

# An Hybrid Converter Derived from SEPIC for Obtaining AC and DC Output

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**ABSTRACT:** A novel hybrid converter which is derived from SEPIC and called as SEPIC derived hybrid converter which has the ability to provide both ac output as well as dc output from a single dc input which can be carried out in a single-stage conversion is suggested. This design is obtained from SEPIC (Single Ended Primary Inductor Converter) topology in which the control switch has been replaced by a single phase inverter bridge network. The suggested topology comes with inherent shoot-through protection capability which is one of the features of this method. Both the dc and the single-phase ac outputs can be regulated independently. This topology can have applications in nano grid architecture, in modern smart residential electric power system, electric vehicles, hybrid fuel cell, aircraft power distribution system etc. In this paper, operating principle of SDHC is explained. The soundness and efficacy of suggested converter and its performance are validated by MATLAB Simulink and experimental results.

**KEYWORDS:** Single ended primary inductor converter (SEPIC), SEPIC derived hybrid converter (SDHC), Photo Voltaic (PV)

## I. INTRODUCTION

Recently, the embodiment of power electronic converters in electric cars, ships and aircrafts has seen a steep rise. The major objective is to reduce the size, weight, maintenance and operational cost of these power systems, along with increasing the efficiency, safety and reliability as well as to enable the usage of alternative energy sources (eg. fuel cells). In these applications majority of energy sources are combined to power system through the power electronic stages. These power systems are distinguished by both ac and dc loads. In most of these applications, addition to the primary power conversion, auxiliary systems needs to be powered up for effective operation of the overall system. To meet this load concern multi-output converter topologies or conventionally dc-dc converter cascaded with voltage source inverter (VSI) are used.

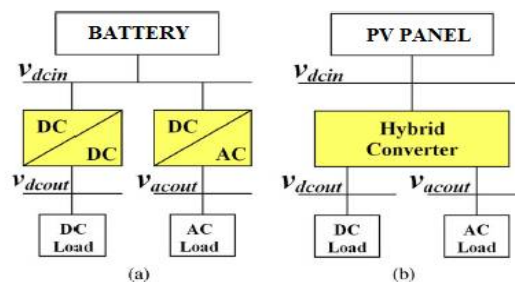


Fig. 1 Architecture with single input and simultaneous dc and ac outputs. (a) Power converter based architecture. (b) Hybrid converter based architecture

Fig.1 shows schematic diagram of a system in which a single dc source supplies to both dc and ac output. The first block diagram represents two separate stages for obtaining dc and ac loads whereas the second block diagram utilizes single stage

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conversion technique to perform both conversions. The latter is called hybrid converter which has the features of higher power processing density, improved reliability and inherent shoot through protection. These qualities make them suitable for compressed power system which has dc as well as ac loads.

The augmentation of the attempt is as follows:

A hybrid converter design has been suggested which supply ac output along with dc output from a single DC input. This design has been derived from SEPIC topology and termed as SEPIC DERIVED HYBRID CONVERTER (SDHC). A hybrid converter called Boost Derived Hybrid Converter (BDHC), has been reported in [1] which is a single stage converter capable of providing ac output and boosted dc output simultaneously.

This paper tends to extend the concept to SEPIC and also by using PV panel as the input DC source.

## II. LITERATURE SURVEY

Detailed literature review of the multiple output system is done. The operation of the SEPIC derived hybrid converter is explained based on configuration and circuit topology. Features of SEPIC derived hybrid converter system are presented using very modern, most recent ideas and methods

**O.Ray and S. Mishra, "Boost Derived Hybrid Converter with simultaneous AC and DC outputs,"***IEEE Trans. Industrial Applications.*, vol. 50, no. 2, pp. 10821093 [1]

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.

