A simple method for controlling buck-boost SEPIC-H bridge inverter

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ABSTRACT

Over the past decade, much research and development has gone into the use of electric power converters, and the trend is upward. Inverters are employed when converting DC voltage to AC voltage. Typically, inverters perform functions such as voltage boost (to compensate for voltage decrease) or both voltage buck and boost. Other issues to consider include the structure of the inverter topology and the control method. Based on the problem, a study was conducted on a buck-boost inverter that integrates an H-bridge inverter and a single ended primary inductor converter (SEPIC). The H-bridge inverter is widely recognized for its simplicity of operation and always runs in buck mode. The SEPIC converter always runs in buck-boost mode. Since it is unipolar, it can operate as a buck or boost when combined with SEPIC AC-AC. The output voltage is significantly improved because it has several filters to enhance the signal. This hybrid topology is controlled by sinusoidal pulse width modulation, resulting in a straightforward control technique with outstanding performance. The H-bridge inverter operates in index modulation 0-100%, and the SEPIC converter more than 50%. 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. The proposed inverter has 4.531% THD_V, 4.531% THD_I, and 97.85% efficiency under simulation.

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1. INTRODUCTION

Everyone has a fundamental need to fuel their energy. Human beings need to provide energy through food to carry out daily tasks and other activities. While coal and oil remain the primary non-renewable energy, sources used to generate electricity, new renewable energy will become increasingly important as these fossil fuel supplies become limited [1], [2]. There are numerous possibilities and sources of renewable energy. Solar energy has one of the greatest energy potentials since it is benign to the environment and readily available sunshine [3]. An inverter is necessary to create an alternating current (AC) because solar power plants only generate direct current (DC) [4], [5]. The demand for quality and reliability of power is 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]. The researchers investigated a full-bridge, single inductor-based buck-boost inverter. It uses two switches and operates at high frequency. This enables the inverter to achieve high efficiency and simple circuit configuration [9]. Conventional inverters are not suitable for use in photovoltaic (PV) due to the unpredictable input voltage of PV. Therefore, the inverter must have a buck-boost operating mode [10].

Every module and transmission protocol-based monitoring technology is examined in terms of its type, architecture, applications, features, and constraints. The setups, monitored parameters, software, platform, achievements, and recommendations are all multiple procedures that must be followed [11]. The use of traditional boost converters usually increases PV voltage [12]. High static gain is frequently used in DC-DC converter designs to boost output voltage and photovoltaic efficiency [13]. Preview study [14], the development of the single ended primary inductor converter (SEPIC) has been researched to produce a new topology and proven to work well. The previous studies [15], [16] have also developed SEPIC converter topology able to work well with a wide operating range. Good results were produced from the SEPIC converter modification; however, the complexity of the SEPIC converter and the components employed must be considered. The drawback of boost converters is a high input current ripple, whereas the drawback of buck converters is a high output voltage ripple [17], [18]. A high-value capacitor is required as a filter to optimize the output wave from buck-boost converters high-harmonic output [19]. While the Cuk converter can work around the issue by adding more capacitors and inductors, the excess current and voltage that pass through each component cause overheating of the components [20]. The 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], and it uses two inductors and two capacitors. SEPIC and Cuk converters were compared, and each has its advantages [23]. The suggested DC-DC converter maximizes the power of the solar photovoltaic panel (SPV) by operating in continuous conduction mode (CCM) in conjunction with a maximum power point tracking (MPPT) controller. In comparison to the classic boost design, the suggested DC-DC topology exhibits lower voltage stress across the power switch and diodes, and high voltage static gain was investigated by [24]. The five-level inverter has been studied by modifying the H-bridge inverter, as done in [25], where the H-bridge inverter is controlled by one leg and has been proven to work well. A novel topology is suggested to take 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 of the inverter: The H-bridge inverter works using a unipolar control technique, and the SEPIC converter is converted into a SEPIC AC-AC by 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 verification of computational simulation and hardware implementation, as reported in section 3. In section 4, conclusions and suggestions will be made on the newly learned topology based on the analysis and tests.

2. METHOD

The H-bridge inverter and SEPIC converter are used to create a hybrid SEPIC and H-bridge inverter that operates 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.

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 conduct (but T1 and T2 do not conduct), 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 in (1).

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

The ratio of the triangular signal to the simulated wave is called the modulation index (m). It is clear from this equation that the output voltage functions as a step-down voltage (buck). The modulation index was operated at 0-100%.

