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Concurrent Feeding of AC/DC Loads Using Enhanced Topology

Nitendra kumar Tiwari and Bhanu Pratap Singh***

ABSTRACT

In this study, a novel hybrid converter topology is shown that can simultaneously supply both DC and AC loads in a single phase. The controlled single switch of the step-up converter can be replaced with a VSI bridge network to create this architecture. This study examines the use of a single step-up (boost) stage architecture to support hybrid loads. This new hybrid converter topology requires fewer switches than the conventional approach. The suggested architecture will improve dependability since it has a built-in feature called shoot through at the VSI stage. The regulated PWM technique is being assessed and modified to acquire the right duty cycle in order to study the behaviour of the BDHC topology. Simulink has been used to construct the integration of a solar panel and a dc battery as a dc input source, and it has been tested to make sure the BDHC architecture is functioning properly. Multiple Simulink models were compared for various duty cycles in order to study the output nature of various sorts of loads.

Keywords: *Solar Panel; Pulse Width Modulation (PWM); Shoot-through; Voltage Source Inverter (VSI); Boost Derived Hybrid Converters (BDHC).*

1.0 Introduction

Over the past 20 years, numerous new renewable energy technologies have been developed and are being employed in both urban and rural areas. There are a variety of commercially accessible renewable energy systems and technologies. The whole range of cutting-edge technologies, including upgraded solar thermal and solar photovoltaic systems, hydrogen energy, fuel cell-driven systems, and electric vehicle systems, among others, will be covered in a planned series of future events on renewable and sustainable energy [3]. Global climate change is rapidly escalating due to the increase in electrical energy consumption brought on by population growth and technological improvements, the depletion of fossil resources, and environmental issues such urban air pollution. Modern progress in the field of hydrogen-powered applications reveals hydrogen as a necessary energy-carrier for the hydrogen economy. As the hydrogen economy grows in the future, future energy models could include renewable energy sources that can be used to make hydrogen, and energy needs might be met by combining renewable energy and fuel cell systems in hybrid topologies.

Different DC/DC and DC/AC converters must be used to provide DC & AC loads because they are both connected to the DC power system. Hybrid converters, which combine DC & AC converters, can still be utilised for DC grids [1].

**Correspondign author; Phd Research Scholar, Department of Electronics & Instrumentation, NIT SILCHAR, India (E-mail: nitintiwari22@gmail.com)*
***Phd Research Scholar, Department of Computer Science, Rama University, Kanpur, Uttar Pradesh, India (E-mail: bhanurai0@gmail.com)*

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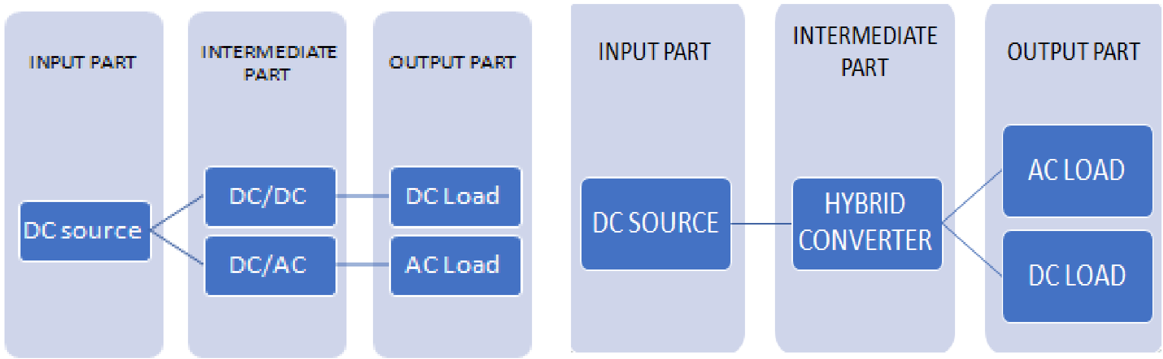
Figure 1: Block Diagram Representation: (a) Conventional Converter Topology (b) New BDHC Topology



Higher gain is achieved by extending the number of stages in a converter cascade, but this comes at the cost of increased switch voltage stress, inductor count, and capacitor voltage [2]. The concept of nano or micro grids is being rapidly incorporated and applied in modern smart power systems. For specialists like technicians, engineers, and scientists, photovoltaic technology holds up the prospect of an exciting and hopeful future in the current environment [3].