**R.Adda,S.Mishra and A.joshi "A PWM control strategy for switched boost inverter,"***in Proc IEEE ECCE, Pheonix, AZ, USA.* [2]

Switched Boost Inverter (SBI) is a single stage DC to AC power converter and it is derived from the Z - source inverter employs an LC impedance network in between the main inverter bridge and the power source. This SBI converter can possible to supply both DC and AC loads simultaneously from a single dc input source. Here, reducing the inverter switching stress. The unique feature of the SBI is that it can operate either in buck or boost mode operations with a wide range of obtainable output voltages from a given input voltage, unlike the traditional buck-type voltage source inverter. The SBI reduce the electromagnetic interference noise immunity when compared to the VSI, which enables the compact design of the power converter. Here BLDC motor drive is using as a DC load and AC load as resistive load and non linear load. The theoretical and modulation concepts presented have been verified in simulation.

**S. Upadhyay, R. Adda, S. Mishra, and A. Joshi, "Derivation and characterization of switched boost inverter, "in Proc. 14th Eur. Conf. Power Electron. Appl.EPE, Birmingham, pp. 110. [5]**

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**S. Mishra, R. Adda, and A. Joshi, "Switched-boost inverter based on inverse Watkins-Johnson topology,"***in Proc. IEEE ECCE, Phoenix, AZ,USA, pp. 42084211. [7]*

Switched Boost Inverter (SBI) is a type of power converter. It converts the power from DC-AC with boosting in a single stage. This can be applied for micro grid and nano grid applications using renewable power sources, as this converter supplies the power for DC loads and AC loads in the same time. The operation of SBI is shoot through of inverter legs without damaging the converter operation. Control signals for SBI is given through the sinusoidal pulse

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width modulation (SPWM), also it has good EMI noise immunity. The proposed Switched boost inverter is explained theoretically & simulated using MTALAB / simulink model.

## **S. Rajasekar and Rajesh Gupta, “Rapid prototyping of power electronics converters for photovoltaic system application using Xilinx System Generator,” *IET Power Electronics* [8]**

The efficient control of Distributed Energy Resources (DERs) is the key for the optimization of renewable energy supplies used in stand-alone micro-generators. A Wind / Photovoltaic combined power generator, with the possibility to incorporate a hydrogen fuel cell as energy backup or connect the system to the grid, in order to achieve reliable, self-sufficient, continuous power to variable sources and loads, is the structure tackled in this research project and the control of the integrated Wind/PV system is the scope of this paper. The research work takes advantage of the new generation of Computer Aided Design (CAD) tools, able to generate a fast hardware implementation from synthesizable high level modelling code.

## **F. Z. Peng, M. Shen, and Z. Qian, “Maximum boost control of the Z-source inverter, ” *IEEE Trans. Power Electron.*, vol. 20, no. 4, pp. 833838 [9].**

This paper explores control methods for the Z-source inverter and their relationships of voltage boost versus modulation index. A maximum boost control is presented to produce the maximum voltage boost (or voltage gain) under a given modulation index. The control method, relationships of voltage gain versus modulation index and voltage stress versus voltage gain are analysed in detail and verified by simulation and experiment.

## **D. Maksimovic and S. Cuk, “Switching converters with wide dc conversion range,” *IEEE Trans. Power Electron.*, vol. 6, no. 1, pp. 151157 [10]**

In dc-to-dc conversion applications that require a large range of input and output voltages, conventional PWM converter topologies must operate at extremely low duty ratios, which limits the operation to lower switching frequencies because of the minimum ON time of the transistor switch. This is eliminated in a new class of single transistor PWM converters featuring voltage conversion ratios with quadratic dependency on duty ratio. Practical circuit examples operating at 0.5 MHz are described.

