A development of an Arduino pure sine wave inverter for a small scale off-grid solar PV system

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Abstract. This paper presents the implementation of Arduino Nano microcontroller for a single-phase pure sine wave inverter, which can convert DC voltage to AC voltage at high efficiency and low cost. Solar-powered electricity generation is being favored nowadays as the world increasingly focuses on environmental concerns. The designed inverter converted DC voltage into AC voltage for a small-scale off-grid solar PV system suitable for electrification in remote areas, pollution-free, and inexpensive. Its inverter uses a sinusoidal pulse width modulation technique and a simple circuit, consisting of only 2 MOSFET switches and 1 MOSFET driver. The H-bridge inverter's output is applied to a step-up transformer with a dual coil input and a single-coil output, and hence, we can create positive and negative sides of the wave. Mitigate a voltage noise; a capacitor is parallelly installed at the secondary side of the transformer. Several simulations are performed to verify the effectiveness of the designed inverter using Proteus software, and continued hardware implementation. Based on some experiments we have done, the designed inverter produces a 230 V r.m.s 50 Hz sine wave with very low harmonics distortion. The highest efficiency was obtained using 2200nF / 400V of the filter capacitor, and the smallest voltage regulation gained using 2200nF / 400V of the filter capacitor when compared with other capacitors. The proposed system is economical, efficient, and reliable and can be used for small scale power applications.

1. Introduction

Electricity is one of the greatest inventions man has ever made, due to its very important role in socio-economic and technological development [1]. The need for electrical energy is increasing every year and also an increase in the government's construction of power plants. The power plant relies on a thermal generator that can produce a large amount of power. On the other hand, thermal generators have several drawbacks, including air pollution, noise, waste, exhausted fuel, and expensive initial investment. Therefore, we need the alternative way to overcome these problems by utilizing renewable energy. One sustainable renewable energy, solar energy, is converted into electrical energy using the Solar PV System.

Solar PV Systems generate DC from sunlight, which can be directly used for DC electrical equipment or to recharge batteries. Solar PV system based off-grid has several advantages, including suitable for electrification in remote areas and pollution-free. Solar PV Systems can be applied to public street lighting systems, electricity needs for boats, recreational vehicles, electric cars, camera detectors, and remote monitors.
Besides, Solar PV Systems are dependent on solar radiation. The current produced is direct current (DC). Thus the Solar PV System requires AC, a converter from DC to AC is needed, an inverter. The inverter converts the DC from the energy storage unit then supplied into the connected AC load.

There are square wave inverters, modified square wave inverters, and pure sine wave inverters. Among the three types of inverters, the most efficient and suitable for all loads is the pure sine wave inverter [2]. It is an inverter that has an output voltage with a pure sine waveform. This type of inverter can provide a voltage supply to inductor loads or electric motors with excellent power efficiency. This paper documents the design of an Arduino-based pure sine wave inverter, focusing on a small scale solar PV system. The inverter's various applications are solar electrical systems, Remote homes, Telecommunications, Computers, Tools, Security applications, Mobile power, Monitoring equipment, Emergency power, and lighting.

2. A review of sine wave inverter

Single-phase inverters are of three types i.e. square wave inverter, modified sine wave inverter, and pure sine inverter. The pure sine inverter is studied in this paper. The square wave or modified sine wave; these two types of inverters are cheaper and are not suitable for delicate electronic devices [3]. The output of pure sine wave inverter is a near-perfect sine wave. Pure sine wave inverters have fewer power losses and less heat generation [4]. The sine wave has minor harmonic distortion resulting in a very clean supply. It makes it most suitable for running electronic systems such as microwaves ovens, computers and motors and other sensitive equipment without causing problems or noise. Pulse Width Modulation (PWM) technique is best for sine wave generation.

