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Boost derived hybrid converter with simulation DC and AC outputs

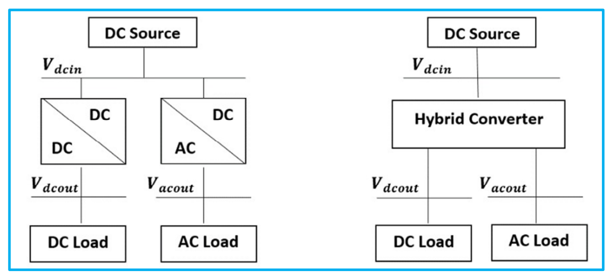
K Prabhavathi[1], M Nagaraju[2]
[1]B.tech scholar, Department of Electrical and Electronics Engineering, Siddhardha Institute of Engineering and Technology, Vinobha Nagar, Ibrahimpatnam, Hyderabad, Telangana-501506
[2]Asst.Prof, Department of Electronics and Communication Engineering, Siddhardha Institute of Engineering and Technology, Vinobha Nagar, Ibrahimpatnam, Hyderabad, Telangana-501506

Abstract:-This Paper introduces new hybrid converter topologies which can supply simultaneously AC as well as DC from a single DC source. The new Hybrid Converter is derived from the single switch controlled Boost and Buck-Boost converter by replacing the controlled switch with voltage source inverter (VSI). This new hybrid converter has the advantages like reduced number of switches as compared with conventional design having separate converter for supplying AC and DC loads, provide DC and AC outputs with an increased reliability, resulting from the inherent shoot through protection in the inverter stage. For controlling switches PWM control, based upon unipolar Sine-PWM is described. Simulink model is used to validate the operation of the converter. The proposed Converter can supply DC and AC loads at 190 V and 48 V (rms) respectively from a 48 V DC source.

Keywords:- *DC Nanogrid, Voltage source inverter(VSI), Boost-Derived Hybrid Converter, Buck-Boost Derived Hybrid Converter, Unipolar PWM.*

I.INTRODUCTION

Nanogrid architectures are greatly incorporated in the modern power system [1-2]. In this system there is DC as well as AC loads supplied by different kinds of energy sources using efficient power electronic converters [3]. Fig.1 shows the schematic of the system in which single DC source supplies both AC and DC loads. Fig.1 (a) shows the conventional architecture in which DC and AC load supplied by separate DC-DC converter and DC-AC converter from a single DC source respectively. Whereas in Fig.1 (b) referred as hybrid converter in which a single converter stage perform both operations. This hybrid converter has the property of higher power processing capability and improved reliability resulting from the inherent shoot through protection. This paper investigates the use of single boost stage architecture to supply hybrid loads.



(a) (b)

Fig1.Architectures supplying DC and AC load from a single DC source.
(a) Dedicated power converter based architecture and (b) Hybrid converter based architecture.

The conventional VSI in Hybrid converter would involve the use of dead time circuitry to avoid the shoot-through. Also misgating turn-on of switches may take place due to spurious noise resulting in damage of switches. For a compact system spurious signal generation is a common place. So VSI in such application need to highly reliable with appropriate measures against shoot-through and EMI induced misgating.

II.BOOST-DERIVED HYBRID CONVERTER

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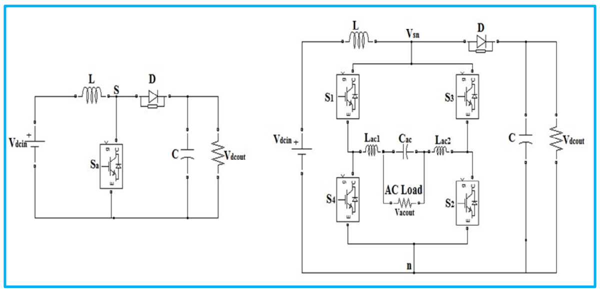
A. Proposed circuit modification

Conventional boost circuit is having two switches, one is a controllable switch (controls the duty cycle) and other can be implemented using a diode. Hybrid converter can be realized by replacing controllable switch in the boost circuit with a voltage source inverter, either single phase or three phase VSI. The resulting converter called as Boost Derived Hybrid converter (BDHC) [4].



(a) **(b)**

Fig 2. (a) Conventional boost converter, (b) Proposed Boost-Derived Hybrid converter obtained by replacing Sa with a single phase bridge network.