The systems mentioned above can be interfaced with a number of traditional and unconventional energy sources thanks to their many loads, including DC and AC loads [4]. To make this connection, power electronic converters are employed. To drive both dc and ac loads concurrently from a single dc input in a single step, a novel BHDC architecture can be constructed in light of this [4]. Figure 1(b) depicts the schematic diagram of a hybrid system, where both DC and AC loads are supplied by a single dc source. It is possible to use a battery, solar panel, or fuel cell stack as the input dc supply.

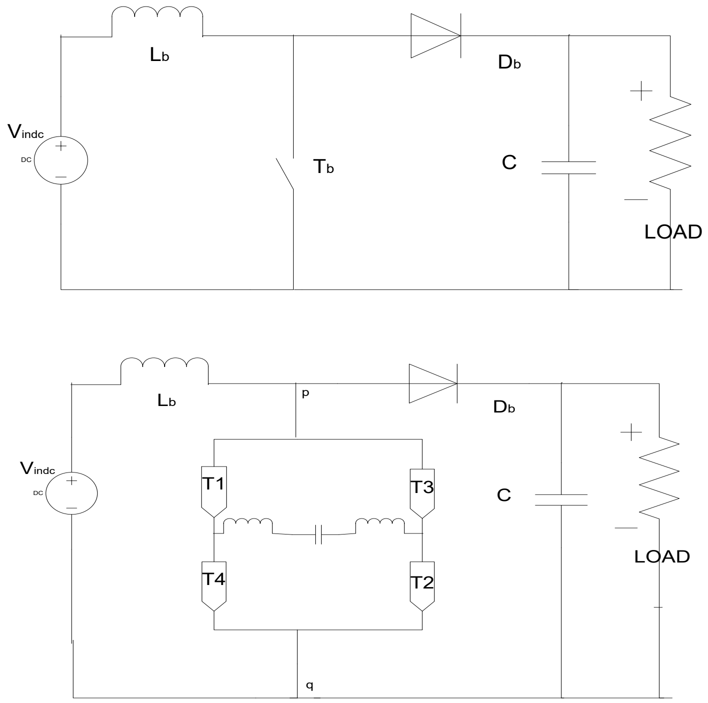
Figure 1(b) illustrates the usage of a single conversion step to complete each conversion, in contrast to Figure 1(a), which depicts the employment of different converters in each conversion stage (DC-DC conversion and DC-AC conversion). The aforementioned design is referred to as a hybrid converter since it naturally shoots through at the VSI stage, making it more reliable. The aforementioned topology provides a high density for power processing when compared to the two conversion stage converters. With all of these improvements in the new hybrid design, a compact system that can operate both DC and AC systems simultaneously is produced.

2.0 BDHC Arrangement

A conventional VSI network replaces the regulated single switch in a traditional step-up (boost) converter [5]. This architecture supports the development of renewable energy systems in rural areas and is made to work with a range of input sources. In order to have simultaneous ac and dc outputs, the VSI network is implemented in place of control switch "Tb" of a traditional boost converter [6]. The hybrid outputs for BDHC have been accomplished using a group of four controlled switches (T1-T4). The following questions are asked of the BDHC operation: I Duty cycle controls boost operation (Dct). (ii) Modulation index (Mb) [11] defines inverter functioning. The following parts will look at each of the aforementioned interrogations.

3.0 Operation of BDHC

Figure 2: (i) Circuit of Conventional Step-Up Converter (ii) Redesigned Hybrid Converter Obtained by Implementing VSI in Place of Ta



3.1 Operating principle and steady state analysis

By simultaneously gating on each switch of a certain leg (T1-T4) or (T3-T2), the shoot through switching can be implemented. It will facilitate the upgraded BDHC's step-up operation. The aforementioned procedure is comparable to turning on the step-up converter's switch Tb, though. As described in more detail in the following section, a modified PWM approach has been used to control the AC output in this new BDHC topology. Only dc input voltage is needed during the power interval, or when power is being transferred from the source. There is no requirement for a fixed dc input voltage because the freewheeling current passes through the inverter switches at additional intervals (i.e. it can be zero). The output of a dc load of a Boost Derived Hybrid Converter can be adjusted like with traditional boost converters by varying the duty cycle (D_{ct}). The duty cycle is the time interval between shoot-throughs in a switching cycle (D_{ct}) [7]. The voltage gain expression for output of dc load is same as that of step-up converter and it is given as:

$$\frac{V_{outdc}}{V_{indc}} = \frac{1}{1-D_{ct}} \quad \ldots(1)$$

The AC ourtput voltage of the BDHC can be regulated by managing the modulation index (M_b). And its value must be between 0 to 1 ($0 \leq Mb \leq 1$). The modulation index can be related as:

$$\frac{V_{outac}}{V_{indc}} = \frac{M_b}{1-D_{ct}} \quad \ldots(2)$$

The BDHC's maximum dc output gain is in the range of 4 to 5. For a specific duty cycle (D ct) value, the modulation index increases together with the gain of the ac output. Because the same set switches control both the ac and dc outputs, the maximum value of modulation index or duty cycle must have a limit, which is provided as:

