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A Simple Method for Controlling Buck-Boost SEPIC-H Bridge Inverter

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ABSTRACT

Over the past decade, a lot of research and development have gone into the use of electrical power converters, and the trend is upward. When converting DC voltage to AC voltage, inverters are employed. As voltage decreases (buck), voltage enhancers (boost), or both (buck-boost), inverters typically perform these functions. There are other problems, such as the structure of the inverter topology and the control method. This study of a buck-boost inverter, which integrates an H-Bridge inverter and a Single Ended Primary Inductor Converter (SEPIC), was conducted. The H-bridge inverter is widely recognized for its simplicity of operation. Because it is unipolar, it can operate as a buck-boost when combined with SEPIC AC-AC, and the output voltage is significantly superior because it has several filters to enhance the signal. This hybrid topology is controlled by a sinusoidal pulse width modulation, resulting in a straightforward control technique with outstanding performance. In the lab, a computational and implementation procedure is used to test the effectiveness of the hybrid topology and control method under consideration. The test results show that the hybrid architecture can function within the desired parameters.

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1. INTRODUCTION

Everyone has a fundamental demand to fill their energies. Human beings need to provide energy in the form of food used in their activities even to carry out daily tasks. Coal and oil are still the primary non-renewable energy sources used to generate electricity, but as these fossil fuel supplies become limited, new renewable energy will become more and more important [1], [2]. Renewable energy sources and possibilities are plentiful. Solar energy has one of the greatest energy potentials since it is benign to the environment and readily available sunshine [3]. A device known as an inverter is required to create Alternating Current (AC) because solar power plants only generate Direct Current (DC) [4],[5]. The demand for quality and reliability of power are higher than ever because of the rapid development of technology [6]. Because they can alter the current so that it can be utilized, inverters are the predominant technology in all fields [7]. Due to its simple control and inexpensive cost, Voltage Source Inverters (VSI) are frequently employed in industrial and commercial applications [8]. Because photovoltaic (PV) has an unpredictable input voltage, conventional inverters only work in step down mode, which makes it less suitable when used to PV [9]. Therefore, the inverter must have a buck-boost operating mode [10].

The installation of power plants with photovoltaic (PV) technology Before the photovoltaic (PV) grid system is linked to the output voltage, a number of procedures must be followed [11]. The use of traditional boost converters generally results in an increase in PV voltage [12]. High static gain is typically used in DC-DC converter designs to increase output voltage and photovoltaic efficiency [13]. The drawback of boost converters is high input current ripple, whereas the drawback of buck converters is high output voltage ripple [17, 18]. In order to optimize the output wave from buck-boost converters' high harmonic output, a high-value capacitor is required as a filter [19]. While the cuk converter can work around the issue by adding more capacitors and inductors, the excess current and voltage that passes through each component causes the components to overheat [20]. The Single Ended Primary Inductor Converter (SEPIC) is a buck-boost DC-DC converter with the advantages of the same polarity at the input and output, minimal current ripple, and the ability to operate in both step-up and step-down modes [21], [22]. It employs two inductors and two capacitors. SEPIC and cuk converters both have semiconductor voltage and current voltages, which have highly comparable properties [23]. Both alternatives have built-in startup and overload inrush current limitations as well as a straightforward transformer isolation implementation [24]. The inverter configuration employed is an H-bridge inverter since it can flow and obtain the output voltage without the need for diodes and capacitors to act as voltage balancers in the circuit [25]. The Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is a switch that is frequently employed because, as a switch, it has the advantages of being quick and not interfering with the current [26]. The H-bridge operates by alternately activating the switch. Using a SEPIC type converter is recommended because it operates in Continuous Conduction Mode) (CCM) [27]. A novel topology is suggested to be researched implementing into consideration the benefits of each of these converters, based on the advantages of the H-Bridge inverter and SEPIC converter. To achieve optimal performance, the H-bridge inverter is run using a unipolar control technique, and the SEPIC converter is converted into a SEPIC AC-AC implementing four active power switches.

