High Gain Buck-Boost Derived Converter for Simultaneous DC & AC Applications

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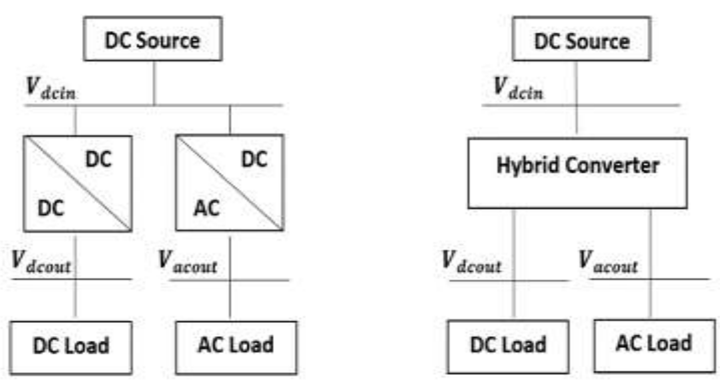
Abstract— This Paper introduces new hybrid converter topologies which can supply simultaneously AC as well as DC from a single DC source. The new Hybrid Converter is derived from the single switch controlled high gain Buck-Boost converter by replacing the controlled switch with voltage source inverter (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. Switches are controlled using 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 96 V and 48 V respectively from a 48 V DC source.

Keywords— DC Nanogrid, Voltage source inverter(VSI),Shoot through, High gain Buck-Boost Converter, Buck-Boost Derived Hybrid Converter, Unipolar PWM, KY Converter,

INTRODUCTION

Nanogrid architectures are greatly incorporated in the modern power system. In this system there is DC as well as AC loads supplied by different kinds of energy sources using efficient power electronic converters. 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.



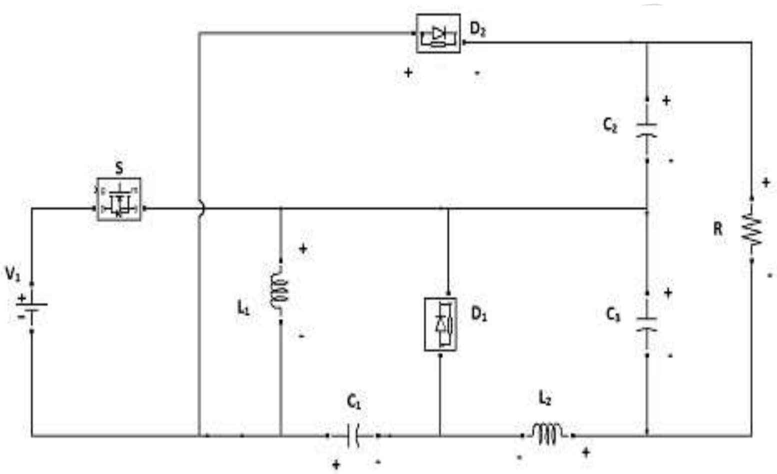
(a) (b)

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

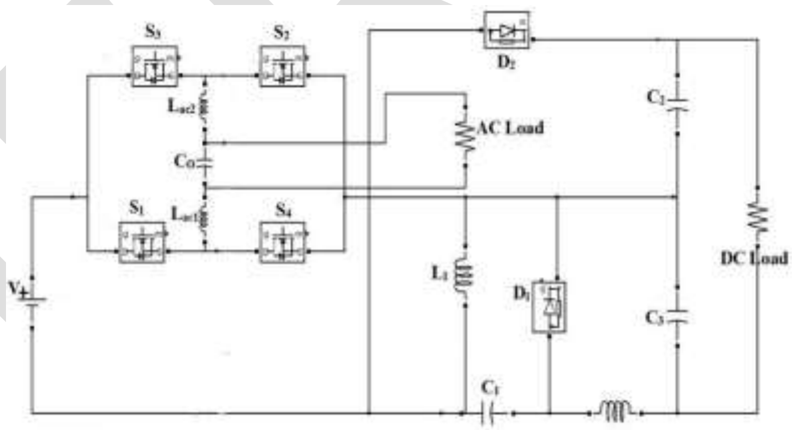
The conventional VSI in Hybrid converter would involve the use of dead time circuitry to avoid the shoot-through. Also misgating turn-on of switches may take place due to spurious noise resulting in damage of switches. For a compact system spurious signal generation is a common. So VSI in such application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

