Solar Powered Portable Electric Stove For Disaster Impacted Areas

Habibullah, Juli Sardi, Aswardi

Abstract: Indonesia is one of the most vulnerable countries to natural disasters, such as earthquakes, tsunamis, volcanic eruptions, landslides, and floods. One of the main issues that occur in areas affected by disasters is the power outage and gas shortage. This situation is added by the difficulty to obtain certain basic needs such as water and fuel. To maintain the availability of food for people affected by disasters, portable electric stoves are one of the solutions. By considering that due to power outage in a disaster-hit regions, this study propose a design of solar powered portable electric stove. This portable stove is designed to have power option of 300 Watt and 600 Watt using an Arduino Uno controller system. Test results showed that it needs 20 minutes to boil 1 litre of water using 300 Watt and only 15 minutes if using 600 Watt of power. Therefore, this equipment is useful for people in disaster impacted areas.

Index Terms: Arduino Uno, Disaster impacted areas, Prototype design, Solar powered portable electric stove.

1. INTRODUCTION

INDONESIA is one of the most vulnerable countries to natural disasters, such as earthquakes, tsunamis, volcanic eruptions, landslides and floods. This is caused by several factors including; Indonesia's position is surrounded by three world tectonic plates namely the Indo-Australian Plate, Eurasia and the Pacific Plate. If the three tectonic plates meet can produce a pile of energy that has a certain threshold. In addition, Indonesia is also on the Pacific Ring of Fire (the ring of fire), which is the most active series of volcanoes in the world that runs along the Pacific plate. This zone contributes almost 90 percent of earthquake events on earth and almost all of them are major earthquakes in the world [1]. 87% of Indonesia is disaster-prone, where as many as 383 out of 440 regencies / cities are natural disaster-prone areas [2]. According to data from the National Disaster Management Agency (BNPB), the number of disasters that occurred in Indonesia during the last 10 years amounted to 20,342 times. As a result of the incident, the death toll and missing reached 11,352 people, injured 164,772 people and displaced and affected 33,513,958 people [3]. The high number of disasters and their impacts must be seriously considered to find the solutions. With the frequent occurrence of natural disasters in Indonesia, disaster risk management is needed for better and systematic handling of disaster relief. One of the main problems that occur in areas affected by disasters is the power outage and the difficulty of obtaining various basic needs and the scarcity of fuel. One of the important activities carried out in the affected area is the provision of consumption for affected communities. This activity usually requires a variety of equipment that requires electricity and gas as the main source of energy. The stove is one of the main equipment needed in cooking various types of food. Moreover, Indonesian culture consumes food that must be cooked every time it is served. To operate a stove requires gas or electricity, and hence we need a solution that can overcome these problems. One solution that can be done is to use solar panels as a power source to operate the stove when cooking. Indonesia is an equatorial country that has relatively many periods to harvest sunlight. Therefore, solar energy can be used as alternative energy when gas becomes scarce and the main grid has power outage. The application of solar panels as a source of energy has been widely applied in supporting various activities carried out by humans in various fields, such as; fishing boats [4], stadium roofs [5] and fertilizer dryers [6]. Therefore, the potential application of solar panels as a source of power for electric stoves is huge. This research aims to design a prototype of a portable solar-powered electric stove that will be applied to the affected areas.

2 METHODOLOGY

Data collection is carried out using a system that has been tested. Data collection and analysis includes:

- Output voltage and current on the solar panel (until the battery is fully charged).
- Trial / simulation of the use of electric stoves directly by battery (checking the output on the electric stove) whether a voltage drop occurs.
- Trial / simulation of using electric stove directly by battery (checking the ability of the battery as a backup source) until the battery is empty (knowing the time of use, is it in accordance with the calculation).
- Analyzing the stability of the voltage and current output on the solar panel as a source of voltage and electric current.
- Analyzing the voltage and current stability of electric stoves, as well as the ability of the stove in terms of function.
- Analyzing the ability of the battery as an electricity storage when the solar panel is not operating (battery durability)

3 SYSTEM DESIGN

3.1 Electric Stove

The specification of portable electric stove is as follows:

- Heating system is using nickel
- Stove structure is made of iron
- Stove power could be regulated 300 W and 600 W

The diagram block and design of the portabel electric stove

• Habibullah, Department of Electrical Engineering, Universitas Negeri Padang, Indonesia.
• Juli Sardi, Department of Electrical Engineering, Universitas Negeri Padang, Indonesia.
• Aswardi, Department of Electrical Engineering, Universitas Negeri Padang, Indonesia.
is shown in figure 1 and 2 respectively.

