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# Solar Energy Management in Electricity Load Application of Household Room Based on IoT

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## Abstract
Currently using electrical energy is very large and electrical energy security continues to be studied by government. Developments starts from using and managing of renewable energy sources. Energy sources will not be run out. One of which is using heat energy from sunlight. Using The use of the concept of renewable energy utilization strategy is still 17%. The energy management method is to use a smart system where if the room is during the day, the LDR sensor will signal to the microcontroller so that the room lights will turn off and if there is heat the DHT22 sensor detects the room temperature of 300 C. Then the fan turns on and cools the room so that it will cool down and the load that is not needed by the grid will not function so that energy consumption will be reduced according to calculated needs. This working system is based on IOT derived from ESP 8266 to store solar energy consumed by the house room. The smart method used in the research is to place 3 DHT22 sensors for optimal heat temperature. Average temperature sensor data, LDR data is stored in the data logger in the form of xls files on Gdrive. xls files then for 15 days. From the results of the date per 15 days on 13-11-2023, the design obtained an average temperature of 30.90 with a consumption of 5.83 kWH at a cost of 7882.16 rupiah.
**Keywords:** Energy Management, Solar PV, IoT

## Introduction
Currently, the use of renewable energy is being promoted by the government. Renewable energy is only 17% in utilised in supporting the total energy available in Indonesia to replace unrenewable energy which amounts to 83%, the development starts from the utilisation and management of natural resources, which is a source that will not run out and will not be extinct, one of which is the utilisation of sunlight energy. The utilisation of solar energy is about 2% in 2025 and this needs to develop the resilience of renewable energy technology used. Renewable energy technology is used to be consumed in household electricity loads (Meliala et al., 2022), (Meliala et al., 2020), (Ismail et al., 2020), (Lukman et al., 2020). To obtain optimal electrical energy and continuity of off grid systems and on grid systems, electrical energy management is required. Continuity of electrical energy can be used by calculating the capacity of the load in use as well as, the capacity of solar panels and batteries and the topology of the combination of PLN electricity grid and PLTS electricity. For monitoring electrical energy consumption, the IOT system can be used as monitoring data for power analysis(Santoso et al., 2018), (Kumari et al., n.d.). For the construction of PLTS plants in each region, the government is still experiencing great budget difficulties for the construction of PLTS because almost all regions or regions located on the equator are very optimal in generating power (Mubarak et al., 2020). Therefore, building a PLTS Plant is applied and a review is needed for the feasibility of installing large-scale PLTS, so the government programme recommends the use of independent PLTS which is needed for small-scale electricity needs or the scale of household electricity needs.

Independent PLTS in households is now much in demand by the community with the Solar Home System topology. Solar home systems are divided into two, namely solar home systems on grid and off grid. Both have advantages and disadvantages in utilising solar energy light (Bhatnagar et al., 2018). Given the use of electricity consumption in households in a day varies greatly due to the behaviour of human needs in using electrical energy consumption cannot be prevented, so this requires a tool that can record and regulate electrical energy consumption in a household room. As well as government programmes to save the use of electrical energy 10% in daily use (Venugopal, 2020).

In the use of PLTS electrical energy in rental rooms or household rooms, it must be monitored for the behaviour of the user's use of PLTS electrical energy (Iqbal et al., 2021), (Arya, 2018). Therefore, a monitoring system is needed to see the changing conditions of electricity load requirements in the room.

In managing and utilising electrical energy from solar panels used in rental rooms, an IOT-based monitoring system is needed (Alfita et al., 2021), (Afonaa-mensah & Wang, 2019). In this research, by placing several current sensors and dc and ac voltage sensors, as well as LDR and DHT 11 sensors to manage the use of electrical energy in the household.

Management of household energy consumption must be organized in an intelligent system.

## Research Methods

### Energy Management

Energy management is a systematically planned and implemented programme to utilise energy effectively and efficiently by planning, recording, monitoring and evaluating continuously without reducing the quality of production and services. Energy management includes planning and operating energy-related consumption and production units to actively manage efforts to save energy use and reduce energy costs (Daud et al., 2023), (Sapto Prajogo et al., 2018). The objectives of energy management are resource saving, climate protection, and cost saving. For consumers, energy management makes it easier to get access to energy according to what and when they need.

### Temperature Sensor (Dht 22)

The DHT 11 sensor detects the source of heat or cold and humidity in a room, and the DHT11 sensor sends data to the microcontroller, the data will be processed by the microcontroller to be forwarded as a command so that it can be displayed on the LCD screen. DHT 22 sensor specifications as shown in Table 1 below.

