ISBN : 978-602-14917-9-9

DESIGN OF THE OFF-GRID SOLAR POWER PLANT INSTALLATION SYSTEM FOR COOKING PROCESS USING ELECTRIC STOVE

Mochammad Nuruddin[1], Ahmad Fahriannur[2], Saiful Anwar[3], Riski Imanu Widya[4]
[1,2,3]Lecture at Engineering Department, State Polytechnic of Jember
[4]Student at Renewable Energy Engineering Study Program, State Polytechnic of Jember
J alan Mastrip Kotak Pos 164 Jember, Jawa Timur 68121

Email: m_nuruddin@polije.ac.id

Abstract. Utilization of solar energy is limited in Indonesia, especially in the field of photovoltaic which is done by converting solar irradiation into electrical energy using solar panels. The electrical energy produced by solar panels can be used for cooking process using electric stoves to warm the food in the meatball seller. The benefits of electric stoves is it can be use to stabilize temperature meatball soup, so that the meatballs always expand and are ready to sell. The temperature used to maintain the quality of the meatballs is ranging from 70-80 ℃. The electric stove can stabilize the soup as much as 10 liters using a 160 Watt dimmer input using 120 V voltage and output current of 0.74 A. The installation using 4 solar panels and each panel has a power generated of 100 Wp. The performance of the Off Grid 400 WP PLTS has been sufficient to meet the need for an electric stove that operates for 6 hours.

1. Introduction

The rapidly advances of technology make humans more depend on electrical energy. The source of electrical energy mainly comes from fossil fuels. The availability of fossil fuels are getting thinner and will run out in a certain period of time. If this condition continues, in the future there will be energy crisis. So it need a solution to replace fossil fuels, like solar energy which is classified as renewable energy, because it is unlimited and environmentally friendly [1].

Indonesia is a country lies in the equator line which has a high level of irradiation. The averages of solar irradiation in Indonesia is 4.8 KWh/m^2 and it has the potential to generate an overall 112,000 GWp. But the potential utilized is still around 10 MWp [2]. There are several regions in Indonesia that have not yet been electrified, due to areas that are remote and unreachable by PLN's electricity distribution. So that we need a power plant that is easy to build and easy to move, like Solar Power Plant (PLTS) that are designed in an off-grid system [3]. Electricity is generated using solar panels that work by photovoltaic effect principle in the form of solar cells made of single crystalline silicon. Electricity is generated in the form of DC voltage and current [4].

Cooking is the most common activity in the household and also for commercial purpose. People usually use gas, wood, charcoal also electricity to cook or warm the food. Food seller is always maintain the warmth of the food they sell. Foods that are always kept warm are foods that have soup such as meatballs,soto, etc. For this reason, cooking stoves is very important for food seller but it is also one of the factors that make operational costs higher.

Fuel is the main factor causing high operational costs and it also can raise the price of the food, especially if there is a scarcity of fuel. Street food seller usually use wood and charcoal that cause air

ISBN : 978-602-14917-9-9

pollution and less cleaning. Alternative fuel is needed to replace the existing fuel and the perfect solution is from solar energy. The suitable stove for this application is electric stove. The aim of this research is to design and tested the off-grid solar power plant (PLTS) installation system combine with electric stoves for the cooking process to warm the meatball soup.

2. Research Method

The installation made is PLTS Off-grid system using 4 solar panels, each with a capacity of 100 Wp. Solar panel output is dc voltage use to charge the battery voltage. However, before entering the battery, the solar panel output is passed into the Battery charge regulator (BCR) to regulate the voltage entering the battery. The PLTS system that was built, is used to turn on the electric stove as a load with a 160 Watt AC voltage power demand, so an inverter is needed on the battery output to reverse the DC voltage to an AC voltage according to load requirements. The block diagram of the system is shown in figure 1.

