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# Implementation of 3000-watt inverter as a source of electrical energy in solar power plants

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**Abstract**

In industry, an inverter is a tool/component for adjusting the speed of an electric motor. By using an inverter for electric motor purposes, it becomes a variable speed, whereas the speed can be changed or adjusted as needed. The method used in this study is an experimental research method, namely designing and measuring the system under study. Measurements are made for non-electrical quantities, namely the inverter of the solar module which is generated by the intensity of sunlight hitting the surface of the solar cell. Measurements are also made for electrical parameters such as current, voltage, power factor, and power. Based on the data obtained from all the tests that have been carried out, the system output voltage cannot reach the expected 220 Volts. Because changes in load affect the output voltage of the system were occurred, as the load of 60 W/220V is added, the output voltage drops to 740.5 Volts. As the load is reduced by 60W/220 V, the output voltage increases by 786.9 Volts, within the average inverter efficiency of 77%.

**Keywords: Inverter, Voltage, Current, CRO or oscilloscope, average voltage efficiency**

## 1 Introduction

One of the renewable energy sources that can be utilized in Indonesia is solar energy. Solar energy is available almost all year round in Indonesia with an average radiation intensity of 4.8 kWh/m per day. Solar energy is utilized by using solar cells that produce electrical energy in the form of direct current (DC), which can be stored in accumulators and can also be used directly. Inverter is an electronic device used to convert DC (Direct Current) voltage into AC (Alternating Current). The inverter output can be AC voltage in the form of a sine wave, square wave and modified sine wave. The inverter input voltage source can use batteries, solar power, or other DC voltage sources. The inverter in the process of converting DC voltage to AC voltage requires a step-up transformer in the form of a step-up transformer.

In industry, the inverter is a tool/component to regulate the speed of electric motors. By using an electric motor the inverter becomes a variable speed, that is, the speed can be changed or adjusted as needed. Processes in industry often require a driving force from an electric motor that needs to be adjusted to produce the desired torque and power. If previously they used a lot of mechanical systems, then switched to slip/incubation motors, now they use a lot of semiconductors. Unlike soft starters which process voltage levels, inverters use the input voltage frequency to regulate the motor speed as it is known, under ideal conditions (no slip)[1][2][3].

In the world of industrial automation, inverters are widely used and are usually installed in applications for linear processes (variable parameters). In the inverter, we have to set the parameters that are adjusted to the components to be controlled through the inverter. Example: Electric Motor Connection, Ampere, Frequency, High Speed, Torque, etc. Manually using the display, can be done by following the manual issued by the inverter vendor[4][5][6][7].

The use of inverters in the industrial world still uses the default parameter settings, meaning that they still use the settings from the inverter vendor itself. The disadvantage of setting the default parameter is that it can only operate the inverter with limited functions, while many functions contained in the inverter can be operated. When the inverter is used as a tool to control electric motors in the industry with default parameter settings, while the industry requires many types of motor control in the production process, the industry must often make parameter settings according to the conditions required to control electric motors. Due to the frequent setting of parameters, the production process in an industry will be disrupted[8][9][10][11].

The inverter circuit that produces a square wave has several weaknesses, so it has the potential to damage electronic equipment (unstable voltage). At the method stage, it is done by designing and measuring with various types of electrical loads that aim to see the output voltage with a pure sine wave form[12][13][14][15].

Because the inverter is the "heart" of the PV mini-grid system. The inverter functions to convert the direct current (DC) generated by solar panels into alternating current (AC)[16][17][18][19]. DC voltage from solar panels tends not to be constant according to the level of solar radiation. This non-constant DC input voltage will be converted by the inverter into a constant AC voltage that is ready to be used or connected to an existing system, such as the PLN network. In general, the voltage and current parameters at the off-inverter output have been adjusted to national/international standards. Because the inverter includes 3KW pure sine wave, which can convert 24/48 Vdc to 220/230/240Vac 50/60Hz based on all digital technology. For this reason, inverters can be applied in many fields, such as household appliances, electric tools and industrial devices, especially for photovoltaic & wind power renewable energy applications.

The inverter in the solar power plant system is a component or tool in the solar panel system that functions to convert the DC (Direct Current) generated by the solar panel into AC (Alternating Current) electric current. Almost all of our household appliances such as AC, TV, Refrigerator, HP Charger, Laptop Charger, Computer, Water Pump, Lamp etc use AC Electric Current. The solar panels on the solar panel system produce DC electric current, to be able to use it for our needs we must convert it into AC electric current using a tool called an inverter[20].