**Table 1.** DHT 22 Specifications

| | |
|---|---|
| Working voltage | 3.3 – 5 V |
| Maximum current | 2,5 mA |
| Humidity measurement range | 0% - 100% |
| Humidity measurement accuracy | 2-5% |
| Temperature measurement range | -40$^0$ C - 80$^0$ C |
| Temperature measurement accuracy | 0,5$^0$ C |
| Sampling speed no more than (data update every 2 seconds) | 0.5 Hz |
| Size | 15.1 mm x 25 mm x 7.7 mm |
| 4 pins with sp | 0,1 " |


| Pin Number | Discription |
|---|---|
| 1 | Vcc(5V) |
| 2 | Signal |
| 3 | Not use |
| 4 | Ground |

**Figure 1**. DHT22 components and pin sequence

## Literature Review

### AC Voltage and Current Sensor (PZEM 004T)

The PZEM 004T sensor is used to measure AC voltage to be converted to a smaller AC voltage so that it can be used for monitoring larger AC voltages and currents. PZEM 004T can measure frequency and power factor as shown in the specifications in Table 2 below

**Table 2**. PZEM 004T sensor description

| Description of Magnitude | Besaran |
|---|---|
| Voltage | |
| - Measurement range | 80 - 260V |
| - Resolution | 0.1V |
| - Measuring accuracy | 0.5% |
| Current | |
| - Measurement range | 0-10A (PZEM-004T-10A); 0～100A (PZEM-004T-100A |
| - Start measuring current | 0.01A (PZEM-004T-10A); 0.02A (PZEM-004T 100A). -100A |
| - Resolution | 0.001A |
| - Measuring accuracy | 0.5% |
| Power | |

| | |
|---|---|
| - Measuring range | 0- 2.3kW (PZEM-004T-10A); 0～23kW (PZEM-004T-100A) |
| - Start measuring power | 0.4W |
| - Resolution | 0.1W |
| - Measuring accuracy | ＜1000W, it display one decimal, such as: 999.9W ≥1000W, it display only integer, such as: 1000W |
| - Measuring accuracy | 0.5% |
| Power Factor | |
| - Measurement range | 0.0 - 1.00 |
| - Resolution | 0.01 |
| - Ketepatan ukur | 1% |
| Frequency | |
| - Measuring range | 45Hz - 65Hz |
| - Resolution | 0.1Hz |
| - Measuring accuracy | 0.5% |
| - Energy | 0 - 9999.99kWh |
| - Measuring range | |
| - Resolution | 1Wh |
| - Measuring accuracy | 0.5% |
| - Measuring accuracy | ＜10kWh, the display unit is Wh (1kWh=1000Wh), such as: 9999Wh ≥10kWh, the display unit is kWh, such as: 9999.99kWh gunakan perangkat lunak untuk mereset |
| - Energi reset | |

**LDR (Light Dependent Resistor) Sensor**

LDR is a light sensor that can be used in various types of electronic devices or circuits at low cost, such as automatic switches using light that if the sensor is exposed to light then the electric current will flow (ON) and vice versa if the sensor is in dark light conditions then the electricity will be inhibited (OFF). LDR is also often used as an automatic street light switch sensor, bedroom lights, automatic anti-theft circuits using lasers, automatic camera shutters, fire alarms, and many others. LDR sensor image shown as Figure 2.3

(a) LDR symbol (b) LDR components

**Figure 2**. The shape of the LDR component

**Smart Sensor System**

To regulate power consumption in room conditions, several sensors are used, namely the LDR sensor, PIR sensor, temperature sensor, for indoor work these two sensors are interconnected, namely the temperature sensor which is set at a temperature of 300 C. Comfortable conditions if there is heat in the room that exceeds above the room temperature, the fan will turn on to cool the air. The LDR sensor is used, namely to detect night or day conditions so that if then at night the bright room lights will turn on and at midnight the lights will dim. This condition works automatically or can be controlled manually using Blink. So that power consumption can be monitored remotely with the Internet of Thinks (IOT) system.

**WI-FI Application**

The wifi application is used to connect temperature sensor data obtained from temperature, voltage or current sensors. The NodeMCU ESP 8266 or ESP 32 device synchronises the data obtained from the temperature sensor and then processes the data to be monitored in real time using a cloud server. The cloud server displays data via internet facilities for viewing and recalling data. Below is the shape of the ESP 8266 MCU Node shown in Figure 3.

