A NEW STUDY AND IMPLEMENTATION OF BOOST DERIVED HYBRID CONVERTER

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Abstract—Due to the decade of fossil fuels, 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 converter by replacing the controlled switch with Voltage Source Inverter (VSI). It 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 implemented. The proposed system is to introduce a family of hybrid converter topologies capable of simultaneously supplying AC and DC loads and to characterize the steady state behavior of the Boost Derived Hybrid Converter (BDHC) topology. It is also help to develop a PWM control scheme for the BDHC and to compare the performance of the BDHC with conventional designs. The main objective is to validate the static and dynamic performance of the BDHC using an experimental prototype and to extend the proposed philosophy to higher order boost converters in order to achieve a higher conversion ratio.

Keywords—PWM modulated converters, Boost derived hybrid converters, DC-DC converters, DC-AC converters, Voltage source converter.

I. INTRODUCTION

Today, power electronics is a rapidly expanding field in electrical engineering and a scope of the technology covers a wide spectrum of electronic converters[8]. Different kinds of power supplies are used everywhere in normal daily routines both at home, office work or in an industrial environment. This is due to the progress in electronic components and equipment development that has been achieved in the last few decades[11]. Electronic and electrical apparatus are everywhere, and all these devices need electrical power to work. Most of electronic supplies are switching semiconductor converters thanks to the efficiency, size, capability to operate at various current and voltage levels, control features and price compared to the linear power supply.

Power electronic converters are switch-mode circuits that process power between two electrical systems using power semiconductor switches. The electrical systems can be either DC or AC. Therefore, there are four possible types of converters; namely DC/DC, DC/AC, AC/DC, and AC/AC. The four converter types are described below:

1. DC/DC Converter

DC/DC Converter is also known as “Switching Regulator”. The circuit will change the level voltage available from a DC source such as a battery, solar cell, or a fuel cell to another DC level, either to supply a DC load or to be used as an intermediate voltage for an adjacent power electronic conversion such as a DC/AC converter. DC/DC converters coupled together with AC/DC converters enable the use of high voltage DC (HVDC) transmission which has been adopted in transmission lines throughout the world.

2. DC/AC Converter

DC/AC Converter described as “Inverter” is a circuit that converts a DC source into a sinusoidal AC voltage to supply AC loads, control AC motors, or even connect DC devices that are connected to the grid. Similar to a DC/DC converter, the input to an inverter can be a stiff source such as battery, solar cell, or fuel cell or can be from an intermediate DC link that can be supplied from an AC source.

3. AC/DC Converter

This type of converter is also known as “Rectifier”. Usually the AC input to the circuit is a sinusoidal voltage source that
operates at 120 V, 60 Hz or a 230 V, 50 Hz, which are used for power distribution applications. The AC voltage is rectified into a unidirectional DC voltage, which can be used directly to supply power to a DC resistive load or control a DC motor. In some applications the DC voltage is subjected to further conversion using a DC/DC or DC/AC converter. A rectifier is typically used as a front-end circuit in many power system applications. If not applied correctly, rectifiers can cause harmonics and low power factor when they are connected to the power grid.

4. AC/AC Converter

This circuit is more complicated than the previous converters because AC conversion requires change of voltage, frequency, and bipolar voltage blocking capabilities, which usually requires complex device topologies. Converters that have the same fundamental input and output frequencies are called "AC controllers". The conversion is from a Fixed Voltage Fixed Frequency (FVFF) to a Variable Voltage Fixed Frequency (VVFF). Applications include: light dimmers and control of single-phase AC motors that are typically used in home appliances. When both voltage and frequency are changed, the circuits are called "Cycloconverters", which convert a FVFF to Variable Voltage Variable Frequency (VVVF) and when fully controlled switches are used, this class of circuit is called "Matrix Converter". Another way of achieving AC/AC conversion is by using AC/DC and DC/AC through an intermediate DC link. This type of combined converter approach can be complex as the correct control approach must be implemented including simultaneous regulation of the DC link, injection of power with a prescribed power factor and bidirectional control of energy flow.

II. LITERATURE SURVEY

The main objective of the project is to analyze the hybrid interlink converter based micro grid for distribution system. The following papers helped in this work.