A pure or true sine wave inverter changes or converts the DC supply into a near-perfect sine wave. The sine wave has minimal harmonic distortion, which results in a very clean supply [5]. It makes it suitable for working electronic systems such as computers, motors, and microwave ovens, and other sensitive equipment without causing problems like noise. Things like mains battery chargers also run better on pure sine wave converters. Ideally, the output waveforms of an inverter should be sinusoidal. However, the waveforms of efficient inverters are non-sinusoidal and contain specific harmonics [6]. Due to the availability of high-speed power semiconductor devices, the harmonic contents present in the output voltage can be minimized significantly by using switching techniques [7].

| Table 1. Comparison of inverter techniques [8]. |
|-----------------------------------------------|
| **Parameter** | **Square wave inverter** | **Modified sine wave inverter** | **Pure sine wave inverter** |
| Output waveform | Square wave | Square except that the output goes to zero volts for a time before switching positive or negative wave. | Sine wave |
| Harmonic distortion | More | Moderate | Less |
| Heat generation | More | Moderate | Less |
| Design complexity | Simpler | Less complex design than pure sine wave inverter | More |
| Cost | Less expensive | Moderate expensive | More expensive |
| Suitability | Not appropriate to delicate electronic devices | Not appropriate to delicate electronic devices | Appropriate to delicate electronic devices |

3. System model of an Arduino-based inverter design

Figure 1, the block diagram below explains that the sources used to make pure sine wave inverters are batteries, batteries, or a 12V DC power supply. This voltage will be converted into AC voltage. In the process of converting DC voltage to AC voltage using a switching circuit, using two pairs of MOSFETs with each side using four parallel MOSFET in order to obtain SPWM waves back and forth from switching the two MOSFET pairs. In the MOSFET switching process, the MOSFET driver IC will be driven by the type IR2110. The MOSFET driver circuit will drive the MOSFET, which has been ordered by the Arduino nano microcontroller. It gives a signal to the MOSFET Driver circuit then forwarded to the MOSFET, where the two pairs of MOSFET have different signal values, where one MOSFET will
be worth one and the other one MOSFET will be worth 0 so that an alternating SPWM signal will be obtained. Reverse, which will produce an AC voltage. The inverter output is in the form of an AC voltage, which will then enter the step-up transformer. This step-up transformer serves to increase the voltage from 12V AC to 220V AC. After the transformer output voltage, a mylar capacitor is installed to reduce the ripple, and the resulting wave is sinusoidal. Then the inverter will be tested by turning on the lamp.

![Inverter Block Flow Diagram](image)

**Figure 1.** Block flow diagram of inverter design.

### 3.1. Software design

In this study, Arduino IDE software for Windows is used, with serials, namely series 1.8.5.0. This software is built-in Arduino, which is useful in compiling the source code for programming the Arduino board. The Arduino IDE software can generate the setting SPWM signal in the pulse configuration. There are two types of SPWM are arranged to obtain alternating waves to produce AC voltage [9]. In the coding PIN D9 and D10 are set as output because these ports include ports that support PWM signals as shown in the coding:

```
DDRB = 0b00000110; // Set PB1 and PB2 as outputs.
```

For a frequency setting of 50 Hz, shown in the coding:

```
ICR1 = 1600; // Period for 16MHz crystal, for a switching frequency of 100KHz for 200 subdivisions per 50Hz sin wave cycle.
```

After the programming process is uploaded, then it will be integrated with hardware to see the SPWM output signal.

### 3.2. Hardware design

In designing the Proteus software, it aims to simulate an inverter circuit to make it easier to manufacture the hardware. In the Proteus simulation that has been made, the inverter circuit concept is converted from DC to AC then the voltage generated is stepped up using a transformer. The transformer used is a CT step-up transformer 12V to 220V. From the simulation, the inverter circuit can be seen in the figure 2 below.
In the picture above, it is explained that the manufacture of this inverter uses two pairs of MOSFET for the switching process, which produces AC voltage. Where to set the PWM control, the picture above to get a PWM signal, then the output voltage from the switching process will be stepped up by using a transformer, the switching output voltage is higher than the input voltage.

The other software design is the design using Eagle software. In this design, the schematic and PCB paths will be used for the hardware. This design is obtained from the correct topology, which is then continued with the schematic design and PCB so that hardware work can be done immediately. The Eagle software consists of 2 types, namely the circuit schematic and the PCB board. The schematic circuit used in the Eagle software can be seen in the Figure below and the PCB board image can be seen in the figure 3 below.

The picture above is a schematic of an inverter using the Eagle software. In this circuit scheme, it is more specific than using Proteus software, where there is a control circuit in the form of an Arduino Nano Microcontroller and a MOSFET Driver circuit, and there is a diode that will reverse the back current that will pass through the MOSFET, no short circuit, and safe. Besides, the power circuit uses 2 pairs of MOSFET with each MOSFET pair, there are four MOSFET arranged in parallel, so that the number of MOSFET used is eight MOSFET to slow down the temperature rise of the MOSFET. In this circuit, the hardware for the inverter is made.
Figure 4. Inverter board schematic circuit in eagle software.