Solar inverters convert the direct current (DC) generated by the solar modules into alternating current (AC) that powers most household appliances. After knowing the advantages and disadvantages of string inverters, you can find out that string inverters are components of communal solar power plants that are safe to use and affordable. This research has a specific purpose, namely to design and implement an inverter using a power amplifier. Then import the excess power generated by the solar panel system. Inverter which is a circuit to convert direct voltage into alternating voltage[21]. The technique used is a switching technique, namely by turning the on and off switch alternately so that a pulse or square wave is formed with negative and positive directions.

In this research scheme, it can contribute to the development of the industrial world, namely as positive contribution, by making an inverter training module to control the speed of electric motors, both single-phase and three-phase. This can be used as a reference material that controlling the inverter for electrical loads and motor speed can be done using several inputs to increase knowledge, understanding, and skills in the world of electricity, especially in the use of inverters. The Solar Inverter made will have a pure sine feature, and has good regulation of output and input from the solar inverter[22][23]. The results of the manufacture of solar inverters will be compared with inverters on the market to then compare their performance on the solar power plant Off-Grid system.

### 1.1 Power Inverters

The use of power inverters in solar power systems is very necessary when using electrical equipment that only works on high voltage alternating current (AC), the use of power inverters seems to be a good solution for solar power systems because there are many electrical equipment. work on high voltage systems. high alternating current. The amount of total power that can be supplied by an inverter is very important because it is related to the power used by the inverter itself and its ability to supply power to the load[24].

In this study, it is planned that the total power that can be supplied is 3000 watts with an output voltage of 220 volts AC 50 Hz. The inverter is made using a 12-volt lead-acid battery as the input voltage source. Using a middle tapping load inverter circuit. To get the desired output power, it is necessary to consider the power required as input to the inverter. To get the desired output power, it is necessary to consider the power required as input to the inverter. Assuming the output power factor is equal to 1 (one) and the transformer efficiency is 80%.

Inverter is an electronic device that is used to convert DC (Direct Current) voltage into AC (Alternating Current) voltage. The inverter output can be AC voltage in the form of a sine wave, a square wave and a modified sine wave. The inverter input voltage source can use batteries, solar power, or other DC voltage sources. The inverter in the process of converting DC voltage to AC voltage requires a voltage amplifier in the form of a step-up transformer[25].

The working principle of an inverter is generally the same as a power supply, which is to supply DC to AC and also functions to convert DC voltage into AC. You need a car battery / DC (Direct Current) so that it can be converted into AC / Alternating Current. The durability of an inverter circuit is determined not by watts but by the battery/battery you use and the load[26]. The working principle of the inverter can be explained by using 4 switches as shown above. When switches S1 and S2 are on, DC will flow to load R from left to right, if switches S3 and S4 are on, DC will flow to load R from right to left. Inverters usually use a pulse width modulation (PWM) circuit in the process of converting DC voltage to AC voltage. The things that must be considered in choosing a DC to AC inverter include:: The load capacity then is supplied by the inverter in watts, try to choose an inverter whose workload is close to the load we want to use so that its work efficiency is maximized., Inverter input voltage source to be used, 12 Volt or 24 Volt DC input., Inverter output waveform, sine wave or square wave for AC inverter output voltage. And This is related to the suitability and efficiency of the DC-to-AC inverter.

### 2.2 DC-To-AC Inverter

Inverter is an electronic device that is used to convert DC (Direct Current) voltage to AC (Alternating Current) voltage. The output of an inverter can be an AC voltage with a sine wave, square wave and modified sine waveforms. The inverter input voltage source can use batteries, solar power, or other DC voltage sources. The inverter in the process of converting DC voltage to AC voltage requires a voltage amplifier in the form of a step-up transformer.

Types of DC to AC Inverters Based on the number of inverter output phases, they are divided into; 1-phase inverters, namely inverters with 1-phase output.and 2-phase inverter, that is, an inverter with 3-phase output.

Inverters can also be distinguished by voltage regulation, namely: Voltage Fed Inverter (VFI), which is an inverter with a constant regulated input voltage, Current Fed Inverter (CFI), namely an inverter with a constant regulated input current and Variable dc linked inverter, namely an inverter with input voltage that can be adjusted.An example of a simple basic inverter circuit shown in Fig1.