Switched Boost Inverter is a single stage DC-AC power converter, whose output voltage can be either greater or less than its input DC voltage [6]. This converter can supply both DC and AC loads, simultaneously, which makes it suitable for micro grid applications. Also, this converter allows shoot-through of the inverter legs without causing any damage to the converter. The principle of operation of the Switched Boost Inverter is explained in detail and the expression for its conversion ratio is derived. Also, a Pulse Width Modulation (PWM) control strategy for the Switched Boost Inverter is formulated and implemented using a simple analog circuit[9].

The topology, consisting of a Quadratic Boost Converter based Voltage Source Inverter (VSI), can achieve high conversion ratio both in inverter as well as rectifier operations without the use of a transformer [3]. In addition, the same architecture can also be used to realize DC-DC conversion (both Step-Up and Step-Down). This improves the adaptability of the topology in renewable system realization, especially in rural areas, and makes it suitable to handle variable input sources.

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Two maximum constant boost control methods [7] for the Z-source inverter, which can obtain maximum voltage gain at any given modulation index without producing any low-frequency ripple that is related to the output frequency. Thus the Z-network requirement will be independent of the output frequency and determined only by the switching frequency.

III. BOOST DERIVED HYBRID CONVERTER

The family of hybrid converter topologies which can supply simultaneous DC and AC loads from a single DC input. These topologies are realized by replacing the controlled switch of single-switch boost converters with a voltage-source-inverter bridge network [8]. The resulting hybrid converters require lesser number of switches to provide DC and AC outputs with an increased reliability, resulting from its inherent shoot-through protection in the inverter stage.

A. Principle of Operation

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) [1]. 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 [1]. This is equivalent to shoot-through switching condition as far as VSI operation is concerned, and it is strictly forbidden in the case of a conventional VSI. 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,
described. The BDHC, during inverter operation, has the same circuit states as a conventional VSI \(^{10}\). The reason for this is as follows: For conventional VSIs, 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 a power transfer with the source \(^{2}\). 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.

Fig 1. Block Diagram of BDHC

**B. Derivation of BDHC Topology**

The control switch Sa of a conventional boost converter shown in Figure 2(a) has been replaced by the bidirectional single-phase bridge network switches (Q1–Q4) to obtain the BDHC topology shown in Figure 2(b). This proposed converter provides simultaneous AC output \(v_{acout}\) in addition to the DC output \(v_{dcout}\) provided by the boost converter.

For the BDHC, the hybrid (DC as well as AC) outputs have to be controlled using the same set of four controlled switches Q1–Q4. Thus, the challenges involved in the operation of BDHC are the following: 1) Defining the duty cycle \(D_{st}\) for boost operation and the modulation index \(M_a\) for inverter operation. 2) Determination of voltage stresses and currents through different circuit components and their design. 3) Control and channelization of total input power to both AC and DC loads.

**C. Operation of BDHC**

The schematic of the BDHC with the reference current directions has been shown in Figure 2(b). The continuous conduction mode of operation has been assumed (the boost inductor current \(i_L\) never goes to zero). In lower case letters represent instantaneous values, upper case letters represent DC or RMS values, lower case letters with tilde represent the AC component and lower case letters with represent the peak value of the variable.

**C. Modified Unipolar PWM Strategy ForBDhc**

The fundamental principle behind the operation of BDHC is based upon the fact that the inverter bridge input must be connected to a positive voltage during the power interval only.

Fig 2.(a) Conventional Boost Converter. (b) Proposed BDHC Obtained By Replacing Sa with a Single-Phase Bridge Network.

This means that the inverter output has to be modulated when \(V_{sn} = 0\) and boost operation occurs when \(V_{ab} = 0\). The inverter output voltage assumes three different values, and hence, the PWM modulation strategy used is based upon unipolar sine-PWM scheme, which provides three voltage levels for output. The PWM control scheme for the BDHC is based upon the switching scheme proposed. 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. As shown in the Figure, turning on all the switches for shoot-through involves more switching during each switching period with their associated losses. The reliability of the circuit also reduces since the time between two successive switching is dependent on \(t_z\), which can be close to zero. This may be
impractical considering minimum switching times for the devices used.

D. Implementation and Control of BDHC

The reference signals to the PWM generation circuit are \( V_{\text{me}}(t) \) and \( V_{\text{ST}(t)} \). The signals S1–S4 are provided to the gates of the controlled switches. \( v_{\text{ST}(t)} \), a DC signal, controls the shoot-through period, and hence, the duty ratio \((D_{\text{st}})\) for the DC output of the boost converter and \( v_{\text{m}(t)} \) controls the modulation index \((M_a)\) for the inverter.