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Mb +Dct≤1 …(3)

The controlling of BDHC switches must satisfy the above constraint. Equality condition of the equation (3) shows that the BDHC will achieve the maximum value of ac gain.

4.0 Implementation of PWM Control Strategy for BDHC

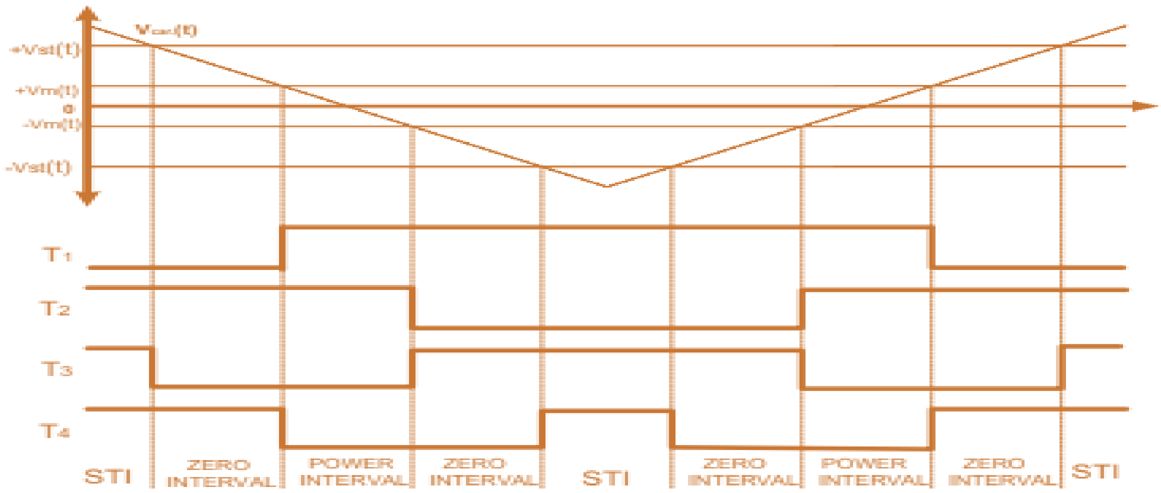
Figure 4 depicts the PWM control strategy. In this method, the switches are gated on based on the following factors to obtain the variable switching times:

Shoot-through state: |Vcar(t)|>|Vst(t)| … (4)

Zero State: $|V_M(t)|$<|Vcar.(t)|<|Vst(t)| … (5)

Power State: 0 < |Vcar(t)|<|Vst(t)| …(6)

Figure 4: Relevant Switching Pattern of PWM Scheme Applied to BDHC Topology



According to the above equations, Equation (4) shows the condition of shoot through interval. Equation (6) shows the condition of power interval in which gating signal is provided to switches of opposite leg (i.e., either T1-T2 or T3-T4 are tuned on). The zero-interval state is achieved, when the equation (5) is considered.

The switching signals are generated by satisfying the following relation (7):

$|V_{ST}(t)| >= V_M$ …(7)