To prove that the system under investigation can work as a buck-boost inverter, the output voltage equation is constructed using the operation methods of the H-Bridge inverter and SEPIC AC-AC. The effectiveness of the newly constructed topology is examined using a verification of computational simulation and hardware implementation, as reported in chapter 3. In chapter 4, conclusions and suggestions will be made on the newly learned topology based on the analysis and tests.

2. METHOD

A H-Bridge inverter and SEPIC converter are used to create hybrid SEPIC and H-Bridge inverter that operate at AC voltage. While the SEPIC AC-AC tries to convert AC voltage, it often operates as a voltage step up-down (Buck-Boost). In contrast, the H-Bridge inverter aims to convert DC electricity to AC and typically operates as a voltage step down (Buck). According to Figure 1, the hybrid topology configuration under study comprises four active power switches in the SEPIC AC-AC and four active power switches in the H-Bridge inverter.

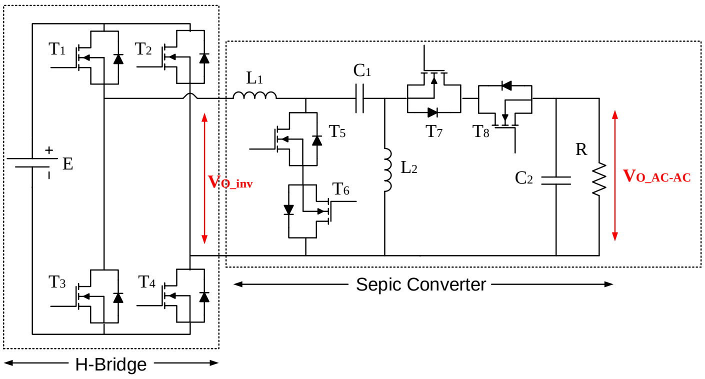


Figure 1. Sepic-H Bridge inverter

2.1. H-Bridge Inverter

The following is an explanation of the unipolar strategy's operational principle. When switches T1 and T4 are conducting and switches T2 and T3 are not conducting, the positive cycle is present, and the H-Bridge inverter's output voltage equation is Vinv = E. When T1 and T2 are conducting (but T3 and T4 are not conducting), or when T3 and T4 are conducting (but T1 and T2 are not conducting), voltage Vinv = 0 can occur. When switches T1 and T4 are not conducting and switches T2 and T3 are conducting, a negative cycle occurs, resulting in the output voltage equation Vinv = -E in the H-Bridge inverter. Since sinusoidal pulse width modulation is used to regulate the H-Bridge inverter, the inverter output voltage is often calculated as follows.

$$V_{o\_inv} = m\,E \tag{1}$$

The ratio of the triangular signal to the simulated wave is called the modulation index, or m. It is clear from this equation that the output voltage functions as a step-down voltage (buck).

2.1. SEPIC AC-AC

Although in this study SEPIC is employed for alternating voltage, its operating principle is essentially the same. The SEPIC AC-AC functions according to the following principle. When T5 is conducting and T6, T7, and T8 are not conducting, the current will flow from the output of the H-Bridge inverter to L1 and back to the H-Bridge inverter, assuming that the output voltage of the H-Bridge inverter is the input and occurs in the positive half cycle. The following equation will then be applicable.

$$V_{o\_inv} = L_1 \frac{di}{dt} \tag{2}$$

Additionally, at that time, the voltage VC1 equals VL2 (discharged), and capacitor C2 maintains the constant SEPIC AC-AC output voltage. The output voltage of the H-Bridge inverter along with the voltage in inductor L1 and the voltage in capacitor C1 (charged) will be pushed to the load when transistors T5, T6, T7, and T8 are not conducting and T8 is conducting. The following equation will then be applicable.

$$V_{o_{AC-AC}} = L_1 \frac{di}{dt} + V_{o\_inv} \tag{3}$$

Since the inductors charge for a longer period in this mode, the output voltage will be higher. The converse is true during the negative half of the cycle. Generalizations from equations (2) and (3) include:

$$V_{o_{AC-AC}} = \frac{D}{1-D} V_{o\_inv} \tag{4}$$

Where D is the SEPIC AC-AC's duty cycle. The output voltage equation for the suggested system is generally as follows:

$$V_{o_{AC-AC}} = \frac{D\, m}{1-D} E \tag{5}$$

Based on equation (5), the SEPIC AC-AC is run with a duty cycle greater than fifty percent so that this topology can operate as a buck-boost inverter, and the H-Bridge inverter is operated with a unipolar control strategy by modifying the modulation index of the sinusoidal pulse width modulation (m).