BUCK-BOOST-DERIVED HYBRID CONVERTER

The circuit configuration of the high gain converter is shown in Figure 2(a). As shown in Figure 2(a), the converter consists of three capacitors, two inductors, one power switch and two diodes. Capacitors C_1 and C_2 are in parallel by two diodes. Their voltages are both D / (1 - D) times of the input voltage. The voltage of the capacitor C_3 is also determined by the capacitor C_1 and the input voltage which is also D / (1 -D) times of the input voltage. The load is connected in parallel with capacitors C_2 and C_3. Therefore the output load voltage will be 2D / (1-D) times of the input voltage.



(a)



(b)

Fig 2. (a) High gain buck-boost converter, (b) Proposed Buck-Boost Derived Hybrid converter obtained by replacing S with a single phase bridge network.

High gain buck-boost circuit is having one switch [1-6], which is a controllable switch (controls the duty cycle). Hybrid converter can be realized by replacing controllable switch in the buck-boost circuit with a voltage source inverter, either single phase or three phase VSI. The resulting converter called as Buck-Boost Derived Hybrid converter (BDHC) [10]. AC and DC outputs are controlled using same set of switches (S1-*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 of input DC power to DC as well as AC loads (c) Determination of voltage and current stresses across various switches.

OPERATION OF BUCK-BOOST DERIVED HYBRID CONVERTER

The buck-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 of the high gain buck-boost converter

The ac output is controlled using a modified version of the unipolar sine width modulation. The hybrid converter during inverter operation has the same circuit switching states as the conventional VSI.

The hybrid converter has four distinct switching states as described below:

Mode 1

During the time interval, the switches S_1 and S_4 is turned on and the diodes (D_1, D_2) are turned off. As seen in Fig. 3(a), the inductor L_1 is energised via input voltage. As it is shown in Fig.3a, the inductors L_2 is also linearly magnetised by capacitors C_1, C_3 and the input voltage. Besides, the energy stored in the capacitorsC_2 and C_3 are discharged to the load.

B.Mode 2

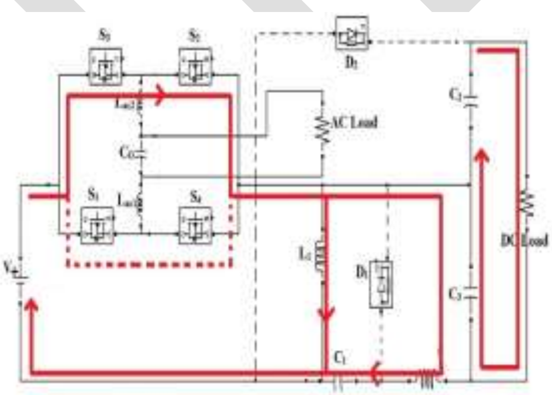
Fig. 3(b) showing the equivalent circuit during power interval. Here inverter current enters or leaves through switch node terminal S. Switches S_3-S_4 or S_1-S_2 turned. Diode is forward biased. Power delivered to both ac and dc loads. The inductor L_1 is energised via input voltage. As it is shown in Fig.3a, the inductors L_2 is also linearly magnetised by capacitors C_1, C_3 and the input voltage. Besides, the energy stored in the capacitors C_2 and C_3 are discharged to the load.

C.Mode 3

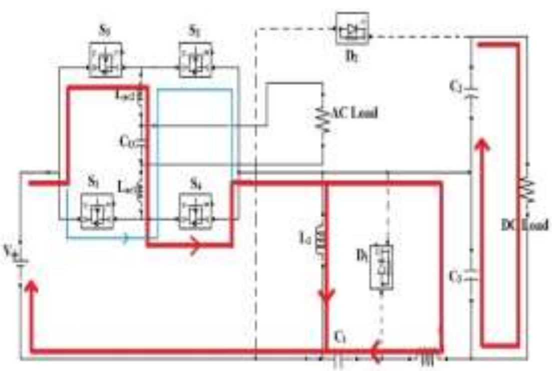
During the time interval, S_1-S_3 or S_2-S_4 is turned on and D_1 is turned on and D_2 is still turned off. As seen in Fig.3(c), the capacitors C_1 and C_3 are charged via inductors L_1 and L_2, respectively. All of inductors are demagnetised linearly also, the energy stored in capacitor C_2 is discharged to the load. Inverter current circulates within the bridge switches.