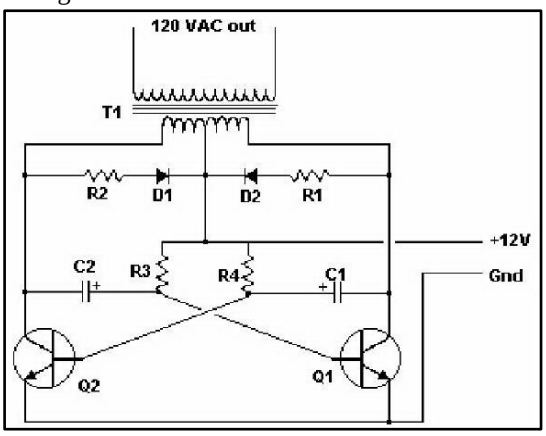


Fig 1. Example of a Simple Inverter Circuit

Based on the shape of the inverters output waveform is divided into: 1. Sine wave inverter, namely inverters that have an output voltage with a pure sine waveform. This type of inverter can provide a voltage supply to the load (inductor) or electric motor with good power efficiency, 2.Sine wave modified inverter, namely an inverter with a modified square wave output voltage resembling a sine wave. This type of inverter has low power efficiency when used to supply inductor loads or electric motors. and 3. Square wave inverter, namely an inverter with a square wave output, this type of inverter cannot be used to supply voltage to inductive loads or electric motors.

#### 2.2.1 Work principle

The working principle of the inverter can be explained using 4 locations as shown above. If the conditions S1 and S2 are on then the DC will flow to the load R from left to right, if the circuits S3 and S4 are on voltage then the DC will flow to the load R from right to left. Inverters usually use a pulse width modulation (PWM) circuit in the process of converting DC voltage to AC voltage. As shown in Fig 2.

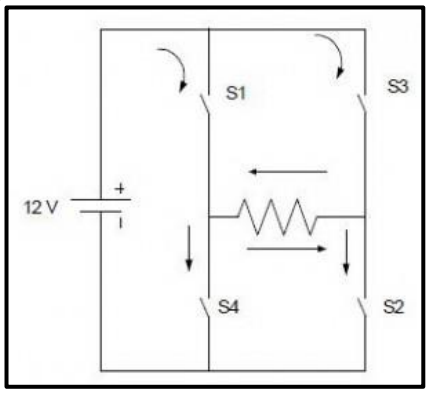


Fig 2. working principle

#### 2.2.2 Half Wave Inverter

The working principle of a single-phase inverter can be explained in the picture above. When transistor Q1 is on for time T0/2, the voltage across the load V0 is Vs/2. If transistor Q2 is only for T0/2, Vs/2 will pass through the load. Q1 and Q2 are designed

to work interchangeably. The Fig. 3 also shows the waveform of the output voltage and current of a transistor with a resistive load. This type of inverter requires two DC sources (a symmetrical DC voltage source), and when the transistor turns off the reverse voltage on Vs becomes Vs/2, as in equations 1 and 2 below.

$$Vo = \frac{V_S}{2} \quad (1)$$

$$Veff = \frac{2\,V_S}{\sqrt{2\,\pi}} = 0{,}45\ .Vs \quad (2)$$

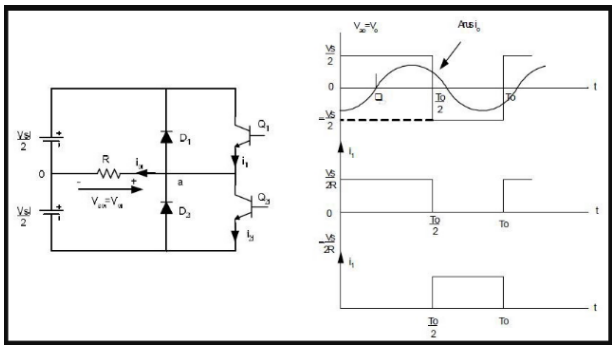

Fig 3. Half Wave Inverter

### 2.2.3 Full Wave Inverter

The basic circuit of a full-wave inverter and the output waveform with a resistive load is shown in the Fig.4. When transistors Q1 and Q2 work (ON), the voltage Vs will flow to the load but Q3 and Q4 do not work (OFF). Furthermore, transistors Q3 and Q4 are working (ON) while Q1 and Q2 are not working (OFF), so a –Vs voltage will appear on the load. Things that must be considered in choosing a DC to AC inverter include: The load capacity to be supplied by the inverter in Watts, try to choose an inverter whose workload is close to the load we want to use so that work efficiency is maximized. The inverter input voltage source to be used, is 12 Volt or 24 Volt DC input. Inverter output waveform, Sinewave or square wave for inverter AC output voltage. This is related to the suitability and efficiency of the DC-to-AC inverter.