2.3 Control Strategy

Figure 3 depicts the methodical switching of each power switch to obtain an accurately measured output voltage because of the developing control method based on sinusoidal pulse width modulation from the observed operating modes. A new control technique based on sinusoidal pulse width modulation can be developed based on the switching behavior of each power switch, as shown in Figure 2.

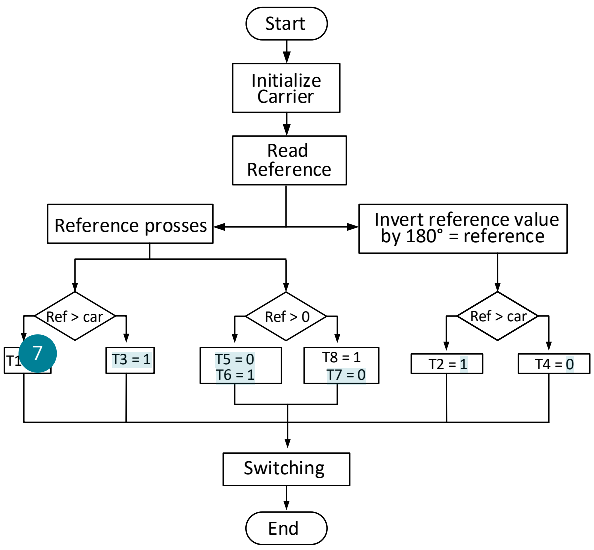


Figure 2. Flowchart of a new control technique

A one-leg unipolar method is employed to regulate the H-Bridge inverter. In this scenario, a gating signal pulse is used to control the power switch, and the other leg employs a 50Hz by zero crosing detection approach. According to equation (5), the SEPIC AC-AC duty cycle needs to be higher than fifty percent to achieve a higher voltage.

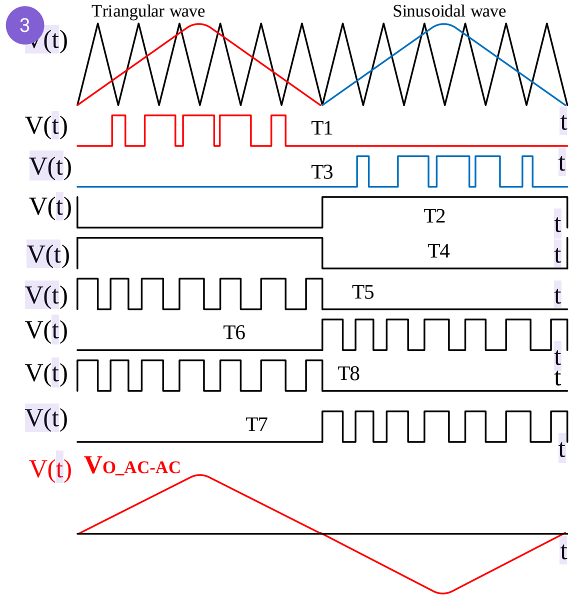


Figure 3. Switching pattern

3. RESULTS AND DISCUSSION

Based on the results of the computer simulation, the new buck-boost inverter topology that has been studied is put into practical. The parameters utilized in the simulation and implementation are displayed in Table 1.

Table 1. Simulation and implementation parameter

Parameters	value
DC Source	120V
Capacitor C1	30µF
Capacitor C2	20µF
Inductor L1 dan L2	1Mh
Resistive Load	100Ω
Power MOSFET	IRFP460
Switching Frequency	10KHz

The hardware for the investigated H-Bridge inverter coupled to SEPIC AC-AC (New topology) is shown in Figure 4. The STM32F407GT microcontroller incorporates the intended controller system. The power switch driver part of the prototype uses a TLP250 type optocoupler and a B1215S-1W type DC-DC isolator as the isolation power supply, while an IRFP460 type MOSFET serves as the active power switch. On simulation and implementation carried out in the measuring lab with a ten percent attenuation.

