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Realization of Single Phase Full Bridge Boost Inverter Using Arduino

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ABSTRACT

This paper discusses a single-phase boost inverter that functions to increase and convert DC voltage to AC. A boost inverter is a combination of two DC-DC boost converters that can be operated as an inverter with a load connected in an opposite direction between the two converters. The boost inverter in this final project is implemented with an Arduino UNO328 microcontroller using the sinusoidal pulse width method (SPWM) as a trigger. The output frequency value given varies from 50Hz to 70Hz. In the design of this single-phase boost inverter, it consists of several main components, namely the Arduino microcontroller, which functions as a pulse width modulation signal generator; a MOSFET gate driver using the IR2841S IC functions to switch the IRFP260N MOSFET, where the MOSFET is switched with a constant frequency of 30 kHz and a 5V power supply as a voltage supply for Arduino and a 12V supply voltage for the gate driver; as well as capacitors and inductors. The test results in the design of this single-phase boost inverter run according to the design because the circuit has been able to increase and convert the voltage, namely from an input voltage of 12VDC to 31.59Vac with an output frequency of 50Hz. The selection of component quality in the circuit also affects getting more accurate results.

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1. INTRODUCTION

Power converters play an important role in various electrical energy conversion applications, such as converting electrical energy from direct current (DC) to alternating current (AC) or vice versa [1]. This energy conversion is carried out in order to obtain the desired electrical energy characteristics. In addition to being able to change the form of electric current, power converters can also be used to change other electrical quantities, such as voltage and frequency. The power converter feature that can change various electrical quantities makes power converters widely used for various applications in the electrical field, such as applications in solar power plants and wind power plants [2]-[10].

Solar power plants that use Photovoltaic (PV) as a generator of electrical energy, generally have a low DC output voltage rating, namely 12 Volts on small-power PV and 24 Volts on large-power PV [11]-[13]. The same thing also applies to wind power plants that use generators with low output voltage. For control needs on the generator side, such as speed control to obtain maximum output power, wind power plants are usually equipped with rectifiers that produce DC voltage. On the other hand, consumers of electrical energy use a lot of ac voltage for various purposes. Therefore, a power converter is needed that can convert DC voltage to ac voltage while increasing the voltage. Several converter configurations can be applied to achieve this goal, such as a combination of a DC-DC boost converter as a voltage booster on the DC side with an inverter as a converter of DC voltage to ac or by using an inverter as a converter of DC voltage to ac plus a step-up transformer as a voltage booster on the ac side [14]-[20].

In this paper, a power converter is designed that can convert DC voltage to AC voltage while simultaneously increasing the voltage for a single-phase system. The converter used is a boost inverter type. This converter is a combination of two boost converters that can also function as an inverter [21]-[25]. The advantage of this converter is that it only uses four active switches and does not use a transformer to increase the voltage, so the manufacturing cost is cheaper than a single-phase inverter that uses a transformer. The output voltage of this boost inverter is influenced by the duty cycle of its switch modulation, the value of the inductor, capacitor and load used. The duty cycle is determined by the modulation technique used. In general, inverters can be modulated with several Pulse Width Modulation (PWM) methods, such as the sinusoidal PWM (SPWM), Space Vector PWM (SVPWM) and so on [26]-[27]. In this study, the switch boost inverter was modulated with the SPWM method. In this method, the duty cycle is determined by the magnitude and frequency of the reference signal in the form of a sinus. In this paper, SPWM is designed using Arduino microcontroller.

2. METHOD

Inverter is one type of power converter used to convert DC voltage to AC voltage using power semiconductors, such as SCR, Transistor, MOSFET or IGBT. Based on the switch structure, inverters can be grouped into half-bridge inverters and full-bridge inverters [4]. Based on the number of output phases, inverters can be grouped into single-phase inverters and three-phase inverters. Figure 1 shows the schematic of a single-phase full-bridge inverter.