Figure 4 above is the board that will be printed onto the PCB, so that connection paths can be made between components so that hardware can be made inverter. In designing the hardware system, it integrates the inverter topology that has been made, which is then made a schematic circuit in the eagle software, which will be made a schematic board and printed in PCB form. After that, the components are integrated into the PCB and soldered. In this hardware, there are several parts in making an inverter, namely a switching driver circuit, an inverter or switching circuit, a step-up transformer circuit, and a filter circuit. Tools and materials in making pure sine wave inverters can be seen on table 2.

Table 2. Tools and materials in making pure sine wave inverters.

| Elements of the Design       | Quantity |
|------------------------------|----------|
| Arduino Nano                 | 1        |
| Modul Step Down LM2596       | 1        |
| MOSFET IRF3205               | 8        |
| MOSFET Driver IR2110         | 1        |
| Dioda 6A05MIC                | 1        |
| Dioda UF4007                 | 2        |
| Elco 4700 uF/35 Volt         | 1        |
| Capacitor non polar 100nF    | 1        |
| Capacitor Milar 470nF        | 1        |
| Capacitor Milar 1000nF       | 1        |
| Capacitor Milar 2200nF       | 1        |
| Resistor 10 ohm              | 8        |
| Resistor 100 ohm             | 2        |
| Resistor 1000 ohm            | 8        |
| IC Regulator LM7805          | 1        |
| Transformer 20 A             | 1        |
| Post Binding Connectors      | 1        |
| Fan DC 12 Volt               | 1        |
| Heatsink                     | 1        |

In designing the inverter hardware, the first stage is the inverter. The inverter used is the push-pull topology. The working principle of push-pull is that when there is a voltage source in the form of a DC voltage, which will be converted into AC voltage, then there are two switches that will be used, namely S1 and S2. At first, switch S1 will close, a voltage will appear on the load, where the electric current will flow from the negative source to S1 then to load 1 then to the positive source. Then S1 will be opened while S2 will close so that a gap appears between the loads, thus current will flow from the negative source to load and then to the positive source. If done continuously will result in AC voltage. The switch used is a N type MOSFET. The MOSFET used is a MOSFET IRF3205 with input from the inverter in the form of a 12V DC voltage. In the N-type MOSFET, the gate output voltage value is the same as the gate input voltage. How the MOSFET works when the condition is ON where the MOSFET condition is active or there is a current flowing from the MOSFET to the drain leg to the source leg so that the Vds value is more than 0. While the OFF condition or no current flows from the MOSFET to the drain leg then to the source leg, so that the value of Vds equals 0.
Figure 5. (a) The push-pull inverter circuit topology, (b) IR2110 MOSFET driver circuit.

Figure 5 (a), it explains that the circuit converts DC voltage into AC voltage with a frequency of 50 Hz. The MOSFET used is the IRF3205 type because the ability of the Vds MOSFET has a maximum value limit of 55 Vds and Id 110 A. Figure 5 (b) shows a series of IR2110 MOSFET Drivers which will switch 2 pairs of MOSFET that are made which produce high and low signals from the program created. Based on the datasheet related to the MOSFET IR2110 Driver circuit, it will generate an SPWM signal for the MOSFET of the microcontroller used. The microcontroller on the system used is an Arduino Nano. Based on the datasheet related to Arduino Nano pins, this system uses pins D9 and D10 to produce high and low signals because the SPWM setting uses OC1A and OC1B to set high and low signals, which can be seen the Arduino Nano pin configuration. Only a capacitor is used, because the transformer also functions as an inductor for the filter.

The following is the calculation for the ideal transformer [10]:

Inverters are made with a power of 1000 Watts. It can be calculated based on the following equation:

\[ P = V \times I \rightarrow I = \frac{P}{V} \] (1)

If the input voltage is 12 V on the primary side and the desired power is 1000 Watts, then:

\[ I = \frac{P}{V} = \frac{1000}{12} = 83.3 \text{ A} \] (2)

As for the output on the secondary side with an output of 220 V then:

\[ I = \frac{P}{V} = \frac{1000}{220} = 4.5 \text{ A} \] (3)

A center tap transformer is needed which is capable of delivering a current of 83.3 A. However, the transformer used in this test is 20 A:

\[ P = V \times I \rightarrow 12 \times 20 = 240 \text{ W} \] (4)

Thus, in this prototype, the maximum power that can be generated is 240 Watt.