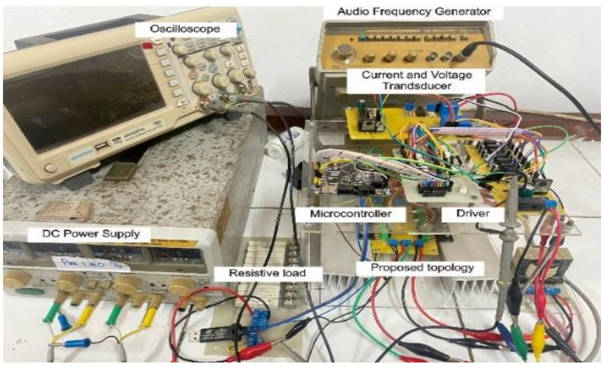
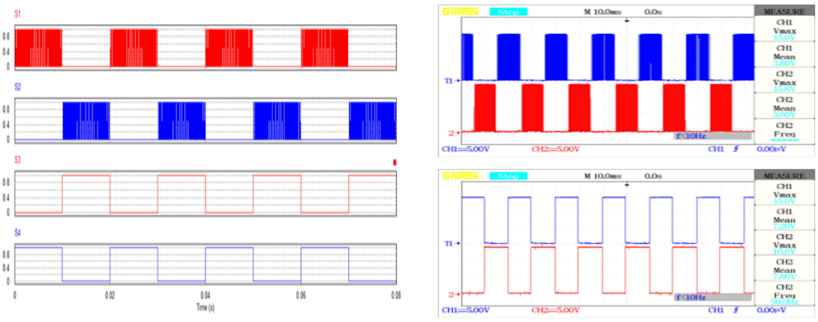


Figure 4. Hardware implementation

The newly planned topology is subsequently put to the test in a simulation setting to ascertain the resulting waveforms and any further parameters needed to support the implementation stage verification procedure. The hardware is tested using the simulated parameter values. The H-bridge inverter's computational simulation result, shown in Figure 5 (A), will be confirmed by hardware testing, shown in Figure 5 (B). The correlation between the results of these two tests indicates that the simulation and implementation are satisfactory and correlated. The power switch in one leg uses sinusoidal pulse width modulation to function at high frequency, while the other leg operates at low frequency (50Hz) as a zero crossing detector.



A B

Figure 5. Switching pattern T1-T4: (A) Simulation (B) Implementation

Figure 6 depicts the pattern of the AC-AC in boost mode based on the SEPIC's switching behavior. T5 (Q1) and T7 (Q3) will be switched over to conduct during the first positive half cycle, with T6 (Q2) and T8 (Q4) conducting during the second half cycle. Figure 6 (A) during simulation and Figure 6 (B) during implementation both depict this procedure, which is always repeated. Since both are correlated, it is possible to conclude that the system is functioning well based on these circumstances.