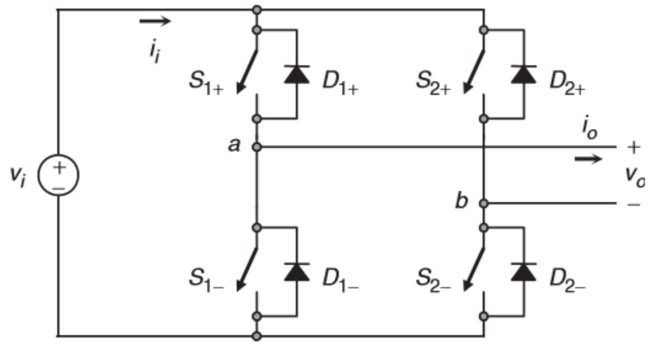


Figure 1. Single phase full bridge inverter

Conventional single-phase inverter topology has the characteristic that the average output voltage is always lower than the input DC voltage. If the output voltage is greater than the desired input, then a transformer must be used on the output side or by adding a boost converter on the input side. A boost converter is a type of direct current power converter that can produce an output voltage greater than the input voltage. Figure 2 shows a schematic of a full-bridge single-phase inverter equipped with a DC-DC boost converter to increase the voltage on the input side. This type of converter requires six active switches to obtain an output voltage greater than the input voltage. The working principle of this converter is that the input DC voltage is first increased by a boost converter, after which it is converted to ac voltage through an inverter.

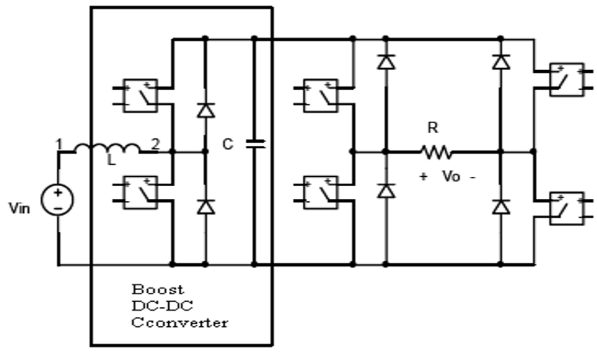
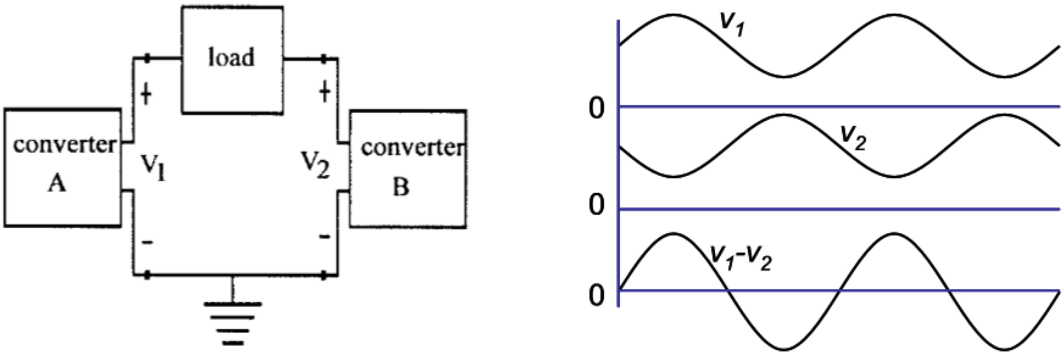


Figure 2. Single phase full bridge inverter with DC-DC boost converter

Another converter topology that has been developed by previous researchers to obtain a higher output voltage than the input voltage is the boost inverter model. This converter was first developed by Caceres in 1999. The boost inverter structure is arranged to form two dc-dc buck converters that can be operated as inverters with loads connected in opposite directions between the two converters, as shown in Figure 3(a). This will cause the current to flow in two directions. Each group of converters will produce voltages V_1 and V_2 that are 180^0 out of phase, as shown in Figure 3(b).