**Figure 3.** NodeMCU ESP 8266 Wi-Fi device

**Internet of Things (IoT)**

Internet of Things is everything objects can use internet facilities to access controlled or monitoring data. To control objects using the internet can be temperature, humidity, voltage, current, power, gas and others remotely. Cloud Server Internet of things in the form of Blynk, Thingspeaks, Ubidots, Gdrive provide data storage for free. The data is monitored remotely in real time and the data logger is stored in the form of xls files so that it can be reorganised to be used as analysis data. Below is a form of cloud server temperature monitoring using Gdrive spreadsheet. How intelligent system control works, sunlight is converted by solar panels and then converted into dc voltage then enters the current sensor and enters the voltage sensor and into the solar charger controller (SCC) then enters the inverter input terminal then to the load and the current sensor is useful for measuring the current flowing from the solar panel, the voltage sensor serves to measure the voltage from the solar panel. And the LDR sensor functions as a regulator of indoor lights in accordance with the intensity of outdoor light and switches on the relay according to the light intensity that has been determined by the intelligent system in the household room. And the DHT22 sensor as a fan regulator, when it is hot, the relay activates according to the temperature that has been determined by the Coding Program. So the electrical energy consumption in the room of the house is regulated automatically by a microcontroller intelligent system and can be seen from afar the daily use of electrical energy. For the circuit of energy management and intelligent system control can be seen Figure 4.

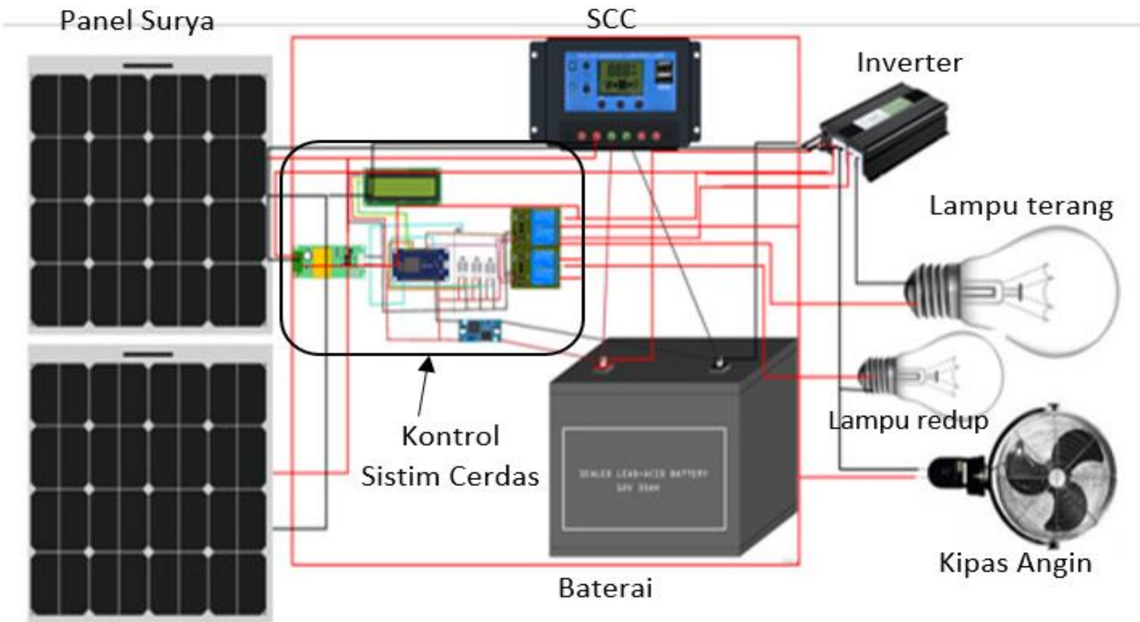


**Figure 4.** Electrical Energy Management Design

**Room Dimensions**

In this study, the prototype is placed in the depN multipurpose room which measures 4 m long and 3 m wide. In the room there is a fan with a power of 64 Watts, one lamp with a power of 40 Watts and a 3Watt bed lamp. So the total power is 107 Watts. Below is the form of Figure 5. The room that did the research

**Figure 5.** Sensor-installed room for electric Energy Management **Prototype**

**Solar Power Generation System**

Utilization of electrical energy is needed for humans, especially in everyday life where a lot of electricity is used for household appliances. Technology continues to develop so that a lot of energy is found - energy that can be used to convert natural energy into electrical energy. one of the natural energies used to produce electrical energy is solar energy. The utilization of solar energy by utilizing solar panels as a converter of solar energy into electrical energy has a very good impact on the use of electrical energy. However, the electricity generated by solar panels cannot be directly used in electronics that use AC electricity, so it is necessary to use several other components so that electricity can be used in household electronic devices. In this study, 2 solar panels are used with the output power of each panel of 120 WP and use solar charge as a battery charging protection using solar panels and an inverter is used to convert DC electricity into AC electricity. In this study, a battery is also used to store power from solar panels so that electricity can be utilized for a long time.