## **D. Boroyevich, I. Cvetkovic, D. Dong, R. Burgos, F. Wang, and F. Lee, “Future electronic power distribution systems A contemplative view,” in *Proc. 12th Int. Conf. OPTIM Elect. Electron. Equip.*, Brasov, Romania, pp. 13691380 [11].**

Although it has long been argued that electronic power converters can help improve system controllability, reliability, size, and efficiency, their penetration in power systems is still quite low. The often-cited barriers of higher cost and lower reliability of the power converters are quite high if power electronics is used as direct, one-to-one, replacement for the existing electromechanical equipment. However, if the whole power distribution system were designed as a system of controllable converters, the overall system cost and reliability could actually improve, as is currently the case at low power levels within computer and telecom equipment. The proposed nanogrid–microgrid–grid structure achieves hierarchical dynamic decoupling of generation, distribution, and consumption by using bidirectional converters as energy control centers. This is illustrated by the description and simulation of static and dynamic operation of a dc nanogrid in a hypothetical future sustainable home. Several ideas for modelling, analysis, and system-level design of such systems, including power flow control, protection, stability, and subsystem interactions, are presented.

### III. SEPIC

SEPIC is a DC to DC converter and is capable of operating in either step up or step down mode and these are widely used in battery operated appliances by varying duty cycle of gate signal of the switch (MOSFET/IGBT). Both step up and step down voltages can be obtained. If the duty cycle is above 0.5 then stepped up voltage is obtained, if the duty cycle is below 0.5 then stepped down voltage is obtained. Some limitations like pulsating input and output current, inverted output voltage, in case of buck converter floating switch makes it unreliable for different application and for a conventional power converter design it is not easy to maintain high efficiency especially when there is need of stepping

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up or stepping down the voltage. All these limitations are overcome in SEPIC DC to DC power conversion. Different designs are used using active and passive components.

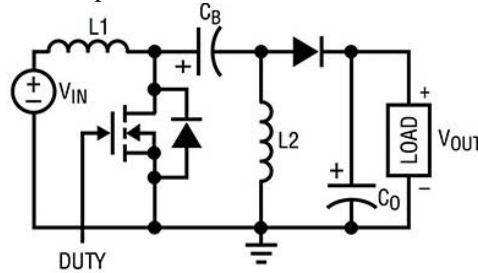


Fig. 2 Simplified circuit of SEPIC

Non- inverted output, low equivalent series resistance (ESR) of coupling capacitor minimize ripple and prevent heat built up which make it reliable for wide range of operation. Few products of SEPIC include UC2577-ADJ, BQ24007, and so on. See Fig. 2 for the simplified circuit of SEPIC. The circuit consists of two inductors  $L_1$  and  $L_2$ , two capacitors  $C_B$  and  $C_0$ , rectifier and switch (i.e., MOSFET/IGBT).

## IV. SDHC

### A. Circuit Modification

The Hybrid converter topology is obtained by replacing the controllable switch S with an inverter bridge network. The inverter bridge can be either a single phase or three phase. The converter obtained after replacing controllable switch is called SEPIC Derived Hybrid Converter [shown in Fig.3]. Also the input DC voltage is provided using a PV panel. The designed circuit has all the features of SEPIC. In addition to that it has ability to provide ac output along with the dc output.

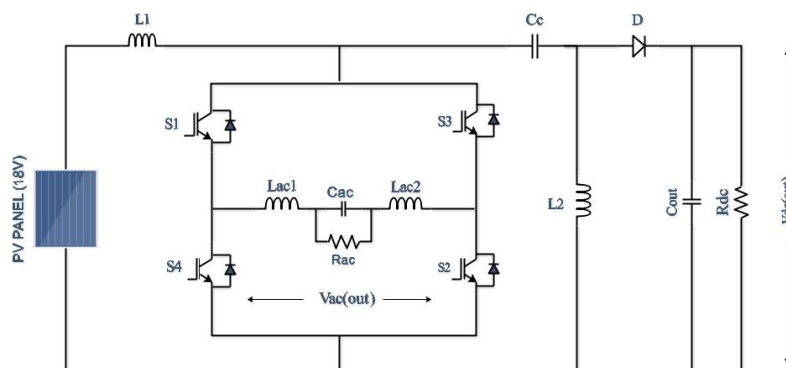


Fig. 3 SEPIC Derived Hybrid Converter (SDHC)