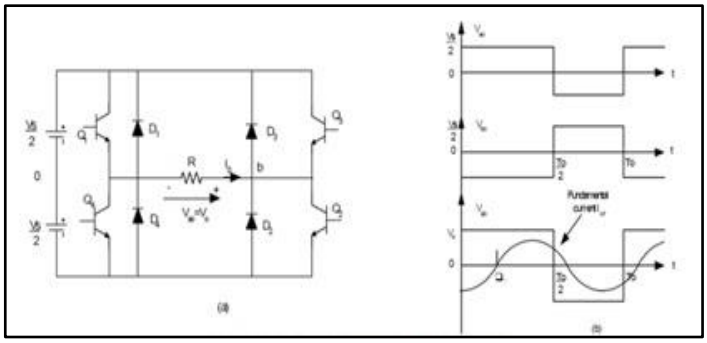

Fig 4. Full Wave Inverter

## 2. Materials and Method

This research was conducted in 2 semesters (12 months) by dividing into two stages, namely the preparation stage, the second stage is the planning stage. The research location is in the Laboratory of the UMSU Faculty of Engineering and as a place of design, load data collection. The method used in this study is an experimental research method, which is to design and measure the system under scrutiny. Measurements are made for non-electrical quantities, namely the inverter generated by the intensity of sunlight hitting the surface of the solar cell. Measurements are also made for electrical quantities such as current and voltage, power factor and electric power.

Solar Energy Capacity of Rooftop Pv Off Grid in residential homes by making observations, analyzing the total daily load used and evaluating daily load data (Watts) and Energy (Wh) per day. This will be used to determine the capacity and number of solar panels to analyze energy requirements then designing an off-grid rooftop Solar Photovoltaic and assembling hardware such as solar panel installation and power data monitoring devices[27].

Research Stage; a. In this study, the first step is to analyze the needs of the tools and materials used, b. Preparation of 3000 Watt solar power inverter design, single phase H-Bridge PWM inverter design, input capacity 12-30 VDC, inverter output voltage 25.96 VAC, equipment output voltage 220-230 VAC, output power 30 W, efficiency 81%, frequency 50 Hz, duty cycle 50%, 1 A, square wave output, c. Inverter test/measurement with resistive load, d. Calculation of total and average energy production of each inverter, e. analyze the results of energy production data processing by comparing energy production 75 % optimum energy string array and comparing inverters with the highest 75 % production proportion with others and f. The characteristics of the output voltage as a Pure Sine Wave Output Inverter will produce a pure sinusoidal output voltage.

## 3. Results and Discussion

Previous researchers have contributed to the development of the industrial world, namely as a positive contribution, namely by making an inverter training module to adjust the speed of electric motors, both 1 phase and 3 phase. This can be used as a reference in my research, that inverter control for electric load and motor speed can be done using several inputs to increase knowledge, understanding, and skills in the world of electricity, especially in the use of inverters.The results of making a solar inverter will be compared with the inverters on the market to then compare their performance in the Off-Grid PLTS system.

Inverter is a circuit to convert direct voltage into alternating voltage. The technique used is a switching technique, namely by turning on and off the switch alternately so that pulses or square waves are formed with negative and positive directions. The switching technique used is to utilize transistors BC 337, BC 327, and IRF 540 MOSFETs. If done repeatedly, a DC voltage that is only straight in one direction will turn into a square signal with different densities and strains. With the PWM (Pulse Width Modulation) method, density and strain will be read as sine signals. The output voltage waveform is in Fig. 5.