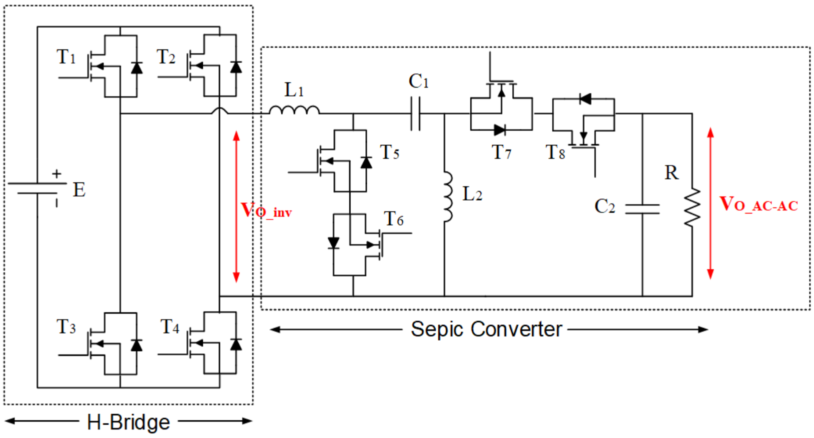


Figure 1. SEPIC-H bridge inverter

2.2. SEPIC AC-AC

Although in this study SEPIC is used for alternating voltage, its operating principle is essentially the same. The SEPIC AC-AC operates according to the following principle. When T5 conducts and T6, T7, and T8 do not conduct, the current flows from the output of the H-bridge inverter to L1 and then 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, as in (2).

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

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, as in (3).

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

Since the inductors charge for a longer period in this mode, the output voltage will be higher. The opposite is true during the negative half of the cycle. Generalizations from (2) and (3) include (4).

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

Where D is the SEPIC AC-AC's duty cycle. The duty cycle was operated at 0-100%. The output voltage equation for the suggested system is generally as (5).

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

Based on (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

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. 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, as shown in Figure 3. 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 50 Hz by zero crossing detection approach. According to (5), the SEPIC AC-AC duty cycle needs to be higher than fifty percent to achieve a higher voltage.

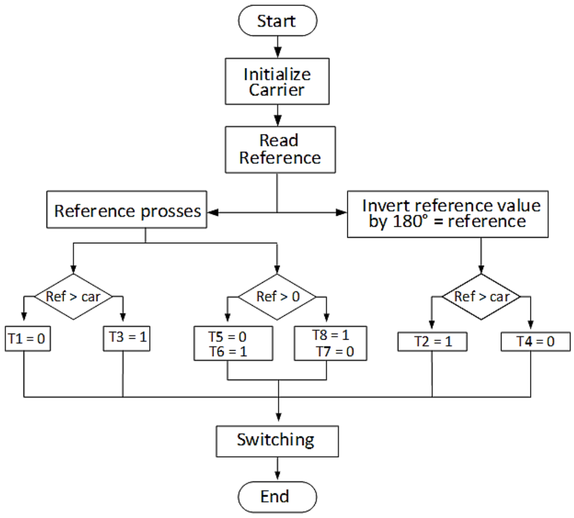


Figure 2. Flowchart of a new control technique

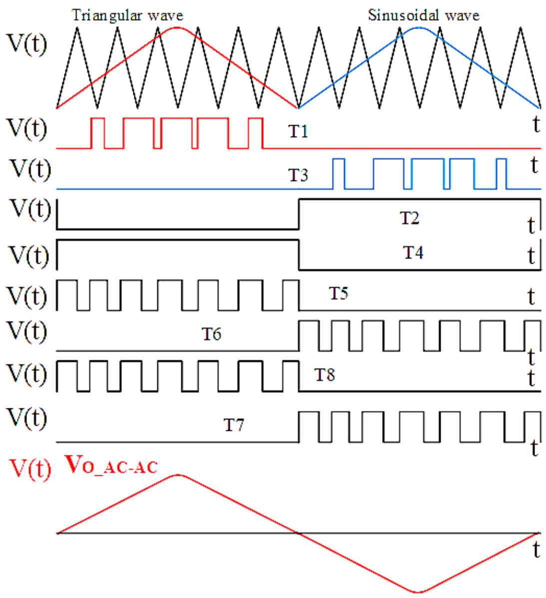


Figure 3. Switching pattern

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 practice. The parameters utilized in the simulation and implementation are displayed in Table 1. 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.

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 (50 Hz) as a zero-crossing detector.

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 the 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.