The electricity generated from PLTS in this study is AC electricity which can be used in household electronic devices. PLTS will be used to replace electricity from PLN so that this will save the use of Listik from PLN. Electronic devices used in this study such as fans with a power of 64 W, LED lights with a power of 40 W and a bed lamp with a power of 5 W. In this study, the system used in PLTS is an Off-Grid System where this system only uses PLTS completely so it does not use PLN electricity. In this system, solar panels will produce energy and be stored in batteries and will be used to supply household electronic devices.

**Figure 6**. Rooftop solar panel 3 x 120 WP

**LDR System**

This research uses a Light Dependent Resistor (LDR) sensor where this sensor works based on the light intensity detected by the sensor. This LDR works by converting light intensity into electric current, the greater the light intensity absorbed by the LDR, the greater the current passing through the sensor. In this study, the LDR sensor is used to turn on and off the lights automatically based on the light intensity on the LDR. When the light intensity decreases, the sensor will detect and activate the relay so that the lights will turn on, while when the light intensity increases, the LDR will deactivate the relay so that the lights will turn off automatically. The use of LDR in research can save excessive power usage because this sensor will work automatically according to the light intensity absorbed by the LDR sensor.

The LDR sensor is set with a light intensity of 100 lux, if the light intensity is less than 100 lux then the LDR will turn on the lights, if the light intensity is more than 100 lux then the LDR will turn off the lights automatically. In this study, the LDR is placed in a place that becomes a reference in setting the light intensity.

**Figure 7.** LDR

The results of the LDR sensor readings will be stored on the Spreadsheet, the LDR sensor readings are based on the light intensity absorbed by the LDR sensor. The results of the LDR sensor readings can be seen in Table 3. Below.

**Table 3.** LDR sensor reading results from Gdrive data logger

| Date | Time | Temperature1 | Humidity1 | Temperature2 | Humidity2 | Temperature3 | Humidity3 | LDR | Voltage |
|---|---|---|---|---|---|---|---|---|---|
| 29/10/2023 | 11.56.35 | 30.00 | 82.60 | 29.40 | 84.10 | 30.70 | 78.70 | 120.64 | 224.10 |
| 29/10/2023 | 12.00.06 | 30.30 | 78.90 | 29.70 | 80.30 | 30.80 | 76.20 | 126.20 | 222.20 |
| 29/10/2023 | 12.03.09 | 30.30 | 78.70 | 29.80 | 79.80 | 30.70 | 76.30 | 127.94 | 222.00 |
| 29/10/2023 | 12.06.11 | 30.10 | 80.00 | 29.70 | 81.00 | 30.50 | 78.00 | 127.75 | 220.80 |
| 29/10/2023 | 12.09.13 | 30.20 | 79.30 | 29.80 | 80.30 | 30.70 | 76.80 | 127.75 | 221.00 |
| 29/10/2023 | 12.12.15 | 30.20 | 79.80 | 29.80 | 80.60 | 30.60 | 77.60 | 127.69 | 222.50 |
| 29/10/2023 | 12.15.17 | 30.20 | 78.00 | 29.80 | 78.80 | 30.60 | 76.10 | 125.39 | 222.40 |
| 29/10/2023 | 12.18.19 | 30.20 | 79.30 | 29.90 | 79.90 | 30.50 | 77.20 | 127.49 | 221.70 |
| 29/10/2023 | 13.37.31 | 30.50 | 78.00 | 30.10 | 78.60 | 31.20 | 74.50 | 123.79 | 221.80 |
| 29/10/2023 | 14.07.31 | 30.70 | 76.90 | 30.30 | 77.60 | 31.30 | 74.00 | 127.43 | 221.90 |
| 29/10/2023 | 14.37.34 | 30.80 | 77.80 | 30.50 | 78.50 | 31.50 | 74.60 | 127.56 | 222.30 |
| 29/10/2023 | 15.07.37 | 30.90 | 75.80 | 30.50 | 76.20 | 31.60 | 72.70 | 128.00 | 220.50 |
| 29/10/2023 | 15.37.39 | 31.00 | 75.30 | 30.70 | 76.10 | 31.70 | 72.50 | 128.13 | 222.70 |
| 31/10/2023 | 18.44.10 | 31.30 | 78.60 | 31.10 | 78.50 | 31.30 | 77.60 | 120.14 | 214.90 |