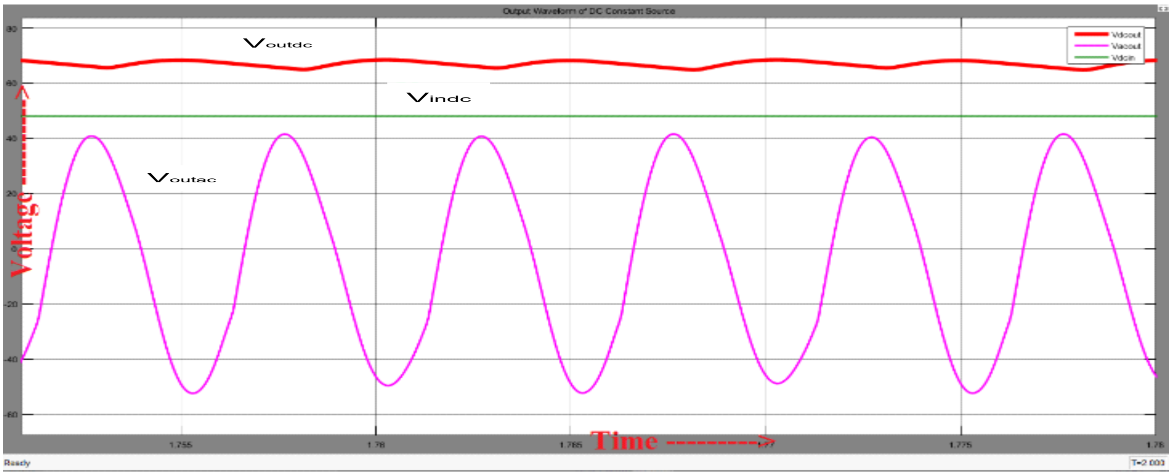
5.0 Simulation Model

The different integrated dc input source models (such as battery-integrated, solar-integrated, and fuel cell-integrated models) are implemented and analyzed using the mathematical computing programme MATLAB).

5.1 Matlab/Simulink model of BDHC for battery

The input dc source voltage is 50volts. The DC and AC output voltage obtained are 68.86 V and 34.79 V (rms) concurrently for duty cycle, D_{ct}= 0.2. While for duty cycle, Dct=0.4, the DC and AC output voltage obtained are 95.26Vand 35.09 V (rms) concurrently.

Figure 6: DC and AC Output Waveforms for Constant DC Source



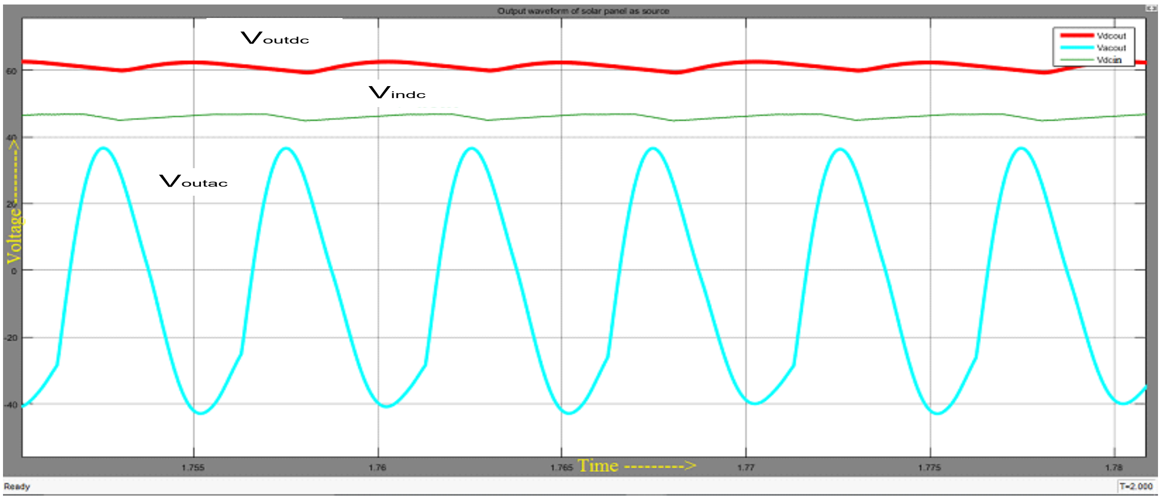
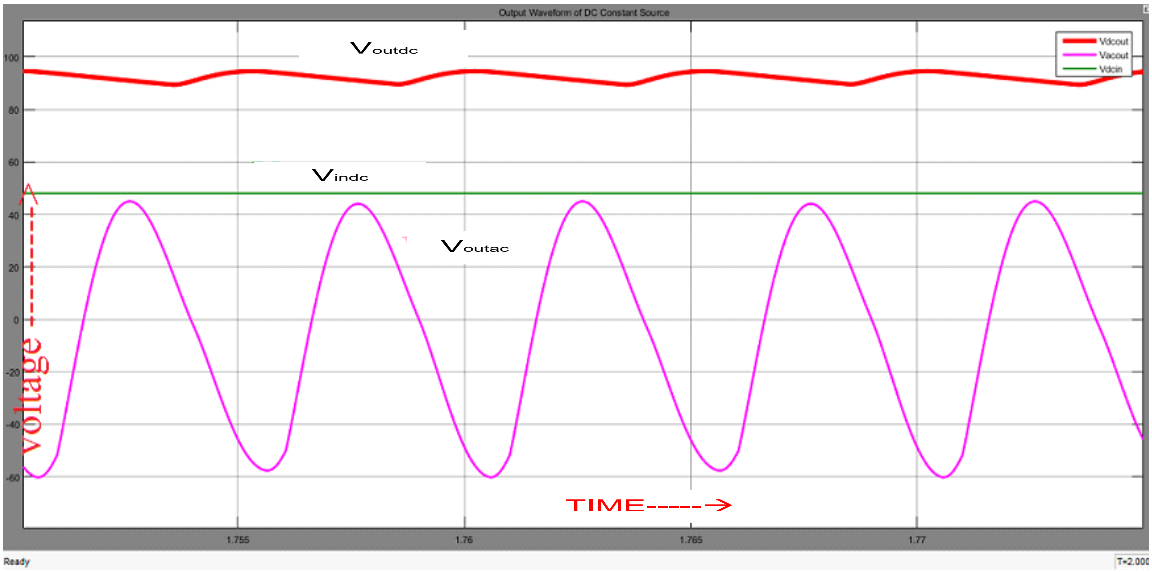


