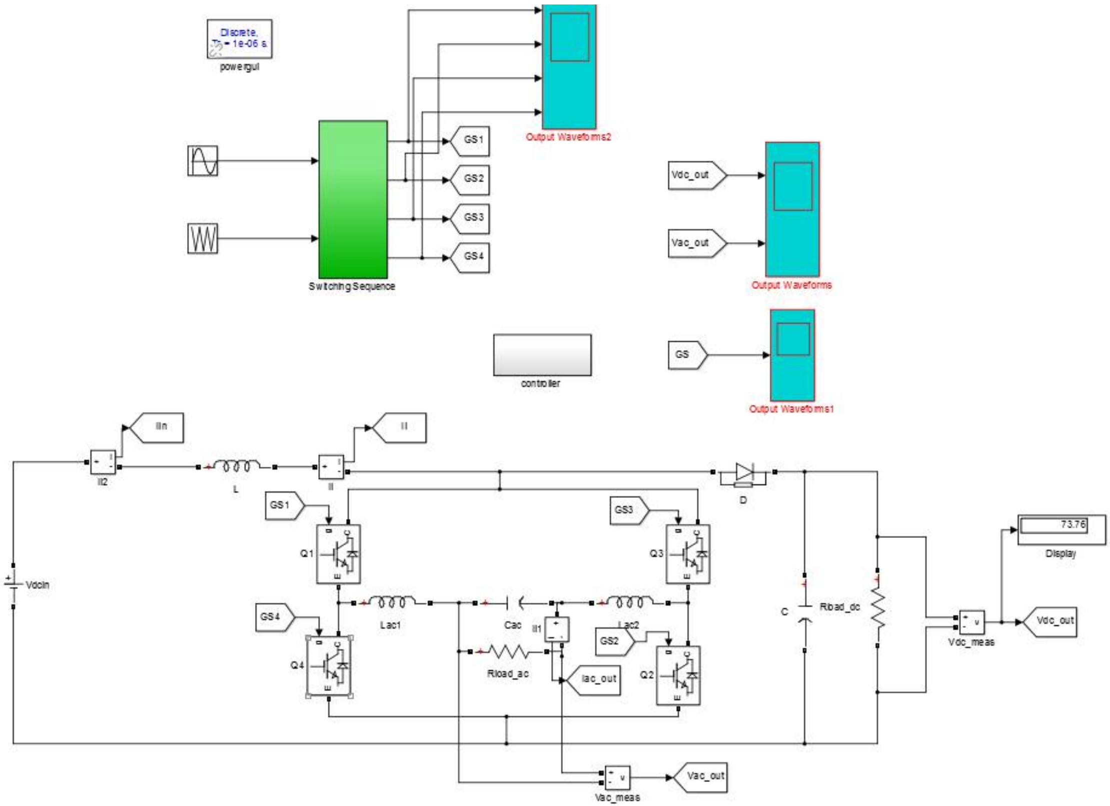

Fig 7: Simulink model for close loop hybrid converter

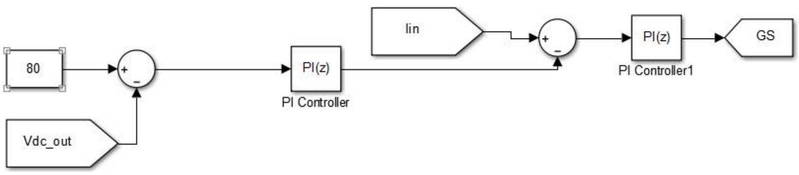

Fig 8: PI controller loop

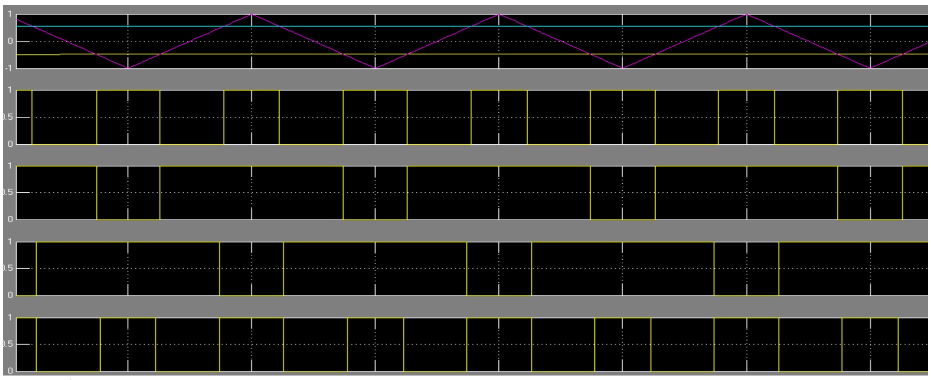

Fig 9:gate pulses for switches S1,S4,S3 and S2 generated by comparing sine wave and V st with carrier wave.