4. Results and analysis

Testing the Pure Sine Wave Inverter without load to find out that the Pure Sine Wave Inverter can work adequately, producing sinusoidal waves at no-load conditions. The inverter will be tested in the form of a waveform and an RMS voltage value. The test was carried out by varying the capacitance value of the capacitor filter with a capacitor variation of 470 nF / 400V, 1000 nF / 400V, and 2200 nF / 400V.

4.1. No-load test

In testing the inverter output waveform at no load, the tools used are Laptop, DC 12V 10A Power Supply, Hantek-6022BE Oscilloscope, 1A Stepdown Transformer. Since the oscilloscope only has a maximum limit of 35V AC, the inverter output side is connected to a stepdown transformer so that the oscilloscope is not damaged.
4.1.1. *Inverter output waveform of no-load test*. In the figure 6, it can be explained that, to test the inverter using a voltage source in the form of a 12V / 10A DC Power Supply. The power supply is connected to the inverter input, and then the inverter output is connected to a stepdown transformer. The output from this stepdown transformer is connected to the oscilloscope to see the inverter wave output, which can be seen from the laptop.

![Figure 6. Output wave test without load and filter capacitors.](image)

In the figure 7, it can be seen that the filter capacitor is installed at the inverter output. The variations of the capacitors used are 470 nF / 400V, 1000 nF / 400V, and 2200 nF / 400V.

![Figure 7.](image)

The inverter output waveform without load and filter capacitor, the waveform is still a lot of ripple noise. The output waveform of the inverter without load, and with a 470nF / 400V filter capacitor, the waveform has become a sinusoidal wave, but at the peak of the wave, there is still a little ripple noise so that the peak waveform is slightly cut off. The no-load inverter output waveform and with a 1000nF / 400V filter capacitor, the waveform has become a better sinusoidal waveform than using a 470nF / 400V capacitor. The waveform has less ripple noise when the wave moves upward and downwards. The no-load inverter output waveform using a 2200nF / 400V filter capacitor becomes a sinusoidal wave better than using a 470nF / 400V capacitor. Its waveform almost has no ripple noise, and only the waveform is slightly cut off when the wave goes up and the time the wave goes down.

4.1.2. *Inverter output RMS voltage of no-load test*. In testing the measurement of the value of the inverter output RMS voltage at no load, the tools used are the DC 12V / 10A Power Supply and the True RMS Multimeter.
Table 3. The RMS voltage measurement results.

| Without filter capacitors (Volt) | Using a filter capacitor (Volt) |
|----------------------------------|---------------------------------|
| 470 nF                          | 1000 nF                         | 2200 nF                         |
| 297,1                            | 232,7                           | 228,5                            | 226                           |

Table 3, the measurement results of the inverter output RMS voltage value without load and filter capacitor, and with the filter capacitor, the RMS voltage value is different. At the time without the capacitor, the voltage is very high at 297.1 volts. Then after installing the filter capacitor, the inverter output voltage drops. The higher the capacitor value, the smaller the inverter output RMS voltage [11]. It is because of the more significant the capacitor value, the smaller the ripple noise at the inverter output.

4.2. Load-test
Testing of the Pure Sine Wave Inverter with a load aims to determine the performance of the Pure Sine Wave Inverter with the effect of the load. The loads used are bulb lamps with a power of 5 Watt, 10 Watt, 15 Watt, 25 Watt, and 100 Watt, as well as LED lamps with 3 Watt, 5 Watt, 7 Watt, 9 Watt, and 11 Watt. The inverter will be tested in the form of a waveform, RMS voltage value, efficiency, and regulatory voltage. The test was carried out by varying the capacitance value of the capacitor filter with a capacitor variation of 470 nF / 400V, 1000 nF / 400V, and 2200 nF / 400V. The equipment used for testing loaded inverters includes laptops, DC 12V 10A power supply, Hantek-6022BE oscilloscope, 1A stepdown transformer, True RMS multimeter, and bulb and LED lighting loads.

4.2.1. Inverter output waveform with load. In testing the output waveform of the loaded inverter, the tools used are Laptop, DC 12V 10A Power Supply, Hantek-6022BE Oscilloscope, 1A Stepdown Transformer, and bulb and LED lamp loads. Since the oscilloscope only has a maximum limit of 35V AC, the inverter output side is connected to a stepdown transformer so that the oscilloscope is not damaged.