(a) (b)

Figure 3. Single phase boost inverter, (a) structure, (b) wave

The output voltage of each converter group is formulated by :

$$V_1 = V_{dc} + V_m \sin \omega t \quad (1)$$

$$V_2 = V_{dc} - V_m \sin \omega t \quad (2)$$

The voltage on the load which is the output voltage of the boost inverter V_o is the difference between V_1 and V_2, as shown in Figure 3(b). The output voltage of the boost inverter V_o can be formulated as :

$$V_0 = V_1 - V_2 = 2\ V_m \sin \omega t \quad (3)$$

Based on Figure 3, the dc-dc boost converter has two active switches equipped with inductors and capacitors. The boost inverter is a combination of two dc-dc boost converters installed oppositely, as shown in Figure 3(a). Based on Figure 2 and Figure 3(a), the boost inverter circuit is designed as shown in Figure 4. This boost inverter has 4 active switches equipped with two inductors and two capacitors. The dc voltage source as the converter input is placed between the converters. So is the load.

The working principle of the boost inverter is similar to the principle of the dc-dc boost converter. The structure of the boost inverter consists of two boost converters in opposite directions, so the conduction status of each switch in each converter group is also opposite to each other. Based on Figure 4, the conduction status of transistor Q2 in converter group 1 is opposite to the conduction status of transistor Q4 in converter group 2. Likewise on the bottom transistor, where the conduction status of transistor Q1 in converter group 1 is opposite to the conduction status of transistor Q3 in converter group 2. Based on the conduction status of these two converter groups, it can be concluded that the conduction status of transistor Q2 in converter group 1 is the same as the conduction status of transistor Q3 in converter group 2, while the conduction status of transistor Q1 is the same as the conduction status of transistor Q4. Viewed from one group of boost converters, for example group 1 converters, the conduction status of transistor Q1 alternates with transistor Q2. This means that when transistor Q1 is conducting or in ON status, transistor Q2 is in OFF status. Because the conduction status of transistor Q1 is the same as transistor Q4 and transistor Q2 is the same as transistor Q3, then in the analysis of the boost inverter, the circuit can be simplified into one boost converter connected to the load. When transistor Q1 is ON or conduction and Q2 is OFF, then the current flows from the DC voltage source to the inductor forming its own loop. In this condition, the inductor will store electrical energy, while the load will be supplied by the capacitor. Conversely, when transistor Q1 is OFF and Q2 is ON, then the current flows from the source to the capacitor and load through Q2. In this condition, the inductor will release electrical energy, so that the load voltage increases (boost).

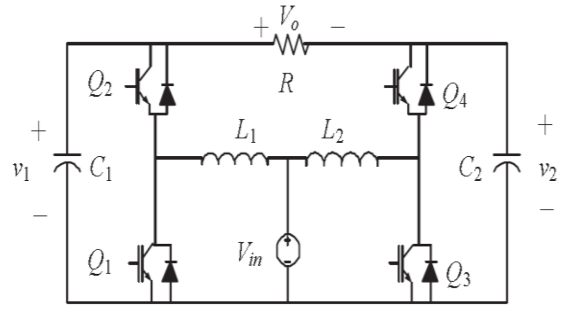


Figure 4. Structure of single phase boost inverter

The magnitude of the boost converter voltage increase is determined by the duty cycle value, capacitor and inductor values. Duty cycle is the ratio of the switch ON time to the switching period. The duty cycle value will determine the duration of each transistor. This duty cycle value will determine the inverter switch modulation pulse using the PWM concept, which is a modulation technique by comparing the reference signal with the Carrier signal . The carrier signal commonly used is a triangle wave or sawtooth wave. The basic principle of the PWM technique is when the amplitude of the reference signal is greater than the amplitude of the carrier signal , a high or on signal is produced and if the amplitude of the reference signal is smaller than the amplitude of the carrier signal , a low or off signal is produced. The reference voltage can be a dc signal or a sinusoidal signal, depending on the type of PWM used. If the reference signal is sinusoidal, it is called sinusoidal PWM (SPWM). In this final project, SPWM is used for boost inverter transistor modulation. In this paper, SPWM pulses for single phase boost inverter are generated using Arduino. Figure 5 shows the schematic of a single phase boost inverter circuit using Arduino. The circuit in Figure 5 consists of a power supply circuit, a boost inverter circuit, a gate driver and an Arduino microcontroller circuit.