## Results and Discussion

### DHT22 Sensor System

DHT22 is a sensor to detect the temperature in the room, in this study 3 DHT22 sensors were used in the room and the results of the sensor readings from the three DHT22s will be averaged. The average results of sensor readings will be a reference in this design. In this design, the DHT22 sensor is used as a reference in turning on the fan automatically, when the temperature in the room increases, the DHT22 will detect and turn on the fan automatically and when the temperature in the room decreases, the sensor will turn off the fan automatically.

The DHT22 sensor will detect the temperature in the room, when the temperature in the room is more than 29 ° C, the sensor will activate the relay so that the fan in the room turns on automatically, when the temperature in the room is less than 29 ° C, the sensor will deactivate the relay so that the fan will turn off automatically. Utilization of the DHT22 sensor is very good at saving excess power usage because the sensor works automatically.

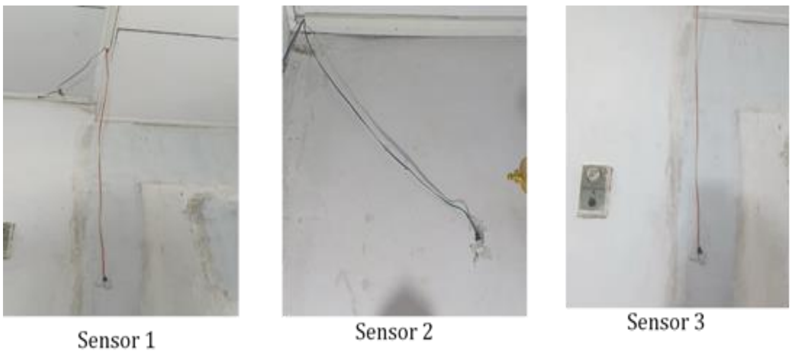


**Figure 8**. Room temperature sensor DHT22

Based on Table 4. It can be seen that the temperature during the day increases, the temperature reading in this design is based on the temperature in the room that is used as a reference for data collection. When the average of the three sensors is more than 29 ° C, the fan will turn on automatically, when the average temperature is less than 29 ° C, the fan will turn off automatically.

**Table 4.** Indoor temperature1, temperature2, temperature3 values

| Date | Time | Temperature1 | Humidity1 | Temperature2 | Humidity2 | Temperature3 | Humidity3 |
|---|---|---|---|---|---|---|---|
| 29/10/2023 | 11.56.35 | 30.00 | 82.60 | 29.40 | 84.10 | 30.70 | 78.70 |
| 29/10/2023 | 12.00.06 | 30.30 | 78.90 | 29.70 | 80.30 | 30.80 | 76.20 |
| 29/10/2023 | 12.03.09 | 30.30 | 78.70 | 29.80 | 79.80 | 30.70 | 76.30 |
| 29/10/2023 | 12.06.11 | 30.10 | 80.00 | 29.70 | 81.00 | 30.50 | 78.00 |
| 29/10/2023 | 12.09.13 | 30.20 | 79.30 | 29.80 | 80.30 | 30.70 | 76.80 |
| 29/10/2023 | 12.12.15 | 30.20 | 79.80 | 29.80 | 80.60 | 30.60 | 77.60 |
| 29/10/2023 | 12.15.17 | 30.20 | 78.00 | 29.80 | 78.80 | 30.60 | 76.10 |
| 29/10/2023 | 12.18.19 | 30.20 | 79.30 | 29.90 | 79.90 | 30.50 | 77.20 |
| 29/10/2023 | 13.37.31 | 30.50 | 78.00 | 30.10 | 78.60 | 31.20 | 74.50 |
| 29/10/2023 | 14.07.31 | 30.70 | 76.90 | 30.30 | 77.60 | 31.30 | 74.00 |
| 29/10/2023 | 14.37.34 | 30.80 | 77.80 | 30.50 | 78.50 | 31.50 | 74.60 |
| 29/10/2023 | 15.07.37 | 30.90 | 75.80 | 30.50 | 76.20 | 31.60 | 72.70 |
| 29/10/2023 | 15.37.39 | 31.00 | 75.30 | 30.70 | 76.10 | 31.70 | 72.50 |
| 31/10/2023 | 18.44.10 | 31.30 | 78.60 | 31.10 | 78.50 | 31.30 | 77.60 |