![Test Report](image)

**Figure 8.** (a) with-load 470nF / 400V (b) with-load 1000nF / 400V (c) with-load 2200nF / 400V.

When the capacitor filter is installed, when the inverter output is connected to the load of the bulb lamp, the output voltage increases as the capacitor value increases, until the highest load is 100 Watt, the output voltage decreases as the capacitor value increases. When the inverter output is connected to the load of the LED lamp, the output voltage decreases with the rated capacitor 470nF / 400V and 1000nF / 400V, and the output voltage rises to the rated capacitor 2200nF / 400V.
4.2.2. *Inverter output RMS voltage with load.* It can be seen on table 4.

**Table 4.** Inverter output RMS voltage with load.

| Load variation | Watt | No capacitor (Volt) | Using capacitor (Volt) |
|----------------|------|---------------------|------------------------|
|                |      |                     | 470 nF | 1000 nF | 2200 nF |
| Bulb           | 5    | 258                 | 215    | 215    | 219    |
|                | 10   | 246                 | 210    | 211    | 215    |
|                | 15   | 234                 | 204    | 206    | 209    |
|                | 25   | 229                 | 202    | 204    | 207    |
|                | 100  | 107                 | 142    | 141    | 140    |
|                | 3    | 294                 | 226    | 224    | 225    |
|                | 5    | 228                 | 223    | 222    | 224    |
|                | 7    | 286                 | 221    | 220    | 223    |
| LED            | 9    | 230                 | 220    | 219    | 222    |
|                | 11   | 275                 | 219    | 218    | 221    |

The measurement results of the RMS voltage value of the inverter output loaded without the filter capacitor, and the filter capacitor, the value of the RMS voltage is different. In the absence of a capacitor, when the inverter output is connected to the bulb lamp's load, the voltage decreases with the magnitude of the lamp power. Moreover, when the inverter output is connected to the LED lamp's load, the voltage is erratic, fluctuates, and when the power of the LED lamp is 3 Watt, 7 Watt, and 11 Watt, the voltage drops gradually. Furthermore, when the power of the 5 Watt LED lamp and 9 Watt LED, the voltage is far from the previous lamp load. It can be concluded that the voltage decreases with the amount of load power. Moreover, the capacitor value that makes the most significant output voltage is the capacitor with a value of 2200nF / 400V.

4.3. *Efficiency inverter*

In simple terms, efficiency can be defined as the percentage of the amount of power released and the amount of power taken. The following equation can calculate efficiency:

\[
\eta = \frac{P_{out}}{P_{in}} \times 100% = \frac{V_{out} \times I_{out}}{V_{in} \times I_{in}} \times 100% \quad (5)
\]

It is necessary to find data on input voltage, input current, output voltage, and output current in order to find efficiency. In measuring the value of efficiency, the tools used are DC 12V / 10A Power Supply and True RMS Multimeter.

![Figure 9. (a) Without filters capacitor (b) with filters capacitor.](image)

In the figure 9 it can be explained that, to test the efficiency of the inverter using a voltage source in the form of a 12V / 10A DC Power Supply. The power supply is connected to the inverter input, then there are four multimeters, each of which has its function. Multimeter 1 is connected in parallel on the input side to measure the input voltage, and multimeter 2 is connected in series on the input side to measure the input current, Multimeter 3 is connected in parallel on the output side to measure the output voltage, multimeter 4 is connected in series on the output side to measure current the output. Moreover, it can be
seen that a capacitor filter is attached to the output of the inverter. The variations of the capacitors used are 470 nF / 400V, 1000 nF / 400V, and 2200 nF / 400V.