**Fig 1. Diagram block of portable electric stove system**

![Diagram block of portable electric stove system](image)

**Fig 2. Design of portable electric stove**

![Design of portable electric stove](image)

### 3.2 Solar Panel

Solar cells consist of a p-n type (p-n junction semiconductor) semiconductor material where electron flow occurs when exposed to sunlight, this electron flow is referred to as the flow of electric current. The main part of converting the sun energy into electricity is the absorber. However, each layer is also very influential on the efficiency of solar cells. Sunlight consists of various types of electromagnetic waves, therefore absorbers here are expected to absorb as much radiation as possible from the sun's rays. Some important characteristics of solar cells consist of open circuit voltage ($V_{oc}$), short circuit current ($I_{sc}$), effects of changes in sunlight intensity, effects of temperature changes and voltage-current characteristics (V-I characteristics) on solar cells [7]. $V_{oc}$ is the voltage that is read when the current does not flow or can also be called a current equal to zero. The way to achieve open circuit ($V_{oc}$) is by connecting the positive and negative poles of the solar module with a voltmeter, so that the solar cell's open circuit voltage value can be seen on the voltmeter [8]. $I_{sc}$ is the maximum current produced by the solar cell module by shorting the positive pole with the negative pole on the solar module. And the value of $I_{sc}$ will be read in ammeters. The current generated by the solar module can determine how fast the module is charging a battery. In addition, the current from the solar module also determines the maximum power of the instrument used [8]. Changes in the intensity of sunlight received by the solar module affect the power generated by the solar module, the greater the intensity of the light that hits the solar module, the greater the power generated by the solar module and vice versa. The energy per hour effective for the sunlight is equal to 600 Wh / 5 hour = 120 Watt. In this case, we use 150 Wp solar panel. Thus, during a fully effective storage time of 5 hour/day, the solar cell can supply the electricity for up to 600Wh.

### 3.3 Battery System

The battery used is a battery specifically for solar systems, with the type of Sealed Lead Acid (SLA) or Valve Regulated Lead Acid (VRLA). The most common size of the battery is 12V or 24 Volt. Battery numbers must also consider autonomy days, or days where the sun is mostly covered by the cloud due to weather condition. This is usually taken into account so that the system remains active even though the weather is cloudy. The maximum PV system cannot convert solar power is for 3 days, hence the need for power per day must be multiplied by 3. Furthermore, it must also be taken into account the efficiency of the battery and when used, the battery should not be used until all power is used up.

Battery capacity is calculated using below equation:

$$\text{Battery Capacity} = \frac{(\text{Power} \times 3)}{\left(0.85 \times 0.6 \times 12\right)}$$

$$= \frac{(102 \times 3)}{\left(0.85 \times 0.6 \times 12\right)}$$

$$= 50 \text{ Ah}$$

Nevertheless, with the limited battery available in the market, the battery used in this study is a 12 Volt MF battery with a capacity of 60 Ah. This battery could store the energy up to 60 Ah x 12 V = 720 Wh. If it used to fulfil 102 W of electric load, the amount of time the battery could work is 720 Wh / 102 W = 7.05 hour. About 20% of the energy would be used for operating the inverter or around 576 Wh.

### 3.4 Solar Charge Controller

To calculate solar charge controller needs, we need to consider the short circuit current ($I_{sc}$) and number of solar panels. In this case, minimum solar charge controller is calculated as:

$$(1 \times 5.72 \text{A}) + (1 \times 1.3 \text{A})$$

$$= 7.02 \text{A}$$

### 3.5 Inverter

The unit of measurement for Inverters is Watt. For equipments that need to be powered by solar systems, we need to know the capacity of the inverter to choose based on the loads that must be fulfilled. Inverters in this study use a ready-made inverter and are available in the market with an output of 600 watts. This inverter is used to convert the DC voltage generated by solar panels into 220 volt AC voltage to supply the electrical energy needed by an electric stove. Diagram block of solar powered portable electric stove is shown in figure 3.
3.6 Arduino Uno
Arduino is said to be an open source platform for physical computing. Arduino is not just a development tool, but it is a combination of hardware, programming language and a sophisticated Integrated Development Environment (IDE). [9] In this research, Arduino Uno is included in the type of Arduino USB board. The Arduino Uno Board has the following new features:

a. 14 digital I/O pins (0-13)
   Functioning as input or output, can be set by the program. Especially for 6 pins of 3, 5, 6, 9, 10 and 11, it can also function as an analog output pin where the output voltage can be adjusted. The value of an analog output pin can be programmed between 0 - 255, where it represents a voltage value of 0 - 5V.

b. USB
   The functions are to:
   • Load programs from the computer into the board
   • Serial communication between the board and the computer
   • Give electrical power to the board

c. SV1 jumper
   The jumper is used to choose the board's power source, whether from an external source or using USB. This connection is no longer needed on the latest Arduino board because the selection of external or USB power sources is done automatically.