D.Mode 4

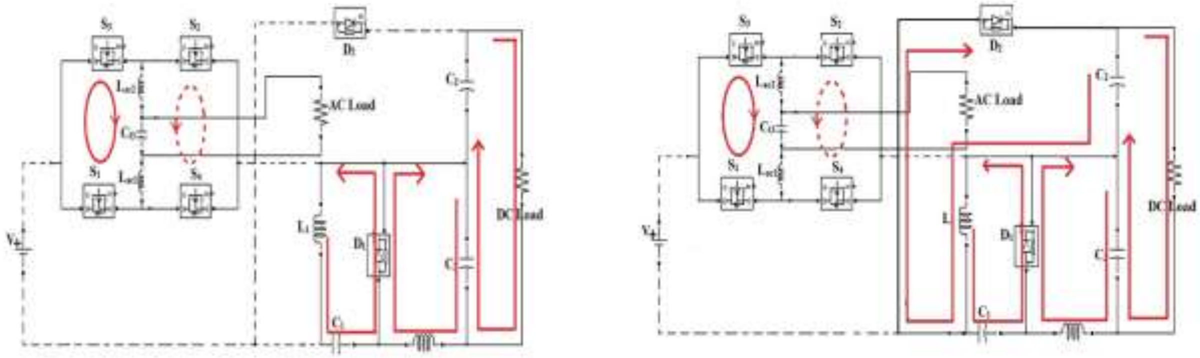
During the time interval S_1-S_3 or S_2-S_4 is turned on. The voltages of the capacitors C_1 and C_2 are equal, so D_2 is turned on as well as D_1. The current flow path is shown in Fig.3 (d). As the voltages of capacitors C_1 and C_2 are the same, the voltage across D_2 becomes zero and after a moment it is changed to positive. Therefore D_2 can be turned on. Then, capacitors C_1 and C_2 are in parallel. It is shown in Fig. 2a that the voltages of capacitorsC_1 and C_2 are the same. The capacitors C_1 and C_2 are charged by the inductor L_1. Also, the inductor L_2 charges the capacitor C_3. All of the inductors are demagnetised linearly at this mode. Inverter current circulates within the bridge switches.



(a)



(b)



(c) (d)

Fig 3. (a) Mode 1 operation (b) Mode 2 operation (c) Mode 3 operation (d) Mode 4 operation

SIMULINK MODEL OF BUCK-BOOST DERIVED HYBRID CONVERTER

For simulation of the proposed hybrid converter Parameters of the different circuit components are taken as: Inductor (L_1) =1.2mH, (L_2) =970μH.DC capacitors C_1= C_3=100μF, C_2= 650 μF. AC filter inductor (L_{ac} = L_4+ L_5) =500μH, AC filter capacitor (C_{ac}) =10μF, DC load R_{dc} = 20Ω, AC load R_{ac} =10 Ω and Switching frequency is taken as 30 KHz.