### Table 5. Efficiency of inverter.

| Watt Lamp | No capacitor | 470nF | 1000nF | 2200nF |
|-----------|--------------|-------|--------|--------|
| 5         | 45%          | 26%   | 28%    | 30%    |
| 10        | 51%          | 35%   | 36%    | 40%    |
| 15        | 56%          | 41%   | 43%    | 47%    |
| 25        | 57%          | 43%   | 45%    | 49%    |
| 100       | 43%          | 54%   | 54%    | 53%    |
| 3         | 16%          | 8%    | 10%    | 12%    |
| 5         | 86%          | 19%   | 18%    | 20%    |
| 7         | 38%          | 19%   | 21%    | 23%    |
| 9         | 91%          | 26%   | 29%    | 31%    |
| 11        | 49%          | 34%   | 33%    | 36%    |
| average   | 53%          | 31%   | 32%    | 34%    |

Table 5 show the results of measuring the efficiency of the inverter without filter capacitors and filter capacitors, the efficiency values differ. At the time without capacitors and at bulb lamp loads, the efficiency value increases with increasing load power. Until the highest load is a 100 Watt bulb lamp, the efficiency value decreases due to the very high rising input current. At the time without capacitors and at a load of LED lamps, the efficiency values fluctuate and fall. The efficiency is low at the load of 3 Watt, 7 Watt, and 11 Watt LED lamps. Moreover, the efficiency is high at the load of 5 Watt, and 9 Watt LED lamps.

When the capacitor is installed, bulb as the load, the efficiency value increases with increasing load power. When the load on the LED lamp, the efficiency value also continues to increase with increasing load power. When compared, the efficiency is higher when the load is bulb lamps than LED lamps. The highest efficiency is when using a 2200nF / 400V filter capacitor rather than other filter capacitors.

It can be concluded that the inverter's efficiency is higher when without a capacitor filter than using a filter capacitor. It is because when the filter capacitor is installed, the filter capacitor will become a burden to the inverter results in the current on the input side getting bigger [12]. When a capacitor filter is installed, the highest efficiency is when using a 2200nF / 400V filter capacitor than other filters. It is because of the more significant the filter capacitor, the smaller the current on the input side [13].

### 4.4. Voltage regulation.

It can be shown on table 6.

### Table 6. Voltage regulation.

| Variety of load | Watt | 2200nF/400V |
|-----------------|------|-------------|
|                 |      | VNL | VFL | VR  |
| Bulb            | 5    | 226 | 219 | 3%  |
|                 | 10   | 226 | 215 | 5%  |
|                 | 15   | 226 | 209 | 8%  |
|                 | 25   | 226 | 207 | 9%  |
|                 | 100  | 226 | 140 | 61% |
|                 | 3    | 226 | 225 | 0.4%|
|                 | 5    | 226 | 224 | 1%  |
|                 | 7    | 226 | 223 | 1%  |
| LED             | 9    | 226 | 222 | 2%  |
|                 | 11   | 226 | 221 | 2%  |
The calculation results of the Voltage Regulation output of the inverter without filter capacitors and with filter capacitors, the value of the calculation of Voltage Regulation is different. When the circuit does not use a capacitor, and the bulb is used as a load, the voltage regulation value continues to increase as the power from the load increases. Moreover, the highest is the voltage regulation value for a 100 Watt bulb lamp load. Then at the load of the LED lamp, the voltage regulation value does not fluctuate.

When a capacitor filter is installed, the voltage regulation value increases continuously as the load power increases [14]. When loaded with a 100 Watt bulb lamp, the highest voltage regulation value is up to 60% more. When a 100 Watt bulb lamp installed, the voltage drops mainly so that the voltage regulation is high. The smallest voltage regulation value is when using a filter capacitor of 2200nF / 400V when compared to other capacitors.

It can be concluded that the value of voltage regulation is small when using a filter capacitor compared to without using a filter capacitor. Furthermore, the smallest voltage regulation value is when using a 2200nF / 400V filter capacitor.

5. Conclusion
A microcontroller-based inverter circuit that generates a pure sine waveform was developed and tested. The Arduino Nano microcontroller pure sine wave inverter was designed and simulated with Proteus Software, programmed with Arduino IDE Software. It was then constructed on a printed circuit board using Eagle Software. When tested, the circuit produced a 230 V r.m.s 50 Hz sine wave with very low harmonics distortion, which makes it suitable for small-scale electronic devices. From the test carried out and obtained, the system performed according to the design specification. The Inverter efficiency without a filter capacitor is higher than using a filter capacitor. The installed filter capacitor turns as a resistance of the inverter, which increases the input current [15]. The Voltage regulation using filter capacitors is smaller than without using filter capacitors. The highest efficiency was obtained using 2200nF / 400V of the filter capacitor and the smallest voltage regulation gained by using 2200nF / 400V of the filter capacitor when compared with other capacitors. The proposed system is economical, efficient, and reliable and can be used for small scale power applications.

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