d. Q1 – Quartz crystal oscillator
   If the microcontroller is considered as the ‘brain’, then the crystal is the ‘heart’ because this component produces beats that are sent to the microcontroller to perform an operation for each beat. This crystal is chosen which beats 16 million times per second (16MHz).

e. Reset button S1
   To reset the board so that the program will start again from the beginning. Note that this reset button is not for removing programs or emptying the microcontroller.

f. In-circuit serial programming (ICSP)
   The ICSP port allows users to program the microcontroller directly, without going through the bootloader. Generally Arduino users do not do this so ICSP is not used even though it is provided.

g. IC 1 – Microcontroller atmega
   The main components of the Arduino board, there are CPU, ROM and RAM.

h. X1 – External power supply
   If we want to be supplied with an external power source, Arduino boards can be given a DC voltage between 9-12V.

   i. 6 pins analogue input
      This pin is very useful for reading the voltage generated by analog sensors, such as temperature sensors. The program can read the value of an input pin between 0-1023, where it represents a voltage value of 0-5V.

4 TESTING RESULT AND ANALYSIS
An equipment or program can be said to work well if it has been tested according to the function of the equipment. The test is intended to get an evaluation of the system that has been designed in order to get better performance by making some improvements to the circuit that experienced shortages when testing. This test is carried out to obtain data and evidence of the final result of the fact that the hardware that has been made can work well. Based on the data and evidence, it can be analyzed the work process which can later be used to draw conclusions from what has been made in this project. The purpose of this test is to see the extent to which the tools made by the author are working well or not, so we get results and comparisons of what was planned beforehand. Tests that will be discussed about the system built is followed by analysis.

In this study, the portable electric stove uses an Arduino Uno to control the whole system by using a current sensor, voltage sensor, 300 W to 600 W Heater as well as controlling the relay module. This automatic electric stove is in the form of a box made of aluminium / with dimension of 30 cm x 25 cm x 30 cm. In this case, the electric stove works by applying several electronic electrical components, microcontrollers, current sensors, relays, LCDs. The testing of the Arduino Uno system was conducted to ensure that the Arduino system used in this study is not damaged. So the program that is embedded in the microcontroller is able to run well. To calculate the length of nickel wire, we must first determine the resistance of it. Given the equation below:

\[ R = \frac{V^2}{P} \]  

(3)

where R is the wire resistance, V is input voltage (220 V) and P is stove power option (300 W and 600 W). The length of nickel wire is calculated using equation below:

\[ L = \frac{R}{\rho} \]  

(4)

where L is the wire length and \( \rho \) is the resistivity (36 \( \Omega \) / meter). Hence, using the equation, the wire length obtained
6.7 meter. Furthermore, we also conduct testing for keypad. This test aims to determine whether the keypad can work well. If the keypad is pressed according to what is desired, then the keypad can be sure to work properly. To see the buttons pressed through the keypad, the status can be displayed on the LCD and the keypad output can be set according to the needs. The keypad function is to control the amount of time this stove is used for cooking. We also tested the LCD display to ensure that the LCD runs well, according to what we want for example to set the timer for cooking. It was programmed by the Arduino uno LCD used 20x4 character LCD. LCD controls are RS, E, D4, D5, D6 and D7 pins which connected to pins A0, A1, A2, A3, A4 and A5 on Arduino. Testing of electric stoves by taking measurements produced by electric stoves when given a power source. From testing the electric stove, we obtained several measurements of current, from both 300 W and 600 W type. We also measure the time taken by both power setting to boil a liter of water. The testing result is shown in table 1 below while figure 5 showing the experimental setup of the portable electric stove.

**Fig 5. Experimental setup of portable electric stove**

**Table 1. Testing result of solar powered portable electric stove**

<table>
<thead>
<tr>
<th>Power</th>
<th>Object</th>
<th>Voltage</th>
<th>Current</th>
<th>Time to Boil</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 W</td>
<td>1 Liter of water</td>
<td>220 Volt</td>
<td>1.3 A</td>
<td>20 Minutes</td>
</tr>
<tr>
<td>600 W</td>
<td>1 Liter of water</td>
<td>220 Volt</td>
<td>2.6 A</td>
<td>15 Minutes</td>
</tr>
</tbody>
</table>

5 CONCLUSION

From this study, it is proved that this portable electric stove will work effectively in a disaster-impacted area where gas supply is very limited. The designed and equipments needed for this type of stove has been carefully examined and experimental testing has been conducted to see the results. Future works in this study is expected to conduct a testing for solar panel and battery reliability. The testing would measure the amount of time for solar panel to charge the battery as well as the maximum time for battery to keep the stove working well.

ACKNOWLEDGMENT

The authors are grateful to the Ministry of Research, Technology, and Higher Education for funding this study through Research and Community Service Unit (LP2M) Universitas Negeri Padang under research grant no. SP-DIPA 042.01.2.400929/2019.

REFERENCES