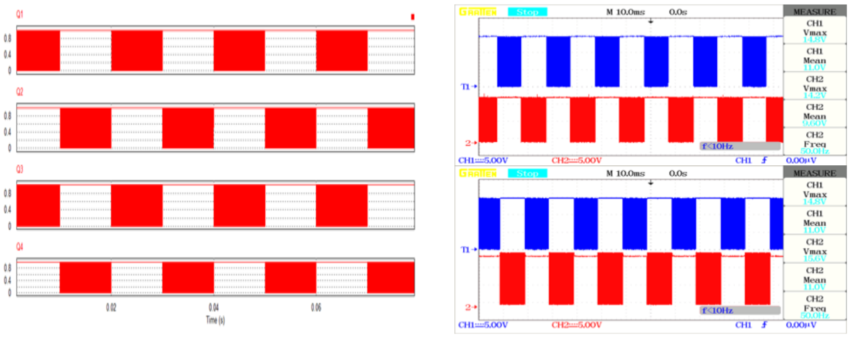


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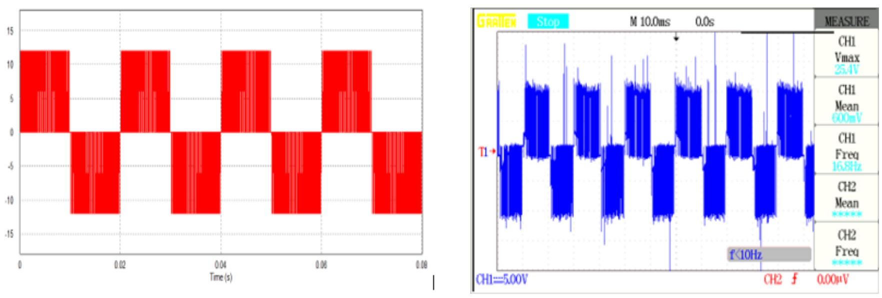
Figure 6. Switching pattern T5-T8: (A) Simulation (B) Implementation

Figure 7 illustrates measurements conducted in the H-Bridge inverter leg at output voltages of +120V, 0V, and -120V. Due to the development of a unipolar pattern, the output of the H-Bridge inverter under these circumstances is accurate. Hardware testing performed in simulation using Figure 7 (A) as a reference is accurate. Hardware testing generates a waveform comparable to Figure 7 (B), demonstrating a link between simulation and implementation.



A B

Figure 7. H-Bridge inverter output waveform: (A) Simulation (B) Implementation

The simulated output voltage and current testing is done in Figure 8 (A), where the first operation functions as a buck inverter, and Figure 9 (A), where the boost inverter. This is done after making sure that the testing of the new inverter in sinusoidal pulse width modulation and the work cycle can operate smoothly. Figure 8 (B) illustrates hardware verification; the voltage and current will be similar to Figure 8 (A) when functioning as a buck inverter. Figures 9 (A) and (B) both function as a boost inverter and are related to one another.