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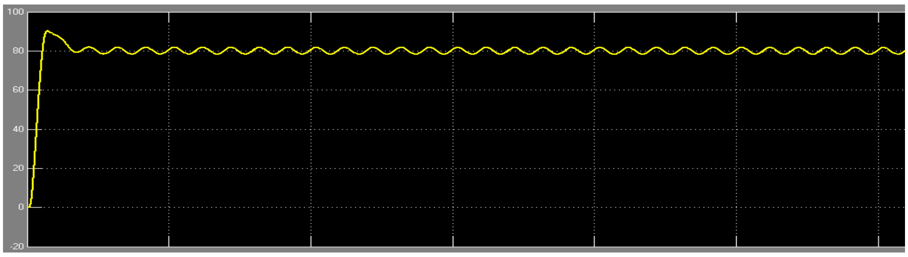

Fig 10: DC output voltage waveform for closed loop BDHC with reference voltage of 73V

Fig 10 shows the DC output voltage waveform for the close loop BDHC. The output voltage depends upon the duty cycle. Here 73V DC output for 0.47 duty cycle is obtained.

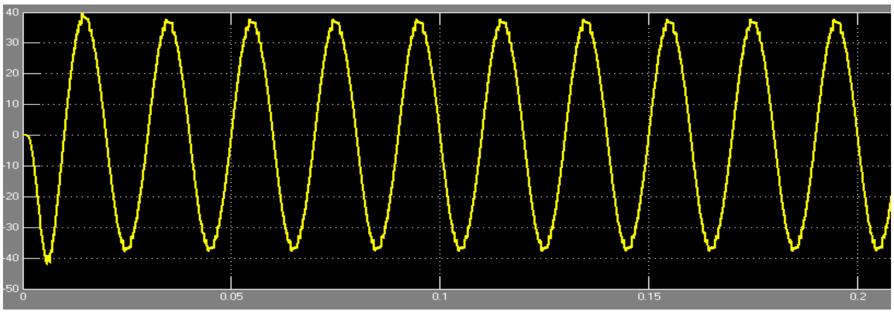

Fig 11: AC output voltage waveform for close loop BDHC

Fig 11 shows the AC output voltage which depends upon the modulation index M. In this simulation we are getting a 38V AC output. Here transformer is used to step up the AC output voltage to 230 volts (fig12).

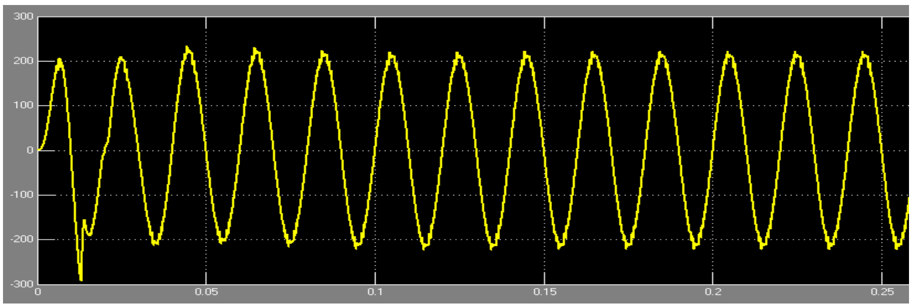

Fig 12: AC output voltage waveform with transformer for close loop BDHC

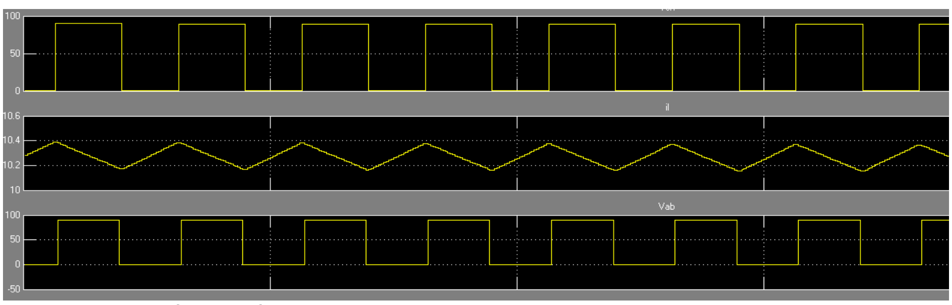

Fig 13:simulation waveforms of Vsn, inductor current and output ac voltage across inverter bridge Vab.

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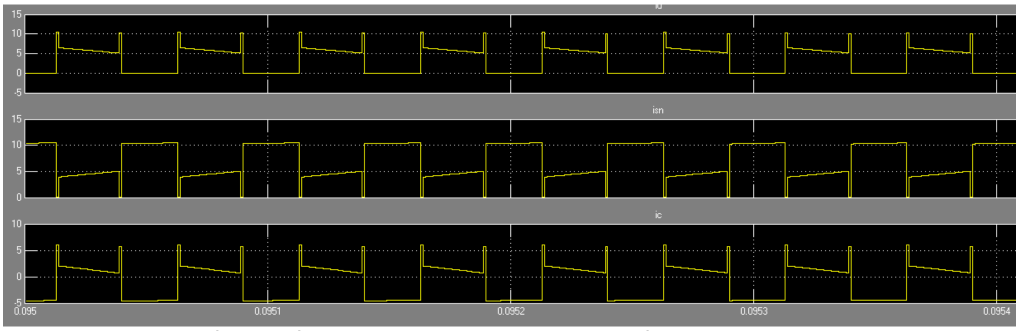

Fig 14: simulation waveforms of diode current iD, input current for inverter isn and capacitor current ic.

VII. CONCLUSION

This paper has proposed hybrid boost converter topology which can supply both ac and dc loads from a single stage dc input simultaneously. The various advantages of this converter stage are described above and compared with conventional system. This converter provides shoot through protection .Simulation results verify the operation of the hybrid converter in an open loop and closed loop.

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