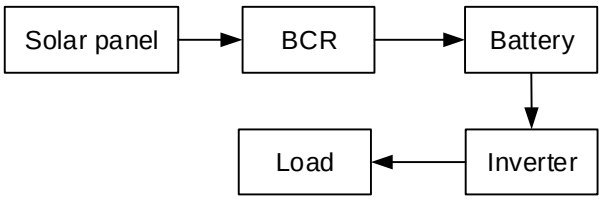

Figure 1. Block diagram system

In determining PLTS specifications that are built, several stages needs to be done, that is :

1) Total Energy Load Consumption
   To calculate the total load energy consumption, you can use the following equation (1)

$$Wb = Pb \, x \, Tlp \quad (1)$$

   Where:
   Wb = total energy of load (kWh)
   Pb = load power (watt)
   Tlp = time of use (hour)

   It is known, the load power in the form of an electric stove of 160 W and turned on for 6 hours, so that the total energy needed is calculated according to equation 1, is 960Wh or 0.9 kWh.

2) Battery and Solar Panel Requirement
   Batteries are used to store electricity from solar panels. To find out the battery requirements, it is necessary to know the value of power generated from solar panels by using equation 2

$$P_t = \frac{Wb\ (Wh)}{Tp\ (hour)} \quad (2)$$

   Where:
   Pt = Genereted Power from solar panel (watt)
   Wb = total energy of load (Wh)
   Tp = charging periode (hour)

   The active system starts at 9:30 until 16:00 WIB. It is assumed that the charging is only until 14:00, because 2 hours later the sunlight conditions have begun to dim. So that the total power generated by solar panels, obtained is 240 W, with the following calculation details

ISBN : 978-602-14917-9-9

$$P_t = \frac{960\ Wh}{4\ h}$$

$$P_t = 240\ \text{W}$$

The solar panel has a maximum power of 100 Wp. If the power is 240 W, 3 solar panels are needed [5]. However, to maximize the power generated, 4 pieces of solar panels installed and arranged in parallel combination. Each has a power of 100 Wp. So that the maximum total generated power of 400 Wp.

Battery energy requirements are calculated using equation 3.

$$Wbt = Wb\left(\frac{Tlp - Ts}{Tlp}\right) \quad (3)$$

Where :

Wbt = total battery energy usage (Wh)
Wb = total energy of load (Wh)
Tlp = using periode (hour)
Tp = charging periode (hour)

Referring to equation 3, a battery energy requirement of 480 Wh is obtained. Assuming duration of usage (Tlp) carried out for 6 hours, charging time (Tp) for 4 hours

$$Wbt = 960\ Wh\left(\frac{6\ h - 4\ h}{4\ h}\right)$$
$$Wbt = 480\ Wh$$

If the battery has an energy of 780 Wh with the specification of 12 volts 65 Ah, then the number of batteries used can be calculated using equation 4.

$$Number\ of\ battery = \frac{Wbt}{780\ Wh}$$
$$= \frac{480\ Wh}{780\ Wh}$$
$$Number\ of\ battery = 0{,}6$$

The calculation results stated that the number of batteries used is 1 piece

3) Inverter Requirement

In Figure 1, it is explained that between the battery and the load there is an inveter to change the DC battery voltage to AC voltage. Known that the load power requirements is 160 W. So that an inveter that has a power value above the load power value is needed, which is 500 W.

4) Overall Design System

The Off Grid PLTS design includes several main components, namely 100Wp solar panel, BCR, Battery, Inverter, Dimmer, Delay Pickup Relay Module, and Omron LY2N Relay. BCR functions as a controller for the entry and exit of electrical energy into the battery. Relay functions as an automatic switch if the Off Grid PLTS is unable to supply the load, the relay will move the source of electrical energy in the load consumption to PLN electricity. Delay pickup relay module functions to control the second relay so that the second timer has a pause

ISBN : 978-602-14917-9-9

of a few seconds to turn on after the first relay is on. The dimmer functions to regulate the current going to the load so that the power needed by the load can be adjusted using a dimmer