B. Derivation of BDHC topology

Control-switch S_a of a boost converter (shown in Fig. 2(a)) is replaced with a single phase bridge network switches (S_1-S_4) to obtain Boost Derived Hybrid Converter (shown in Fig. 2(b)).AC and DC outputs are controlled using same set of switches (S_1-S_4). So challenges involved in the operation of BDHC are, (a) defining duty cycle (D_{st}) for boost operation and modulation index (M_a) for inverter operation (b) control and channelization [5-7] of input DC power to DC as well as AC loads (c) Determination of voltage and current stresses various switches.

PROPOSED CONVERTER TOPOLOGY

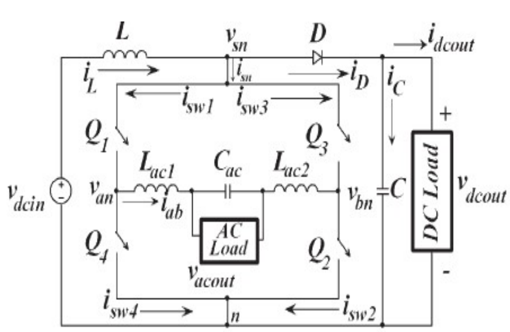


Fig 3. Proposed converter topology

Boost converters comprise complementary switch pairs, one of which is the control switch (controls the duty cycle) and the other capable of being implemented using a diode. Hybrid converter topologies can be synthesized by replacing the controlled switch with an inverter bridge network, either a single-phase or three-phase one. The proposed circuit modification principle, applied to a boost converter, is illustrated in the next section.

The resulting converter, called BDHC, is the prime focus area of this paper. Section VI extends this principle to higher order converters .Each of the four bidirectional switches (Q1–Q4) of BDHC comprises the combination of a switch Si and an antiparallel diode Di (i = 1 to 4). The boost operation of the proposed converter can be realized by turning on both switches of any particular leg (either S1–S4 or S3–S2) simultaneously. This is equivalent to shootthrough switching condition as far as VSI operation is concerned, and it is strictly forbidden in the case of a conventional VSI [8-10]. However, for the proposed modification, this operation is equivalent to the switching "on" of the switch "Sa" of the conventional boost converter.

The ac output of the BDHC is controlled using a modified version of unipolar sine-PWM switching scheme. The BDHC, during inverter operation, has the same circuit states as a conventional VSI. The reason for this is as follows: For conventional VSIs (shown in Fig. 2a), although the input to the bridge is a voltage stiff dc bus, the input dc voltage is required only during the power intervals, i.e., when there is apower transfer with the source. In the other intervals, the current freewheels among the inverter switches and these states do not require the input to be at a fixed dc value and hence can be zero [11]. In the BDHC, the switch node voltage (*Vsn*) acts as the input to the inverter; it switches between the voltage levels—*V*dcout and zero. The switching scheme should ensure that the interval for power transfer with the source occurs only when *vsn*is positive,

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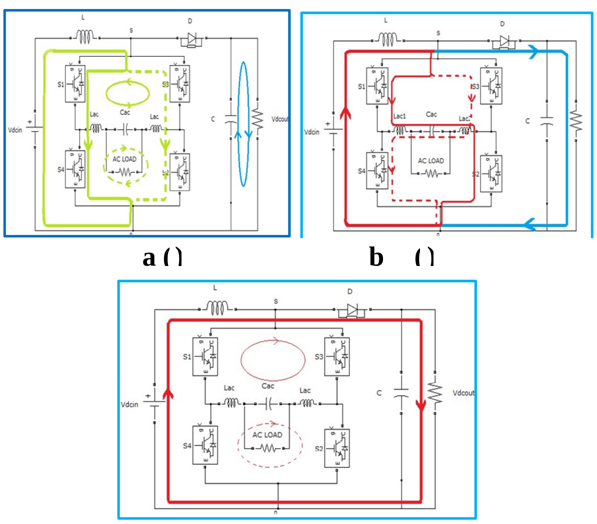
i.e., when *Vsn*is clamped to the dc output voltage *V*dcout.

III. OPERATION OF BDHC

The boost operation is realized by switching on both switches of a particular leg (S_1-S_4 or S_3-S_2). This is equivalent to shoot through operation as far as VSI operation is concerned. However in the operation of hybrid converter is concerned this is equivalent to switching on controllable switch S_a of the conventional boost converter

The ac output is controlled using a modified version of the unipolar sine width modulation [12]. The BDHC during inverter operation has the same circuit states as the conventional VSI. The switching scheme should ensure that the power transfer with source occurs only during V_{sn} is positive.



a () b ()

(c)

Fig. 4(a) Shoot-Through interval, (b) Power interval and (c) Zero interval.