Figure 7: DC and AC Output Waveforms for Solar Panel as DC Source



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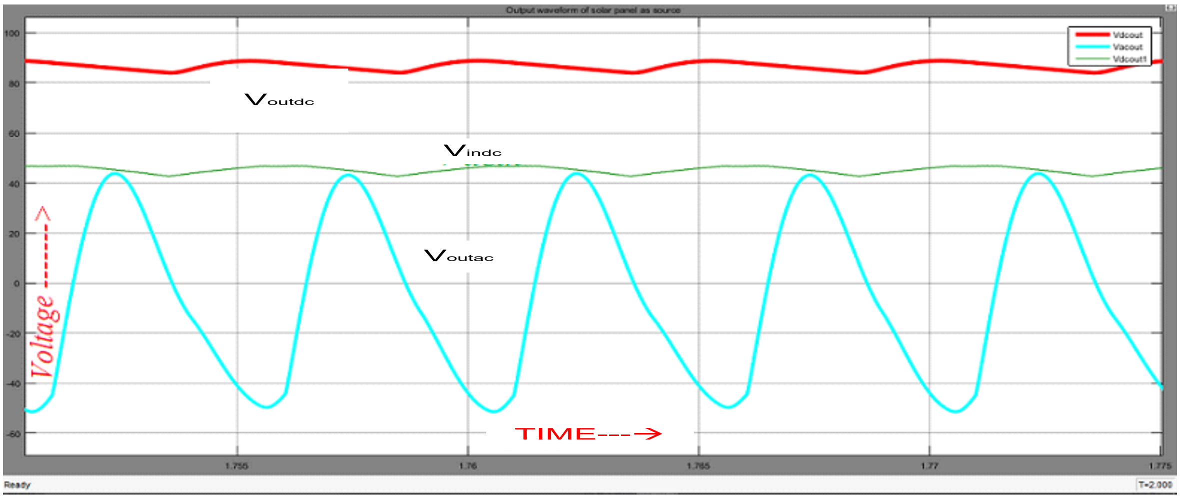

6.0 Output Results for Different Values of Duty Cycle

The tables below assess the steady state values of BDHC for various input voltage sources for various duty cycle values. The following are the parameter values for the various BDHC circuit components: - Input capacitor = 0.693 mF, input inductor = 15 mH, and DC inductor = 15 mH. With 50V as input voltage, the steady-state behaviour of the BDHC is examined for Duty cycles D st= 0.2 and D st= 0.4, demonstrating that the BDHC performs better for Duty cycle, D st=0.4 for all input voltage sources studied in this study.

Table 1: Output Values of Hybrid Converter for Battery and Solar PV on Input Side for D_{st}=0.2

Input ↓ Sources	V_{outdc}	V_{outac}	V_{outac}(rms)	V_m	V_{st}	M_b	V_{ab}
Battery	69	49	35	0.5	0.8	0.8	66.18
Solar PV	63	42	30	0.5	0.8	0.7	61.23

7.0 Conclusion

The use of a solar panel as a DC input source in an open loop in MATLAB/Simulink has been tested and proven to drive both DC and AC loads simultaneously. This Simulink model is compared to the earlier Simulink model of a constant dc source (i.e. Battery) at various duty cycles in order to assess the nature of various types of loads. The output voltage values for the battery and solar PV cell used as inputs are listed in tabular format. The aforementioned integrated dc input source models could be improved upon and studied for a feedback control system.

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