### B. Working principle

SDHC makes use of four bidirectional switches which can be either a MOSFET or IGBT along with anti parallel diodes. The average voltage across the coupling capacitor ( $C_c$ ) is equal to input voltage in case of SDHC. The switching operation required for obtaining dc output can be achieved by turning ON switches of same leg ( $S_1, S_4$ ) or ( $S_3, S_2$ ) and for obtaining ac output switches ( $S_1, S_2$ ) or ( $S_3, S_4$ ) are turned ON. In traditional voltage source inverter, the two switches of same leg can never be switched ON at the same time because it would cause a short circuit (shoot through) to occur, which would destroy the inverter. The block diagram is shown in the Fig. 4.

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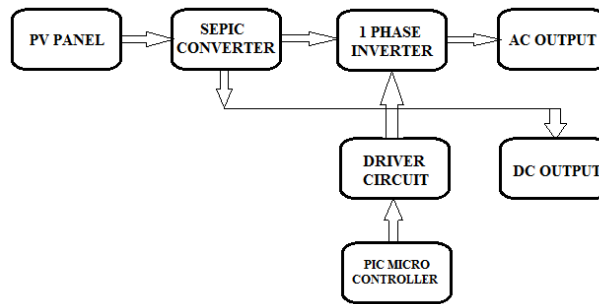


Fig. 4 Block diagram of the converter proposed

The inverter has three switching interval.

*First Interval:* This interval is called as a shoot through interval. During this interval the diode is reverse biased and switches of same leg are turned ON (i.e. either S1 and S4 or S3 and S2). DC output is obtained in this interval.

*Second Interval:* This interval is called as power interval. During the power interval the diode is forward biased and the switches S1 and S3 or S2 and S4 are turned ON. This interval is called as power interval because power transfer to both AC and DC load can be achieved.

*Third Interval:* This interval is called as zero interval. In this interval either all top switches or all bottom switches are turned ON at the same time and inverter current circulates among the bridge network switches.

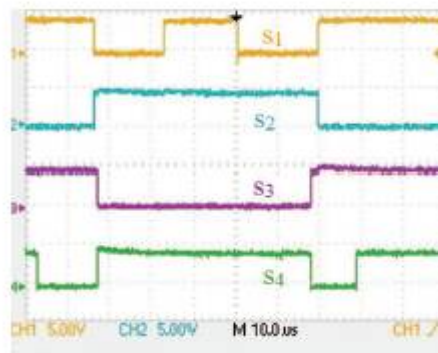


Fig. 5 Switching pulses generated from altium nanoboard 3000 series

The switching pulses for inverter are obtained from the driver circuit which is driven by PIC microcontroller. Switching pulses generated using altium nanoboard 3000 series is as shown in the Fig.5

## V. SIMULATION RESULTS

The complete list of parameters, passive component values and other component specifications are given in Table 1 and 2. The tool used for simulation purpose is MATLAB/Simulink. For the values specified in table 1 and 2 the obtained AC and DC output waveforms are shown in fig. 6 and fig. 7

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SL. NO.	PARAMETERS	ATTRIBUTES
1	INPUT VOLTAGE	18V-24V
2	OUTPUT DC VOLTAGE	20-50V
3	OUTPUT AC VOLTAGE	20V
4	SWITCHING FREQUENCY	20KHz

Table 1 Specification of design

SL. NO.	PARAMETERS	ATTRIBUTES
1	Input Inductor (L1)	4.7mH
2	Output Inductor(L2)	4.7mH
3	Coupling Capacitor (C <sub>C</sub> )	470uF
4	DC Capacitor (C <sub>OUT</sub> )	2.2Mf
5	AC Filter Inductor (L <sub>AC1</sub> & L <sub>AC2</sub> )	500uF
6	AC Filter Capacitor(C <sub>AC</sub> )	10uF

Table 2 Parameter of design

The waveform obtained after simulation is shown in fig. 6. This is the inverter output of the proposed SDHC which is a sinusoidal AC voltage waveform. The value of AC output voltage is 26V and the input is 18V DC