The workings of the Off Grid PLTS system are from solar panels converting solar irradiation into electrical energy and flowing into BCR. The role of BCR in the Off Grid Couplings PV system is very important because it regulates three other main components, namely batteries, relays to turn on or turn off inverters, and relays that function as COS (Change Over Swicth), which transfers electrical energy consumed from PLTS to PLN and from PLN to PLTS. BCR supplies electrical energy from PLTS to the battery, Delay Pickup Relay Module, and the first relay. The electrical energy coming out of the BCR section which functions to supply the load is channeled to the first relay to control the switch from the inverter and the delay pickup relay module which is supplied to the second relay. Electrical energy from the battery is directly transmitted to the inverter without going through the BCR. DC electric current that is converted by the inverter into AC current is flowed to the second relay if in NO (Normally Open) then the electrical energy from the inverter is flowed to the dimmer or load. If the second relay is NC (Normally Close), the electrical energy from the inverter does not flow to the load and the energy flowing to the load uses electrical energy. The block diagram of the tool set is shown in Figure 2.

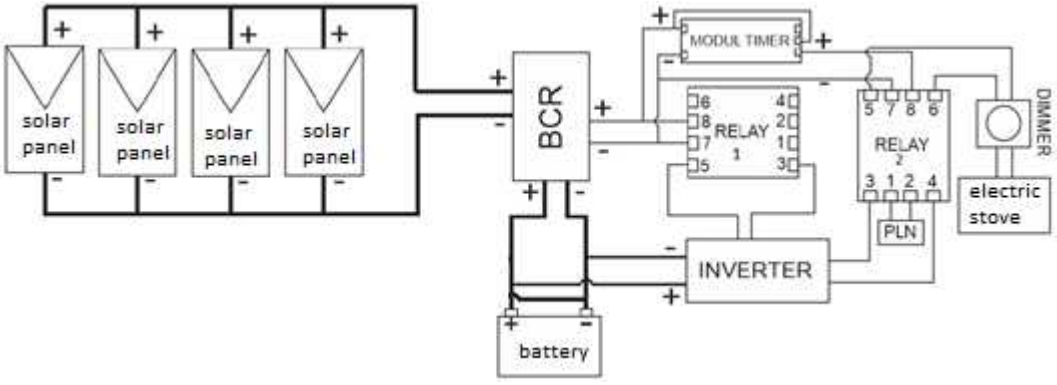

Figure 2. 400 Wp Off Grid PLTS combination

3. Result

Off Grid PLTS system is designed to meet the needs of electric stoves to warm meatballs soup. Electric stoves have operational power ranging from 300 Watt to 600 Watt. The power used is below operational, because the stove is only used as a heater. Electric stove power used to warm meatballs is 160 watts. This electric stove operates for 6 working hours starting at 09:30 - 15:30 WIB to warm the meatballs that have been cooked first. Meatballs that can be warmed by this electric stove as many as 20 large meatballs and 9-10 liters of meatballs soup. The temperature of the meatball soup used to warm the meatballs so they can develop from 70 ℃ to 80 ℃. If the temperature is less than 70 ℃ will cause the meatballs to shrink and get harder. So a tool that can be used to reduce the power of the electric stove from 300Watt to 150Wat is required. The tool used to reduce the power of the electric stove is a dimmer. The dimmer output used by electric stoves to maintain the temperature of the meatball broth is using a voltage of ± 120 Volts and a current of ± 0.78 Amperes.

Before testing the entire system, the solar irradiation for 6 hours is first shown in Figure 3.