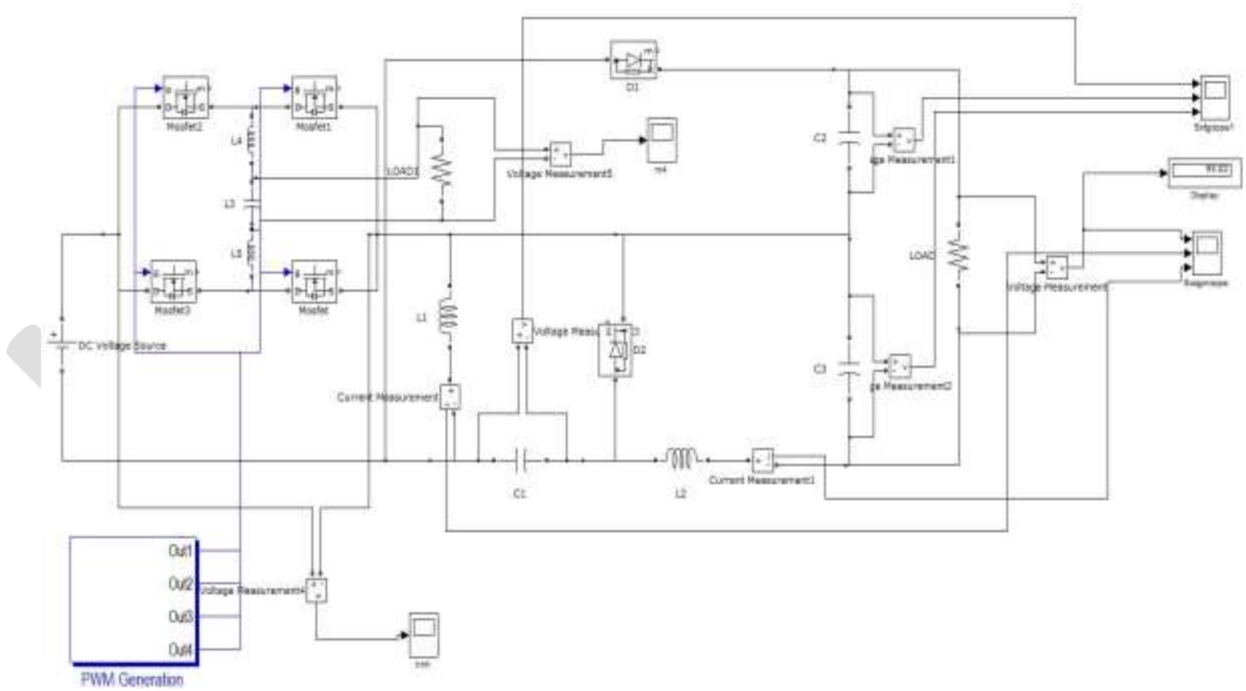


Fig. 4 Simulink model of Boost derived Hybrid converter.

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. V_{st} a DC signal controls the duration of shoot through interval, hence adjust the duty cycle for the boost operation. $V_m(t)$ 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 the converter is equivalent to boost converter, and is around three [7]. Maximum value of AC output voltage is equal to input voltage.