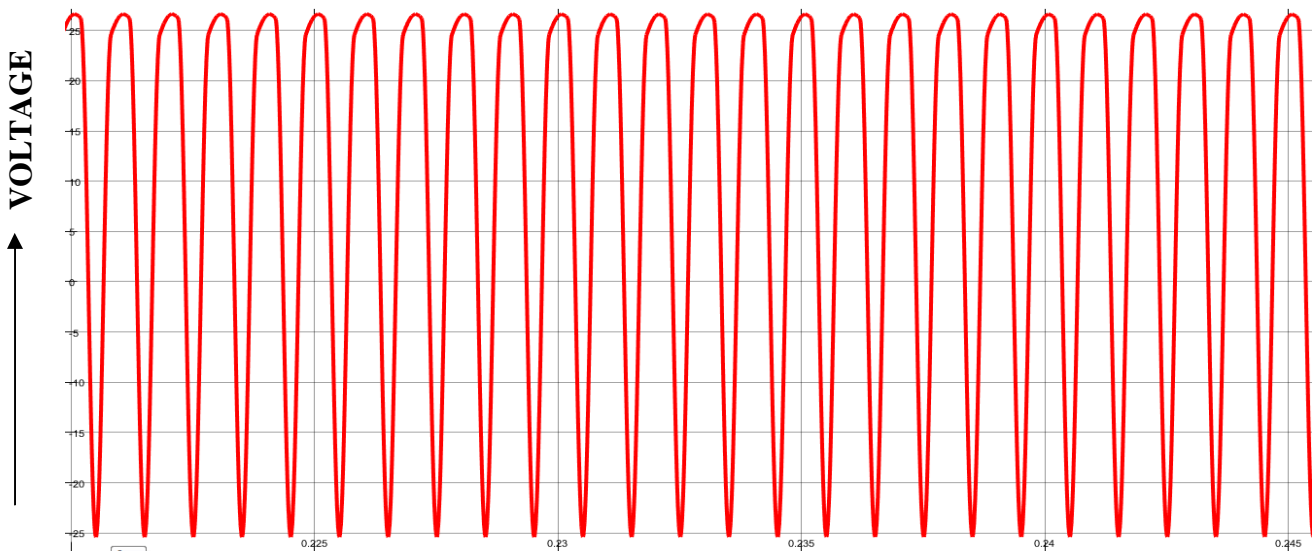


Fig. 6 Simulation results of SDHC producing an AC output of 26V

Fig. 7 shows the simulated result of SDHC. The DC Voltage waveform can be seen here. The input is 18V DC and the obtained output DC voltage is 52V.



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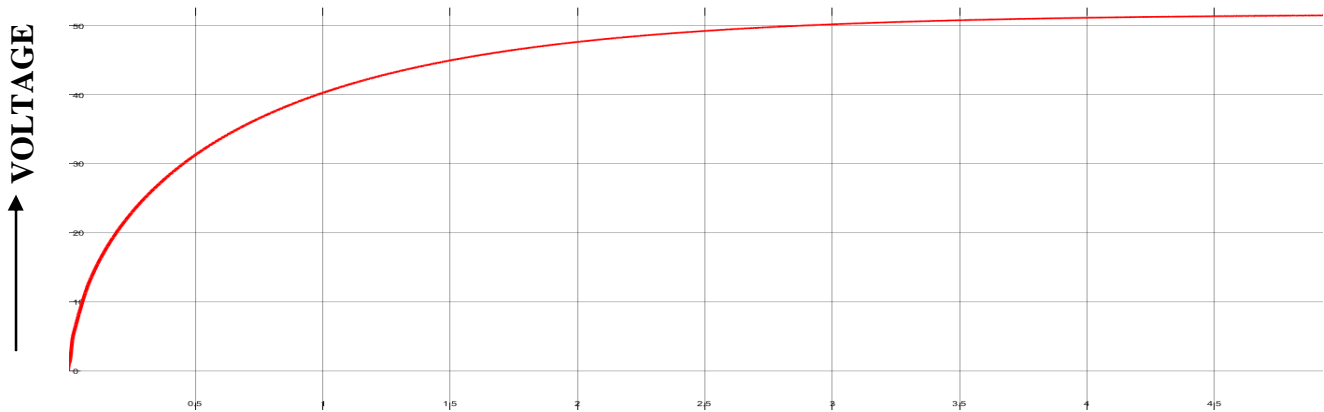