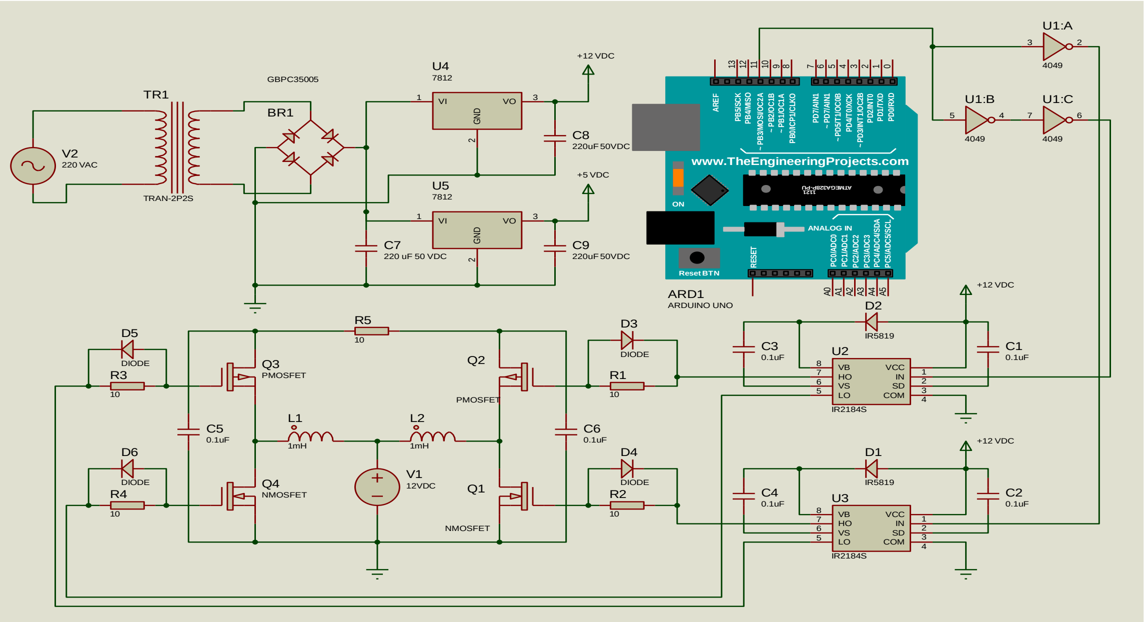


Figure 5. Circuit scheme of single phase boost inverter

The power supply functions to supply electrical power to the Arduino and the MOSFET gate driver. The power supply required for this boost converter system consists of a 5 Volt DC voltage for the Arduino and a 12 Volt DC voltage for the MOSFET gate driver. This power supply is obtained from a 220V AC voltage source which is lowered by a stepdown transformer to 15 Volts, then rectified using a bridge diode. The 12 Volt voltage is obtained using the 7812 regulator IC and the 5 Volt voltage is obtained using the 7805 IC. The boost inverter components are four N-type IRFP260 MOSFETs as active switches, two inductors and two capacitors. The gate driver functions as a voltage and current amplifier on the pulse wave connected to the MOSFET gate, so that the pulse wave that will trigger the activation of a MOSFET can meet the requirements to activate the MOSFET gate. In addition, the gate drive also functions as an isolation and safety between the power and control circuits. The Arduino Uno microcontroller functions as a processor for the work of the tools to be made. Arduino Uno is used to generate PWM pulses for MOSFET modulation. In Arduino Uno, PWM is designed in the form of SPWM with varying reference signal frequencies

3. RESULTS AND DISCUSSION

A device and program can be said to work well if it has been proven to work according to its function. From this test, data and evidence will be obtained from the final results of the design of the device that has been made can work well and can be combined with software. Based on the data and evidence, an analysis can be carried out on the work process which can later be used to draw conclusions from what has been made. Figure 6 shows a single phase full bridge boost inverter that has been made.