The BDHC has three distinct switching states as described below:

A. Interval 1:Shoot-Through interval

Fig. 3(a) showing the equivalent circuit during shoot-through interval. In this interval we adjust the duty cycle for the boost operation by turning on both switches of any particular leg at the same time [5-6]. Diode D is reverse biased during this interval. Inverter current circulates within the bridge switches.

B. Interval 2: Power interval

Fig. 3(b) showing the equivalent circuit during power interval. Here inverter current enters or leaves through switch node terminal S. Switches S_1-S_2 or S_3-S_4 turned. Diode is forward biased. Power delivered to both ac and dc loads.

C. Interval 3: Zero interval

Fig. 3(c) showing the equivalent circuit during zero interval. Here diode is in forward biased condition and power delivered to dc load. Inverter current circulates within the bridge switches [13-14].

IV. SIMULINK MODEL OF BOOST DERIVED HYBRID CONVERTER (BDHC)

For simulation of the proposed hybrid converter Parameters of the different circuit components are taken as: Input inductor (L) =5mH, DC capacitor (C) =1 mH, AC filter inductor (L_{ac}= L_{ac1} +L_{ac2}) =500μH, AC filter capacitor (C_{ac}) =10μF, DC load R_{dc} = 20Ω, AC load R_{ac}=10 Ω and Switching frequency is taken as 20 KHz.

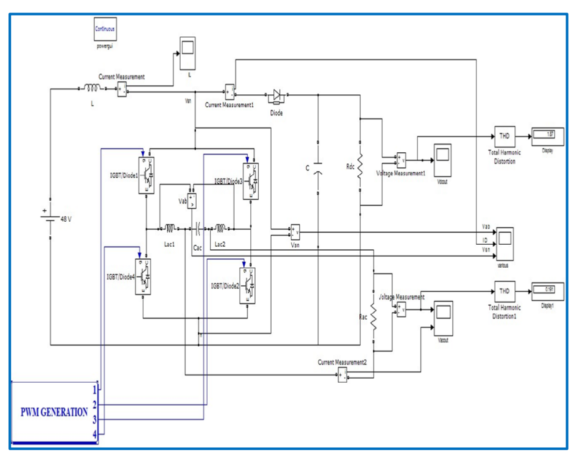


Fig. 5 Simulink model of Boost derived Hybrid converter.

V. SIMULINK MODEL OF PWM GENERATION CIRCUIT

Fig. 5 shows the Simulink model for the modified unipolar PWM control strategy. The signals shown in Fig.6 provided to gates of the controllable switches S_1-S_4. (t) A DC signal controls the duration of shootthrough interval, hence adjust the duty cycle for the boost operation. (t) Controls the modulation index for inverter operation. Fig. 7(a) and (b) shows the DC and AC output voltage waveform. DC voltage gain can be achieved by BDHC is equivalent to boost converter, and is around four to five [7]. Maximum value of AC voltage is equal to input voltage.