Fig. 7 Simulation results of SDHC producing DC output voltage of 52v

## VI. EXPERIMENTAL RESULTS

The experimental prototype of the system is implemented for the design specifications shown in Table 1 and 2. The specifications of switches and controller are given in Table 3. The control circuit is implemented with the help of Altium nanoboard 3000 series. The photograph of experimental setup is shown in Fig. 8.

SWITCHES (S1- S4)	IGBT SGH40N60UFD
DIODE	FR303
IGBT DRIVER	TLP250
CONTROLLER	ALTUM NANABOARD 3000

Table 3 Component list of power circuit

The specification of the PV panel used in this topology is as shown in Table 4.

$I_{SC}(A)$	1.929
$V_{OC}(V)$	22.575
$P_M(W)$	34.550
$I_{PM}(A)$	1.838
$V_{PM}(V)$	18.795
Temp(C)	25.71

Table 4 Specification PV panel

The fig. 8 (a) shows the experimental setup of hybrid converter derived from SEPIC which draws its input DC voltage from the solar energy. The specification of solar panel is as shown in the Table 4. The main circuit of SDHC is shown in fig. 8 (b)

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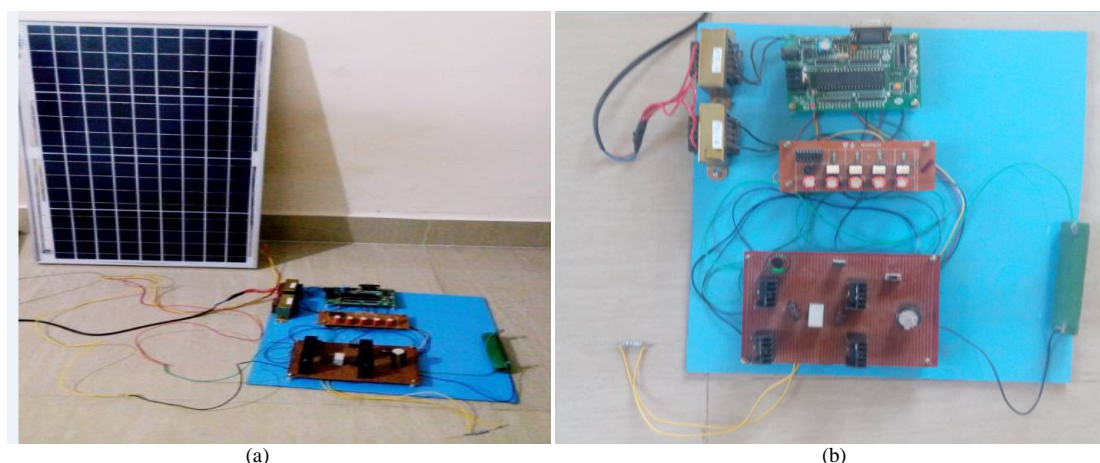


Fig. 8 Experimental setup for SDHC (a) complete model including PV (b) main circuit of hybrid converter derived from SEPIC

### VII. CONCLUSION

The novel converter called SEPIC Derived Hybrid Converter (SDHC) which can supply both ac and dc loads from a single dc supply has been proposed. The DC supply here is obtained from solar energy which a renewable energy source and thus making the proposed topology more efficient and reliable one. The operation and behaviour of SDHC is verified using MATLAB/Simulink model and also validated experimentally.

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