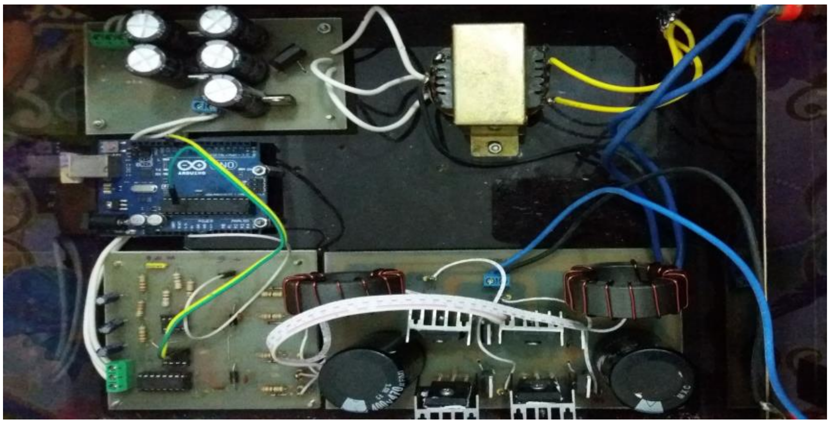


Figure 6. Hardware of single phase boost inverter

The single phase full bridge inverter circuit is tested with varying output voltage and frequency through PWM pulse regulation. The output voltage value is determined by the modulation index on the PWM pulse. The output frequency is varied from 50 Hz to 70 Hz. The PWM pulse is varied with the Gate driver using two IR2184S ICs as isolators of the low voltage side with the high voltage side. Figure 7 shows the PWM pulse on the oscilloscope when the output voltage frequency is varied from 50 Hz to 70 Hz.