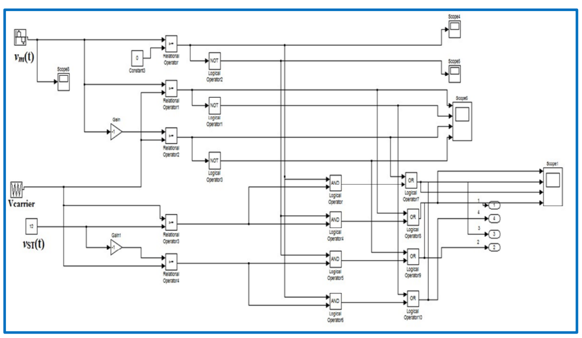


Fig. 6 Simulink model of PWM

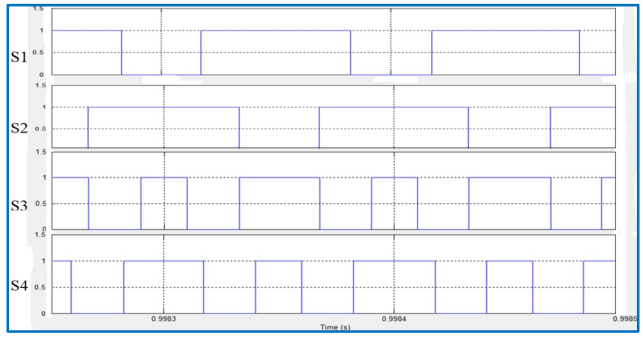
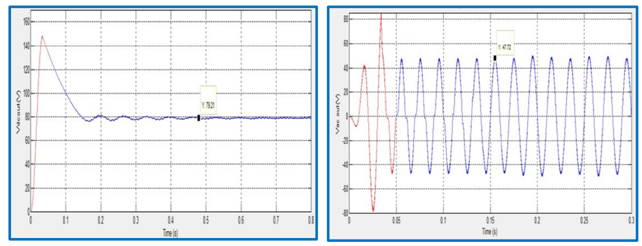


Fig. 7 Control signals to the S_1-S_4



(a) (b)

Fig.8 (a) Output DC voltage waveform, (b) Output AC voltage waveform.

VI. BUCK-BOOST DERIVED HYBRID CONVERTER (BBDHC)

The Buck-Boost Derived Hybrid Converter (BBDHC) is derived from the single switch controlled BuckBoost converter by replacing the controlled switch with voltage source inverter (VSI), either single phase or three phase. Fig. 8 shows the Simulink model for the BBDHC. The same control strategy used in the Boost Derived Hybrid Converter (BDHC) can be used for the control of BBDHC. The modes of operation of BBDHC is similar to that of BHDC. The limitation of Voltage control below input voltage in boost converter can be avoided with BBDHC.

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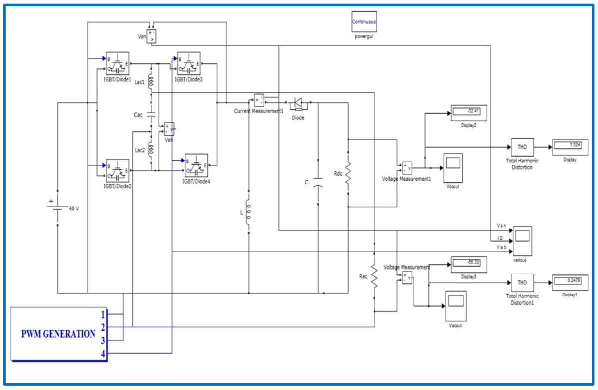
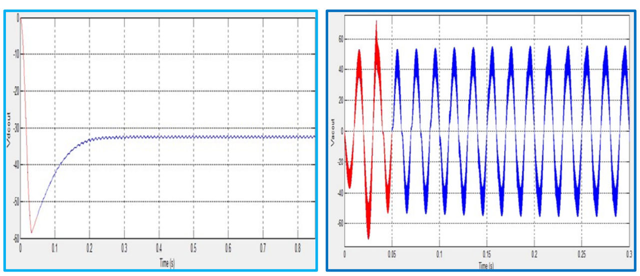


Fig.9 Simulink model of Buck-Boost derived hybrid converter.

VII. SIMULATION RESULTS

Fig. 9(a) and (b) shows the DC and AC output voltage waveform. Similar to Buck-Boost Converter DC

voltage is negative with respect to common DC link.



(a) (b)

Fig.10 (a) DC output voltage waveform, (b) AC output voltage waveform

VIII. CONCLUSION

This paper proposes new Hybrid converter topologies which can supply simultaneously both DC and AC loads from a single DC supply. The two hybrid converter topologies discussed in this paper are Boost Derived Hybrid Converter (BDHC) and Buck-Boost Derived Hybrid converter (BBDHC).The proposed hybrid converters has the following advantages, shoot-through condition does not cause any problem on working of the circuit hence improves the reliability of the system, Implementation of dead time circuitry is not needed, Independent control over AC and DC output and the converter can also be adapted to generate AC outputs at frequencies other than line frequencies by a suitable choice of the reference carrier waveform.

Limitations on voltage gain obtained by a BDHC can be achieved by BBDHC topology. In case of BDHC, for an input Voltage of 48V, maximum DC output voltage obtained is 190 V (THD=25.99%). Maximum AC voltage obtained as same as input voltage i.e. 48V AC (rms) (THD=18.65%). In order to obtain AC voltage levels higher than the input voltage a step up transformer need to be interfaced with the hybrid converter.

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