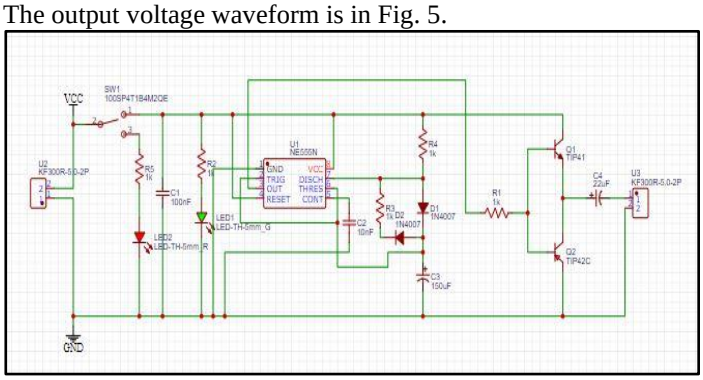

Fig 5. Pure and Modified Sine Waveform for 120 VAC, 60 Hz

When the square wave is close, the voltage will read high and when it is loosed it means the voltage is low, therefore, a square wave with periodic sparse density will form a periodic sine wave as well. So from this concept, DC voltage in the same direction will be an alternating sine wave (AC voltage). It also shows the shape of the Modified Sine Wave for comparison. In Sine Wave, the voltage rises and falls smoothly with a smoothly changing phase angle and also changes its polarity instantly when it crosses 0 Volts. In a modified Sine Wave, the voltage rises and falls suddenly, the phase angle also changes suddenly and stays at zero V for some time before changing its polarity. So any device that uses a control circuit that detects phase (for voltage/speed control) or an instantaneous zero crossing voltage (for a timer) will not work properly from the voltage it has, shown in Fig.s 6 and 7.

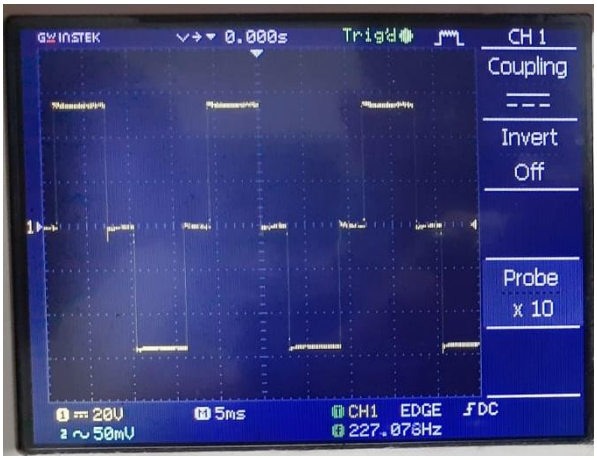


Fig 6. Modified Sine Wave

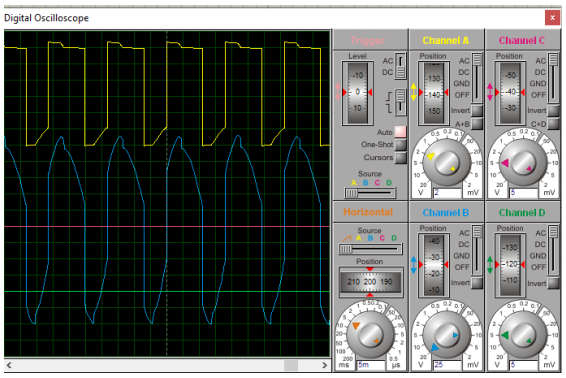


Fig 7. Simulation Results Using Proteus Software

To increase the voltage on the inverter, a Step-Up Transformer is used to increase the output voltage of the inverter so that the final output of 220 Volts is obtained. In designing a step-up transformer, what needs to be considered is the power and efficiency of the transformer as follows:

Pout = 450 W.
Vout = 220 V.
Vin = 70 V.
Iout = Pout/Vout
= 450/220
= 2.05 A
Pin = 1.25 X Pout is the value (Efficiency = 80%).
= 1.25 X 450
= 562.5W.
Iin = Pin/Vin
= 562.5/70
= 8.03 A

In the step-up transformer, this is done to determine the efficiency of the step-up transformer which has been designed using an input voltage transformer with a resistive load. In the step-up transformer, this is done to determine the efficiency of the step-up transformer which has been designed using an input voltage transformer with a resistive load. From the calculation results, it is known that the output power is 450 Watts, the output voltage is 220 Volts, the input current is 2.05 Ampere and the input power is 562.5 Watts.

Table 1. shows the test results of the step up transformer:

| V In (Volt) | I In (Ampere) | V Out (Volt) | I Out (Ampere) | P In (VA) | P Out (VA) | Efficiency (%) |
|---|---|---|---|---|---|---|
| 70 | 5.5 | 215 | 0.75 | 385 | 161 | 41.8 |
| 70 | 6.75 | 210 | 1.55 | 472 | 325 | 69 |
| 70 | 7.5 | 200 | 2 | 525 | 1050 | 200 |

Table 1 shown that the efficiency of transformers using resistive loads and sinusoidal voltage sources averages 103.6%, in Fig. 8.