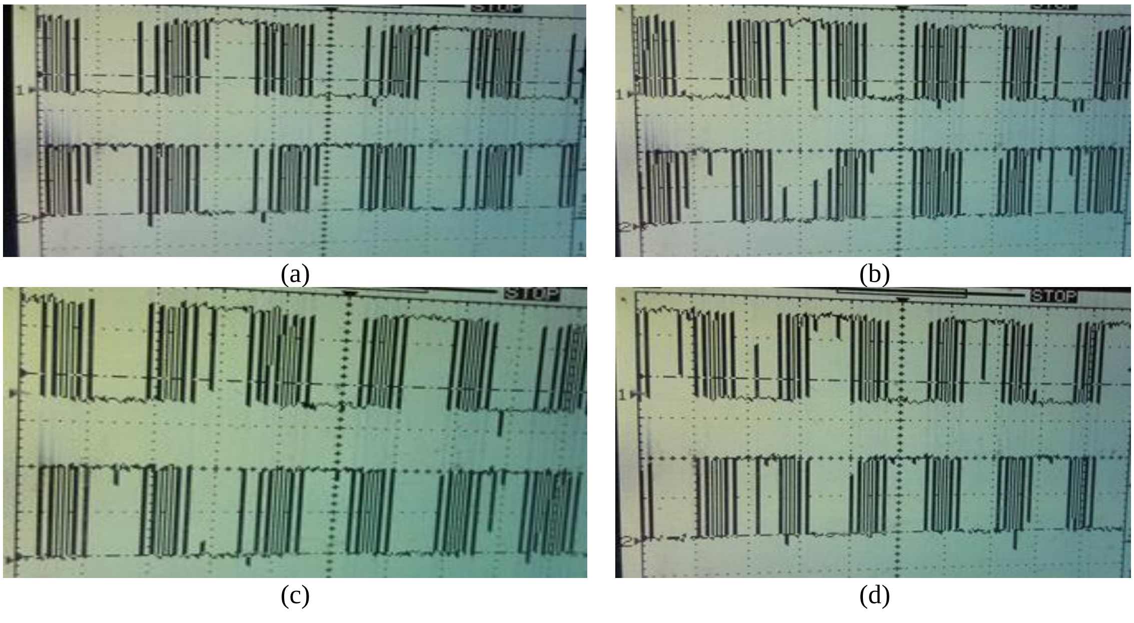
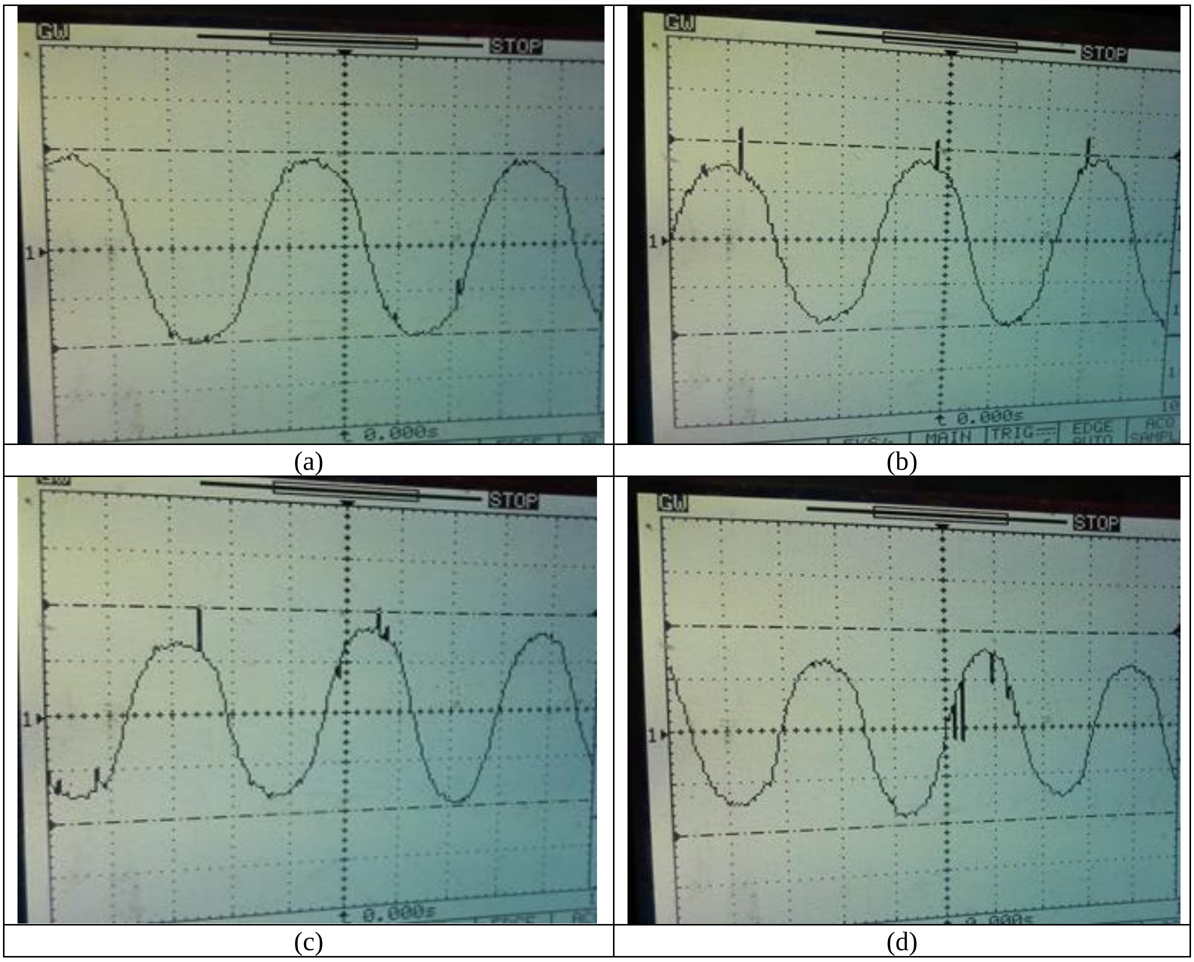


Figure 7. PWM pulses with varying frequencies, a) 50 Hz, b) 55 Hz, c) 60Hz, d)70 Hz

In the measurement using an oscilloscope, the peak-to-peak voltage (Vpp) is measured at 12Vdc to 13Vdc and the resulting waveform is different. This is in accordance with the principle of MOSFET switching expected in this final project, which produces two different signal outputs of 1800. In this case, MOSFETs 1 and 4 have the same conduction status as well as MOSFETs 2 and 3. In this test, the boost inverter circuit is given a voltage input of 12 Volts with an output frequency varying from 50Hz to 70Hz. The results of testing this boost inverter circuit can be seen in Figure 8.