![Implementation of the PWM Scheme](image)

Fig 3. Implementation of the PWM Scheme

E. Steady-State Analysis

**Gain Expression for DC and AC Outputs:** Similar to conventional boost converters, the DC output of the BDHC can be regulated using the duty cycle, denoted by \( D_{\text{st}} \), and is defined as the shoot-through time interval in a switching cycle, as shown in Figure 3. For the purpose of analysis, we assume that the output DC capacitor voltage and the input inductor current have small ripple compared to their DC values. Hence, the expression for the voltage gain of the DC output is similar to that of a boost converter and can be derived as

\[
\frac{V_{\text{dout}}}{V_{\text{dcin}}} = \frac{1}{1 - D_{\text{st}}}
\]

(1)

The modulation index, denoted by \( M_a (0 \leq M_a \leq 1) \), regulates the AC output voltage of the BDHC, and its definition is similar to that associated with conventional VSIs. The peak output AC voltage is related to the input as

\[
\frac{V_{\text{acout}}}{V_{\text{dcin}}} = \frac{M_a}{1 - D_{\text{st}}}
\]

(2)

The maximum DC output gain achieved using the BDHC is similar to that of boost converters and is around four to five. The AC gain increases with the increase of modulation index \((M_a)\) for any fixed value of duty cycle \( D_{\text{st}} \). As the same set of switches controls both the DC and AC outputs, there is limitation to the maximum duty cycle or modulation index that can be achieved for this topology. The switching strategy must satisfy the following constraint:

\[ M_a + D_{\text{st}} \leq 1 \]

(3)

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. The resulting converter, called BDHC.
IV. RESULT AND DISCUSSION

A. Input Side

The input voltage of 48 V DC for the steady-state open-loop behavior of the BDHC is shown in the Fig. 5. It is for the switching controls of the PWM signals.

B. PWM Generation

It shows the gate control signals for the BDHC switches and the resulting switch node voltage \( v_{sn} \). The control schematic has been used for the generation of the gate signals. The waveforms validate that, whenever the switches S1 and S4 or S2 and S3 are “on” at the same time, \( v_{sn} = 0 \). This interval refers to shoot-through, and it controls the DC output. The AC output is modulated using the reference signal \( v_m(t) \).

C. AC and DC output

Fig. 7 and Fig. 8 given below shows the steady-state open loop behavior of the BDHC. For an input voltage of 48 V DC, the output DC voltages achieved are 75.4 V and 108 V DC for duty cycles of 0.4 and 0.6, respectively. The AC output is 30 V (rms) for modulation indices of 0.6 and 0.4, respectively. From these results, it is validated that, when the equality condition of relation (3) is maintained, for any value of duty (\( D_s \)), the magnitude of the AC output voltage is always 0.707 times the input voltage. Here, the DC and AC loads are 30 and 9 \( \Omega \), respectively. Hence, the prototype serves 390-W DC and 110-W AC loads approximately.

V. CONCLUSION

The proposed converter called boost-derived hybrid converter (BDHC) as it is obtained from the conventional boost topology. The steady-state behavior of the BDHC has been simulated in this paper. A suitable pulse width modulation (PWM) control strategy, based upon unipolar sine-PWM results has been generated and verified. A DSP-based feedback controller is designed to regulate the DC as well as AC outputs. The proposed converter is calculated and simulated so as to able to supply DC and AC loads at 100 V and 110 V (rms), respectively, from a 48-V DC input. The performance of the
converter is demonstrated with inductive and nonlinear loads Simulink blocks and design. The converter exhibits superior cross-regulation properties to dynamic load-change events. The proposed concept has been extended to quadratic boost converters to achieve higher gains.

It has proposed hybrid power converter topologies which can supply simultaneous DC and AC loads from a single DC input. The various advantages of using this single converter stage like shoot-through protection have been described and compared to traditional VSIs. It has been shown that a class of converters can be achieved by describing the BDHC and QBDHC. The cross-regulation behavior of the converter has been studied along with its behavior to different load types. Experimental results of the operation of the BDHC in an open loop using MATLAB SIMULINK was tested and verified.

REFERENCES


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