Figure 7 illustrates measurements conducted in the H-bridge inverter leg at output voltages of +120 V, 0 V, and -120 V. 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 match between simulation and implementation.

Table 1. Simulation and implementation parameter

Parameters	Value
DC source	120 V
Capacitor C1	30 µF
Capacitor C2	20 µF
Inductor L1 dan L2	1 Mh
Resistive load	10 Ω
Power MOSFET	IRFP460
Switching frequency	10 KHz

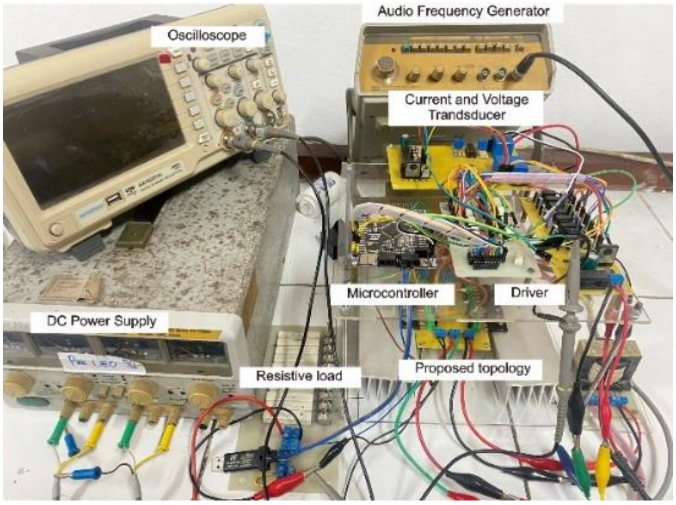
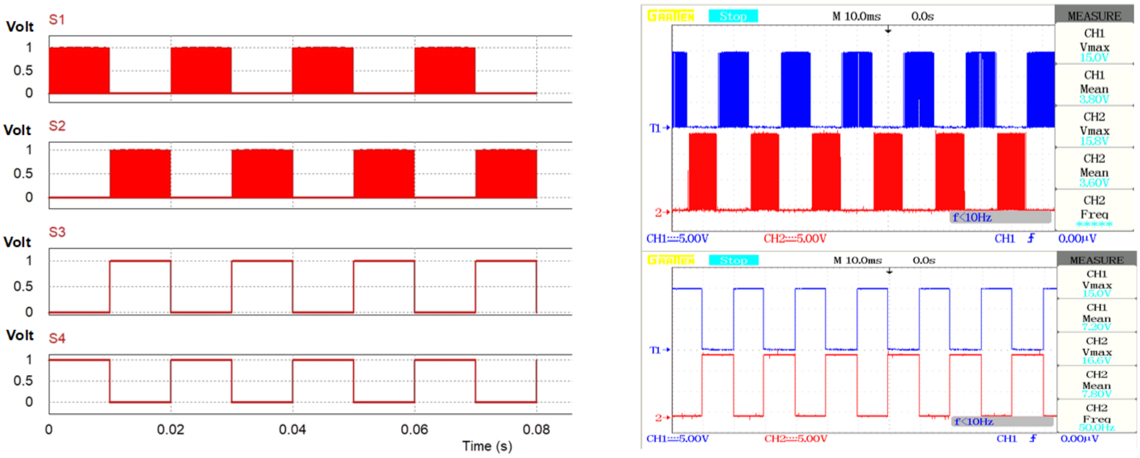
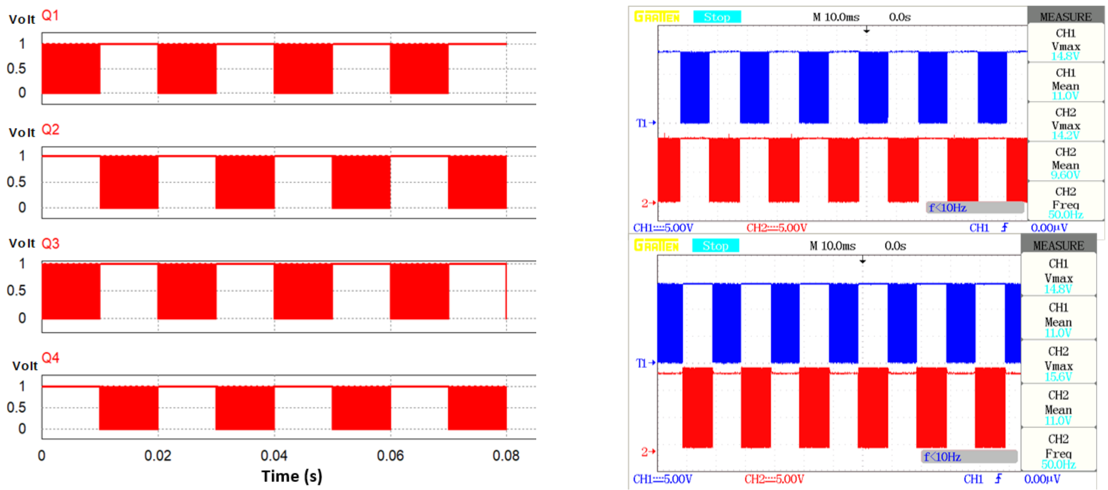