(a) (b) (c) (d)

Figure 8. Output voltages of single phase boost inverter, a) 50 Hz, b) 55 Hz, c) 60Hz, d)70 Hz

The results of the boost converter circuit hardware test show that the boost inverter device made in this Final Project has worked well. The boost inverter has been able to convert DC voltage to AC voltage, as shown by the oscilloscope display in the Table above. The measurement results also show that the boost inverter has also been able to increase the voltage from 12 volts DC on the input side to 31.59 Volts on the output side when the output frequency is 50 Hz, as shown by the voltmeter readings in the Table above. When the output frequency is 70 Hz, an output voltage of 24.07 Volts is obtained. This shows that the higher the frequency of the output voltage, the lower the voltage value. In addition to being influenced by frequency, this output voltage is also influenced by the capacitor value, inductor value and load used in the boost inverter. The test results above show that the boost inverter made has worked well to increase the voltage and convert DC voltage to AC. This is an advantage of the boost inverter, where this device can increase the voltage without using a transformer.

The success of this boost inverter is inseparable from the performance of the two dc-dc boost converters that form the boost inverter. In order to produce a balanced alternating voltage on the output side of the boost inverter, the output voltage waveform of the two dc-dc boost converters must also be balanced, so that the difference can be an alternating waveform in the form of a sine, according to Equation 3. The voltage waveform of the two dc-dc boost converters in this test is shown in Figure 9.

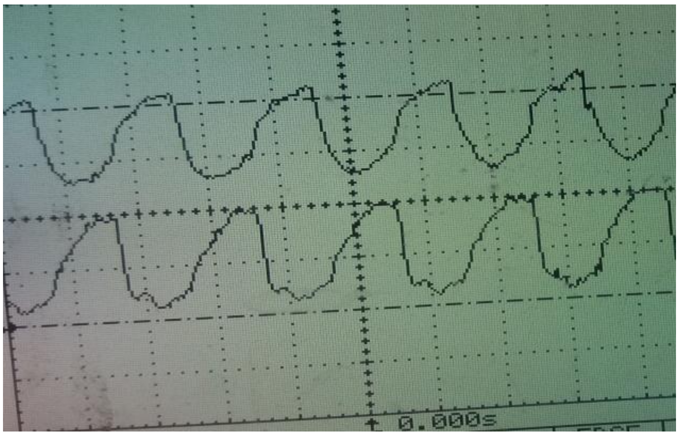


Figure 9. voltages waveform of V_1 and V_2

Figure 9 shows that the output voltage waves of the two dc-dc boost converters are in a balanced condition with opposite directions, so that if the first voltage V_1 is reduced by the second voltage V_2, a voltage difference is obtained in sinusoidal form which is the output voltage of the boost inverter. All test results show that the single phase boost inverter in full bridge configuration has worked well according to the plan. The single phase boost inverter has been able to produce an output voltage greater than the input voltage.

4. CONCLUSION

The single-phase boost inverter circuit's analysis and test results indicate that the proposed boost inverter circuit can effectively raise and convert DC voltage to AC. When the output voltage frequency is set to 50 Hz, the boost inverter that has been created can transform the input voltage from 12 volts to 31.59 volts in sinusoidal form on the output side. The load employed, the output frequency, and the values of the capacitor and inductor all have an impact on the boost inverter's output voltage. The output voltage is 24.07 volts at a frequency of 70 Hz and 31.59 volts at a frequency of the same frequency. The greater the production.

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