ISBN : 978-602-14917-9-9

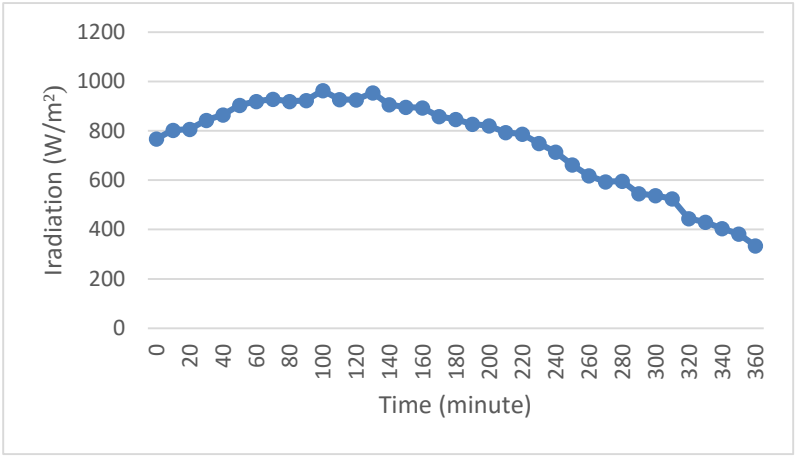

Figure 3. Test graph for solar irradiation 400 Wp

Solar irradiation at the time of this test was classified as bright and it allows solar panels to produce optimum electrical energy. The highest irradiation achieved at 100 minutes with irradiation of 964 W/m² and the lowest irradiation achieved at 360 minutes with irradiation of 335 W/m². Irradiation in this test is quite good because solar irradiation can be stable above 800 W / m² for ± 3 hours.

Comparison of AC voltages in the Off Grid 400 WP PLTS system that includes panel output, inverter input, and BCR voltage can be seen in Figure 4.

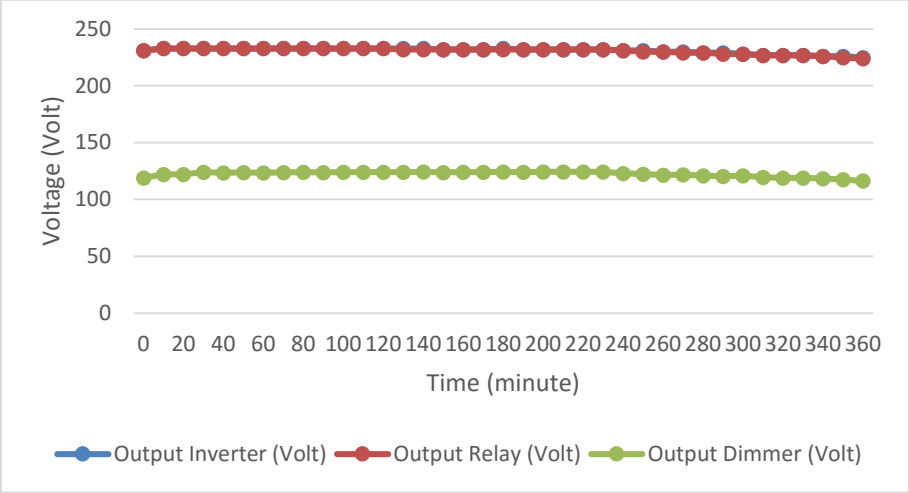

Figure 4. Graph of voltage comparison in 400 Wp PLTS Off-Grid System

The graph shows that the output voltage of the inverter and relay is coincident, because there is no electrical energy consumption in the relay. The output voltage of the inverter and relay tends to be stable within 6 hours in the range of 225 V - 234 V. Dimmers are used to regulate the voltage on the electric stove. The voltage received by electric stove is linear or proportional with the heat generated. Electric stove is expected to release heat at a temperature of 70 – 80 ºC, so that the voltage is lowered in the range of 120-140 V using a dimmer.

Measurements result taken for the temperature at the output of the electric stove are shown in figure 5. The meatball soup was previously heated using another stove at a temperature of almost 82 ºC. After reaching this temperature, the meatball soup is transferred to the electric stove, so that in Figure 5 it appears that in the first data, the temperature shows a value of 81ºC. Then, the meatball which is in freezing conditions immediately put into the soup so that the temperature drops immediately. However, the temperature of the meatball soup gradually rises and falls again in the 230th minute due to the decreasing intensity of sunlight entering the solar panels.