Figure 4. Hardware implementation



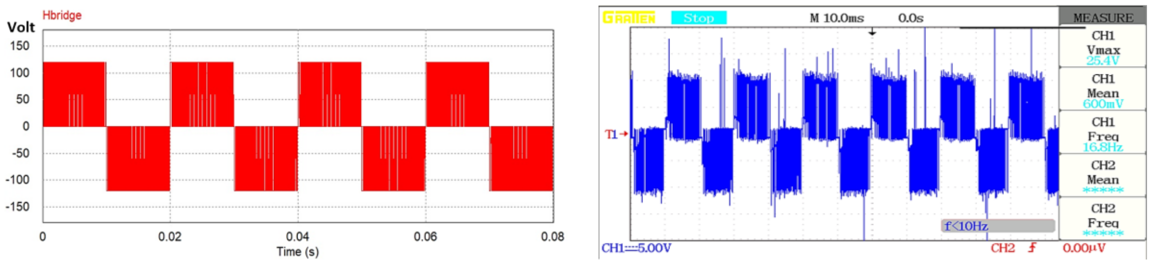
(a) (b)

Figure 5. Switching pattern T1-T4 (a) simulation and (b) implementation



(a) (b)

Figure 6. Switching pattern T5-T8 (a) simulation and (b) implementation

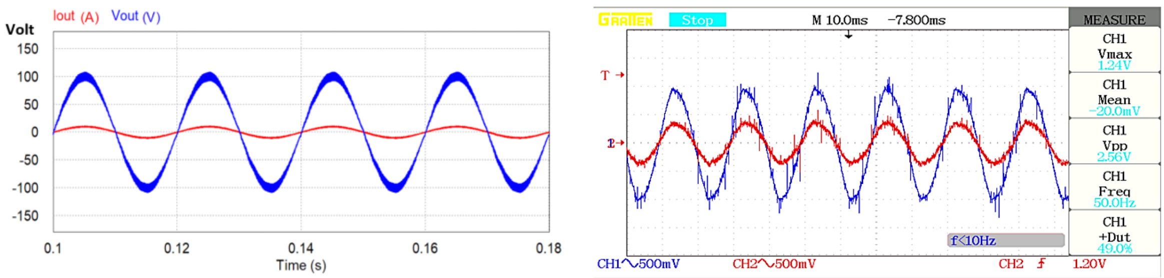


(a) (b)

Figure 7. H-bridge inverter output waveform (a) simulation and (b) implementation

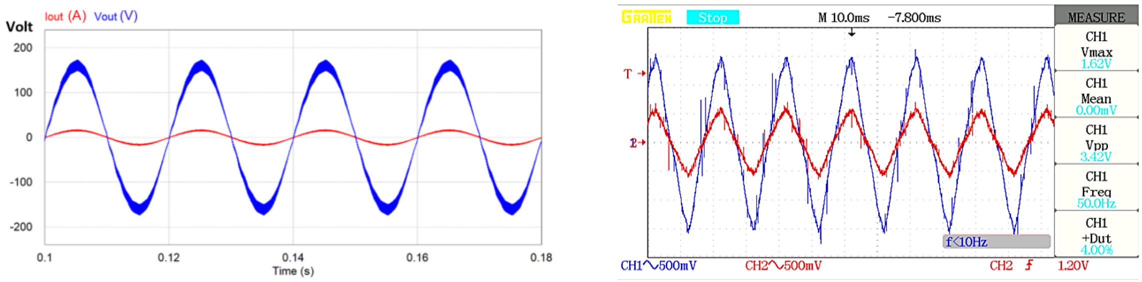
The simulated output voltage and current were tested in Figure 8(a), where the first operation functioned as a buck inverter, and Figure 8(b) illustrates the hardware verification. The voltage and current will be similar and related to each other. This was done after ensuring that the testing of the new inverter in sinusoidal pulse width modulation and work cycle could work smoothly. The simulated output voltage and current test was carried out in Figure 9(a), where the first operation functioned as a boost inverter, and Figure 9(b) illustrates the hardware verification; the voltage and current will be similar and related to each other.