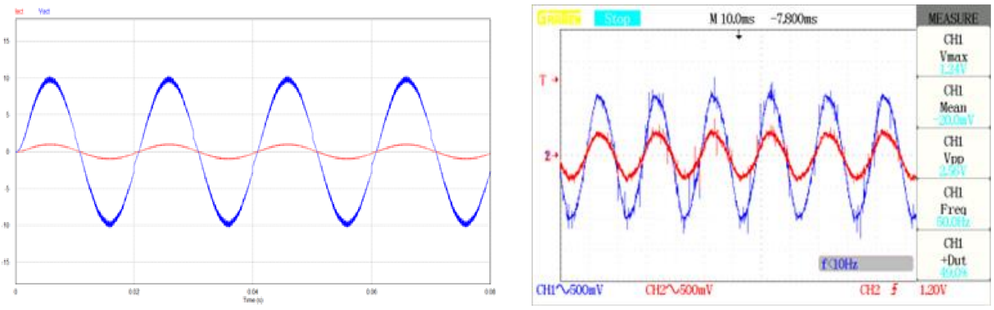


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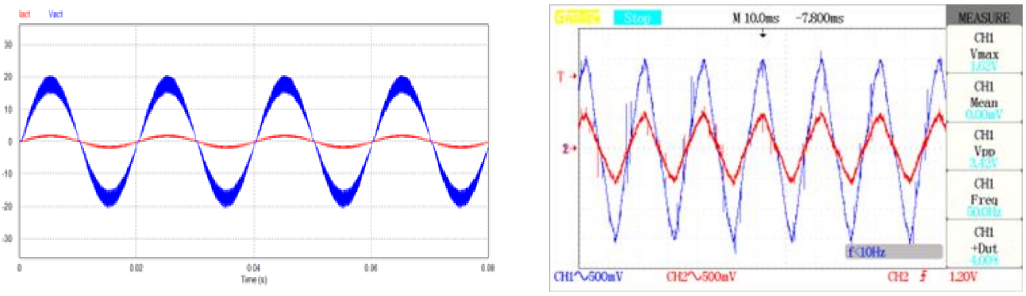
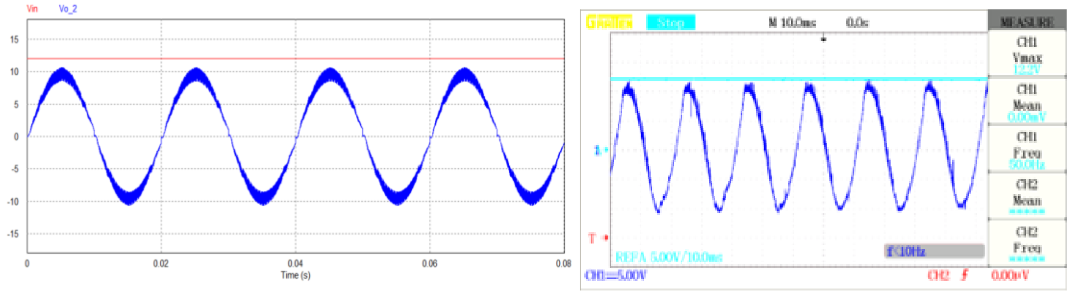
Figure 8. Voltage and current output waveform buck condition: (A) Simulation (B) Implementation



B

Figure 9. Voltage and current output waveform boost condition: (A) Simulation (B) Implementation

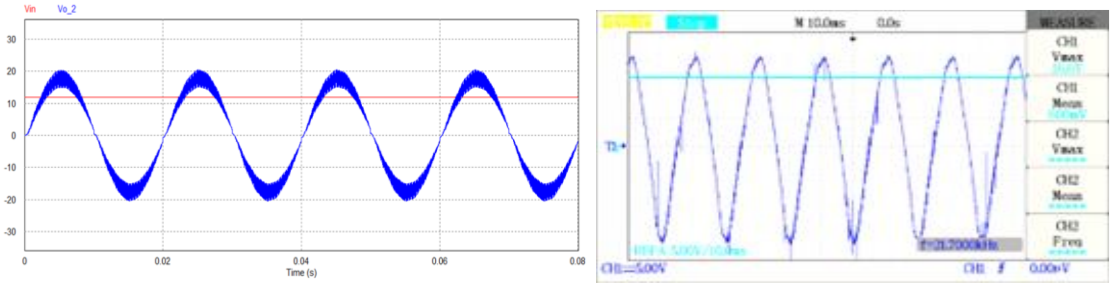
The output voltage's magnitude is compared to the input DC voltage to confirm the test's final step. Figure 10 (A) shows the simulation of the first test in buck mode. The magnitude of the AC output voltage is less than the magnitude of the DC input voltage. The final results of the hardware implementation, shown by Figure 10 (B), are then compared to this result. Both the findings and the new inverter's ability to function as a buck inverter are interrelated.



A B

Figure 10. Voltage output inverter Vs Voltage input DC under buck condition: (A) Simulation (B) Implementation

As seen in Figure 11(A), the output voltage in boost mode is tested in simulation when the inverter's output voltage is greater than its DC input voltage. Figure 11(B) shows the comparison between these simulation results and the hardware implementation results. These two data points are connected.



A B

Figure 11. Voltage output inverter Vs Voltage input DC under boost condition: (A) Simulation (B) Implementation

The SEPIC-H-Bridge inverter can perform effectively based on all buck and boost tests, however in order to get the boost inverter to run, SEPIC AC-AC duty cycle must be considered seriously.

4. CONCLUSION

The newly discovered inverter topology is an H-bridge inverter connected SEPIC AC-AC that performs excellently in both boost and buck modes. This has been demonstrated through simulation, and hardware testing has confirmed this. As a result of using fewer active power switches, the H-bridge inverter connected SEPIC AC-AC is more efficient, which is supported by the test results. Modulation index is used for controlling the H-bridge inverter, and a duty cycle of at least fifty percent is used to operate the SEPIC AC-AC. Because so many filters are used when employing SEPIC AC-AC, the output voltage ripple is significantly better.

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