ISBN : 978-602-14917-9-9

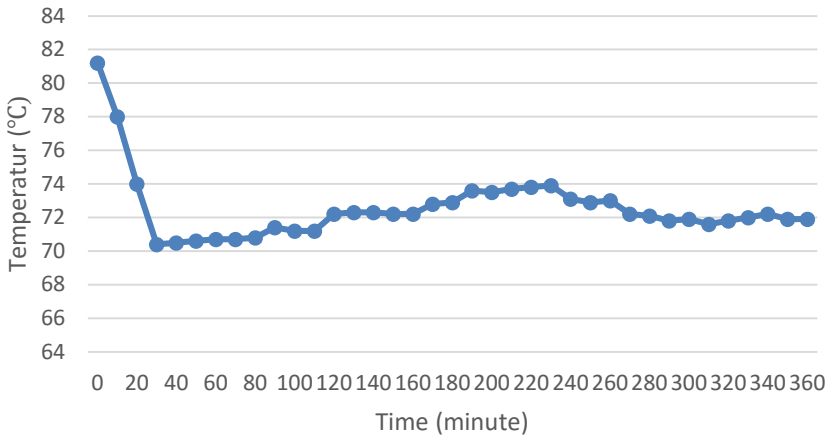

Figure 5. Meatball soup temperature in the Off-Grid PLTS test

4. Conclusion

Based on the test results, it can be concluded that :

a. The 400 Wp Off-Grid PLTS system for cooking process using 160 W electric stove consists of 4 x 100 Wp solar panel, 12 V – 65 Ah battery, BCR, 500 W inverter, dimmer, and relay.
b. The Off-Grid PLTS system that was built, successfully warmed the meatballs soup using an electric stove for 6 hours.
c. The temperature of the meatball soup that is warmed using an electric stove, has an increase and decrease in temperature due to the intensity of the received sunlight changing, but still in the range of temperatures expected.

REFERENCE

[1] Syafrialdi Roni and Wildian 2015 *Rancang Bangun Solar Tracker Berbasis Mikrokontroler Atmega8535 Dengan Sensor LDR dan Penampil LCD (Jurnal Fisika Unand Vol. 4, No. 2)* (Padang) pp 113–122

[2] Hamdi Saipul 2014 *Mengenal Lama Penyinaran Matahari Sebagai Salah Satu Parameter Klimatologi* (*Berita Dirgantara. Vol. 15 No. 1*). (Lapan: Penelitian Pusat Sains dan Teknologi) pp. 7-16

[3] Bachtiar, Ibnu Kahfi. and Mhd. Syafik 2016 *Rancang Implementasi Pembangkit Listrik Tenaga Surya (PLTS) Skala Rumah Tangga Menggunakan Software HOMER Untuk Masyarakat Kelurahan Pulau Terong Kecamatan Belakang Padang Kota Batam. (Jurnal Sustainable. Vol. 5, No. 02. ISSN: 2087-5347)* pp. 17-25

[4] Julisman, Andi, Ira Devi Sara, and Ramdhan Halid Siregar 2017 *Prototipe Pemanfaatan Panel Surya Sebagai Sumber Energi Pada Sistem Otomasi Atap Stadion Bola. (Elektro: Jurnal Online Teknik Elektro. Vol. 2 No. 1. e-ISSN: 2252-7036)* pp. 35-42.

[5] Duka, Eric Timotius. I Nyoman Setiawan and Antonius Ibi Weking 2018 *Perencanaan Pembangkit Listrik Tenaga Surya Hybrid Pada Area Parkir Gedung Dinas Cipta Karya, Dinas Bina Marga Dan Pengairan Kabupaten Bandung (E-Journal SPEKTRUM Vol. 05. No. 02)* pp: 67-73