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 that of the DC input voltage. The final results of the hardware implementation, shown in 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.



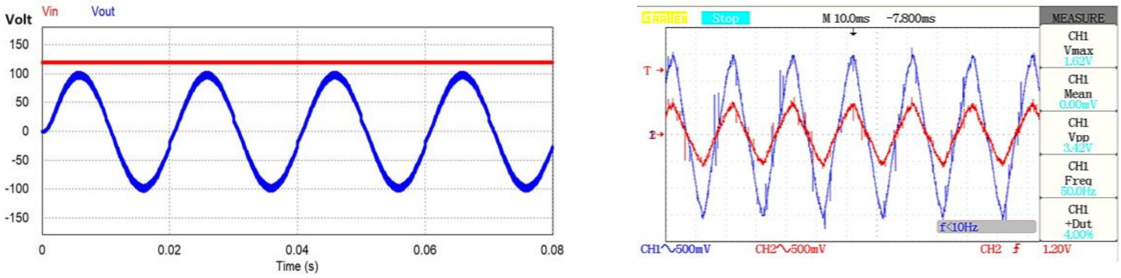
(a) (b)

Figure 8. Voltage and current output waveform buck condition (a) simulation and (b) implementation



(a) (b)

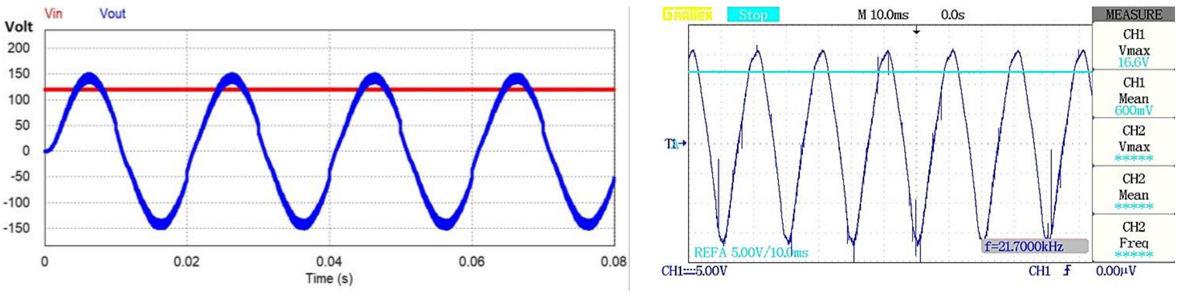
Figure 9. Voltage and current output waveform boost condition (a) simulation and (b) implementation



(a) (b)

Figure 10. Voltage output inverter Vs voltage input DC under buck condition (a) simulation and (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. The SEPIC-H-bridge inverter can perform effectively based on all buck and boost tests under 144 Watt: 120V DC input, 50 Hz frequency operation,10 Ohm, 4.531% THD_V, 4.531% THD_I and 97.85 % efficiency under simulation, Figure 12. However, to get the boost inverter to run, the SEPIC AC-AC duty cycle must be considered seriously.



(a) (b)

THD

Fundamental Frequency	5.0000000e+001 HZ
Iout	4.5312791e-002
Vout	4.5312791e-002

Average of the |X| Value

Time From	6.0001000e-001
Time To	8.0000000e-001
Pin	5.1110593e+002
Pout	5.0065176e+002

Figure 11. Voltage output inverter Vs voltage input DC under boost condition (a) simulation and (b) implementation

Figure 12. Analysis THD and efficiency (a) THD_I Vs THD_V and (b) power input Vs power output

4. CONCLUSION

The newly discovered inverter topology is an H-bridge inverter connected to 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 to SEPIC AC-AC is more efficient, which is supported by the test results: 4.531% THD_V, 4.531% THD_I, and 97.85% efficiency under simulation. The modulation index is used to control the H-bridge inverter, and a duty cycle of 50% or more is utilized to operate the SEPIC AC-AC. Due to the utilization of numerous filters with the SEPIC AC-AC, the output voltage ripple is considerably enhanced. The inverter has two-way independent control: the first for the H-bridge inverter, and the second for the SEPIC AC-AC converter.

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