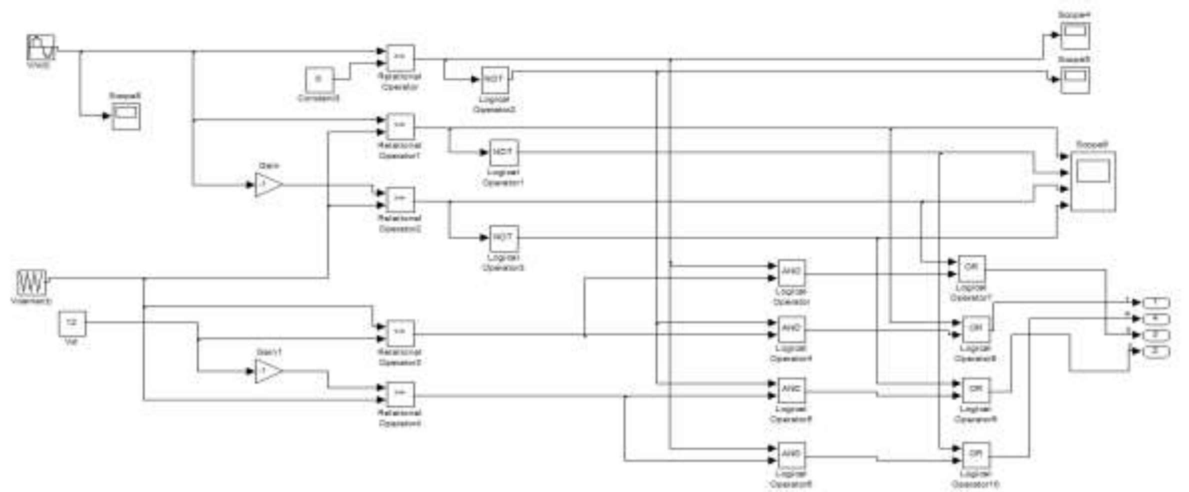


Fig. 5 Simulink model of PWM generation circuit

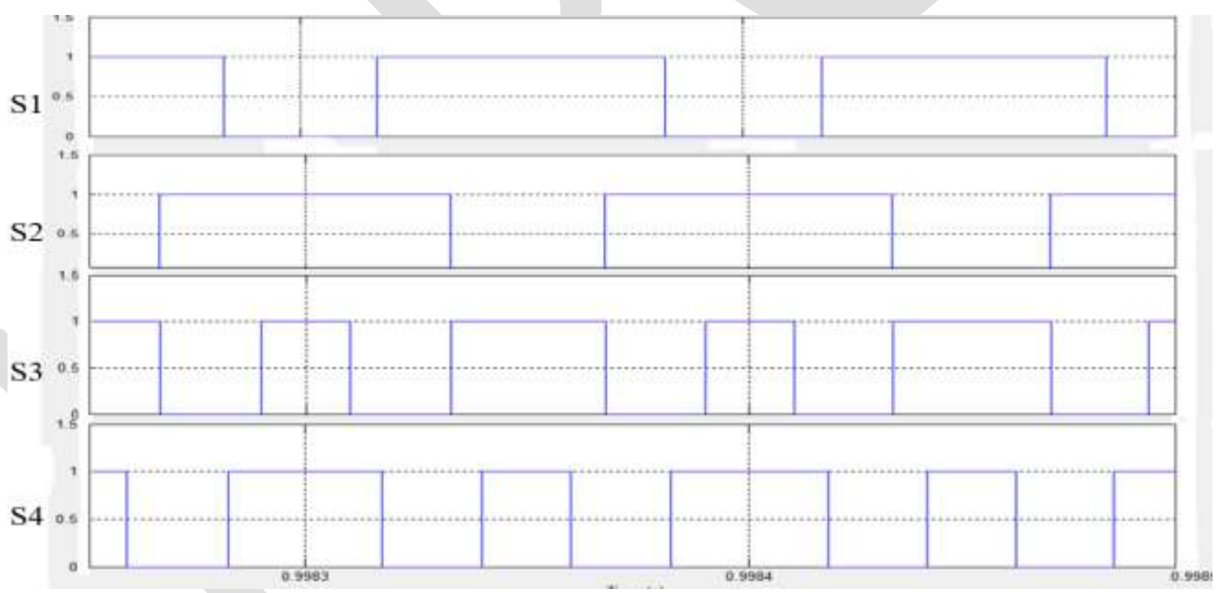
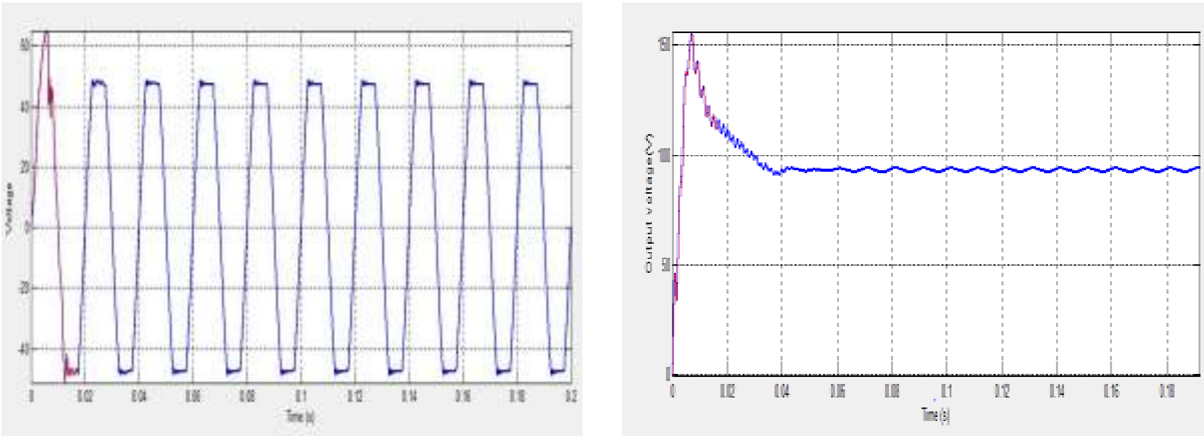


Fig. 6 Control signals to the switches S1-S4



(a) **(b)**

Fig.7 (a) Output AC voltage waveform, (b) Output DC voltage wave

CONCLUSION

This paper proposes new Hybrid converter topologies which can supply simultaneously both DC and AC loads from a single DC supply. The hybrid converter topology discussed in this paper is 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.

In case of hybrid converter, for an input Voltage of 48V, maximum DC output voltage obtained is 96V. Maximum AC voltage obtained as same as input voltage i.e. 48V AC. 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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