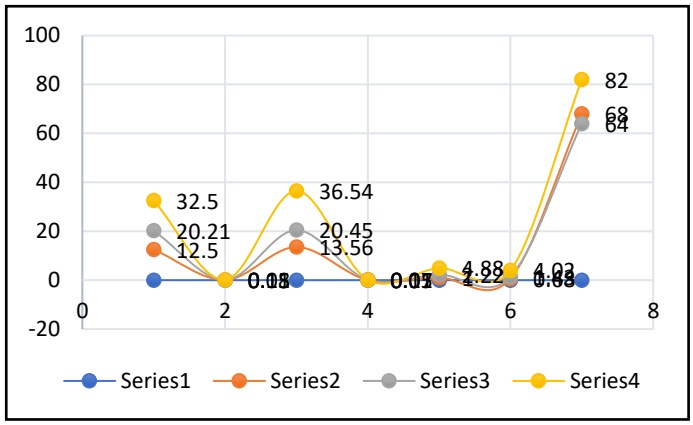


Fig 8. Graph of power and efficiency values

In the inverter test using a 60 Volt power supply, a 10 Ampere power supply in table 2 shows the results of measuring input voltage, output and input current, output with efficiency.

Table 2. Inverter Test Data

| V IN (VOLT) | I IN (A) | V OUT (VOLT) | I OUT (AMPERE) | P IN (VA) | P OUT (VA) | EFFICIENCY (%) |
|---|---|---|---|---|---|---|
| 12.5 | 0.08 | 13.56 | 0.05 | 1 | 0.68 | 68 |
| 20.21 | 0.11 | 20.45 | 0.07 | 2.22 | 1.43 | 64 |
| 32.5 | 0.15 | 36.54 | 0.11 | 4.88 | 4.02 | 82 |
| 40.2 | 0.18 | 42.66 | 0.14 | 7.24 | 5.97 | 83 |
| 42.7 | 0.2 | 44.17 | 0.17 | 8.45 | 7.15 | 88 |

Table 2 is shown that the average inverter efficiency is 77%, in Fig. 9.

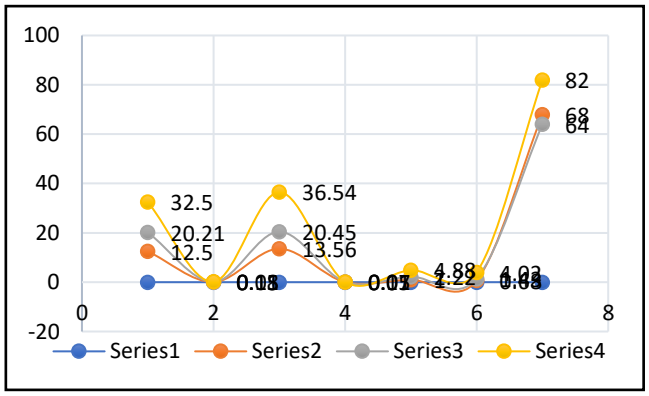


Fig 9. Graph of voltage, current and power test results

Based on the data obtained from all the tests that have been carried out, the system output voltage cannot reach the expected 220 Volts. Because load changes affect the system output voltage, where when the load is added 60 W/220V, the output voltage drops to 740.5 Volts. while when the lamp load is reduced by 60W/220 V, the output voltage increases by 786.9 Volts. with an average inverter efficiency of 77%..

## 4 Conclusion

Inverter is an electronic device used to convert DC (Direct Current) to AC (Alternating Current) voltage. The inverter output can be AC voltage in the form of sine wave, square wave and modified a sine wave. The inverter input voltage source can use batteries, solar power, or other DC voltage sources. The inverter in the process of converting DC voltage to AC voltage requires a step-up transformer in the form a step-up transformer. That the efficiency of a transformer using a resistive load and an average sinusoidal voltage source is 103.6%. In the inverter test using a 60 Volt power supply, the 10 Ampere power supply shows the results

of measuring input voltage, output and input current, output with efficiency. Based on the data obtained from all the tests that have been carried out, the system output voltage cannot reach the expected 220 Volts. Because load changes affect the system output voltage, where when the load is added 60 W/220V, the output voltage becomes 740.5 Volts. while when the lamp load is reduced by 60W/220 V, the output voltage increases by 786.9 Volts. with an average inverter efficiency of 77%.

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