**Power Management**

To manage PLTS electricity that is more efficient and more practical, namely regulating it automatically and energy power consumption can be seen from real-time monitoring. Electricity that is regulated automatically is regulating the use of lamp power at night 40 Watts and at midnight at 11 lights 5 watts will turn on until the morning intesistas sunlight starts to light up while in daylight conditions LDR will turn on so that the power consumption of electrical energy is regulated automatically and the cost of use in a day - day or hourly can be monitored. So that electricity consumers can find out the use of their electrical energy consumption and daily prices can be seen in the Gdrive datalogger spreadsheet as Table 5. below.

**Table 5**. Electric energy consumption (KWH) and its price from Gdrive data logger

| Date | Time | Temperature room average | Humidity | LDR | Voltage source | Current | Power | Energy comsumption (KWH) | cosphi | Price (Rp) |
|---|---|---|---|---|---|---|---|---|---|---|
| 29/10/2023 | 15.37.39 | 31.28 | 75.30 | 128.13 | 222.70 | 0.02 | 2.70 | 0.31 | 0.53 | 416.42 |
| 31/10/2023 | 18.44.10 | 31.25 | 78.60 | 120.14 | 214.90 | 0.02 | 2.70 | 0.40 | 0.52 | 546.21 |
| 01/11/2023 | 18.53.17 | 31.75 | 79.00 | 95.05 | 220.50 | 0.25 | 32.30 | 0.52 | 0.66 | 709.80 |
| 02/11/2023 | 20.32.27 | 30.65 | 81.60 | 92.44 | 223.70 | 0.02 | 2.70 | 0.72 | 0.50 | 968.03 |
| 03/11/2023 | 13.10.47 | 31.53 | 80.00 | 98.39 | 222.20 | 0,01 | 2.70 | 0.87 | 0.52 | 1178.94 |
| 04/11/2023 | 23.54.59 | Nan | nan | 120.00 | 227.10 | 0.02 | 2.70 | 1,04 | 0.52 | 1402.02 |
| 05/11/2023 | 11.38.29 | 32.10 | 78.00 | 0.00 | 219.80 | 0.00 | 0.00 | 1,04 | 0.00 | 1410.14 |
| 06/11/2023 | 23.45.10 | 31,3 | 83.18 | 120.00 | 228.00 | 0.02 | 2.70 | 1.35 | 0.54 | 1822.50 |
| 07/11/2023 | 23.45.28 | 31.80 | 84.50 | 120.00 | 226.10 | 0.19 | 26.90 | 1.88 | 0.64 | 2535.00 |
| 08/11/2023 | 23.50.06 | 30.60 | 87.00 | 120.00 | 227.10 | 0.19 | 27.40 | 2.59 | 0.64 | 3507.09 |
| 09/11/2023 | 23.47.50 | 30.40 | 90.30 | 120.00 | 222.40 | 0.18 | 26.20 | 3.47 | 0.64 | 4691.44 |
| 10/11/2023 | 23.50.43 | 30.90 | 89.30 | 120.00 | 225.00 | 0.33 | 57.00 | 4.30 | 0.77 | 5817.66 |
| 11/11/2023 | 23.34.08 | 30.40 | 85.40 | 120.00 | 224.30 | 0.34 | 59.80 | 4.85 | 0.78 | 6562.61 |
| 12/11/2023 | 23.46.11 | Nan | nan | 120.00 | 228.80 | 0.02 | 2.70 | 5.51 | 0.51 | 7449.52 |
| 13/11/2023 | 17.06.05 | 31.70 | 79.70 | 114.41 | 222.90 | 0.18 | 26.40 | 5.83 | 0.65 | 7884.86 |

Based on the table above, it can be seen that the use of PLTS continues to increase; this is due to the load that is on in the form of a fan. The use of consumption can be seen from the google spreadsheet sent from the PZEM 004T sensor which functions to measure the energy used during electricity usage. This electric usage is also converted to rupiah unity at a price of Rp.1,352 / KWH so that when using energy of 5.83 KWh, the price that consumes the use of electrical energy is Rp.7884,86 as shown in the orange plot line in Table 5. This energy reading will be converted continuously and the results of the reading will be sent via the internet and stored in a google spreadsheet.

## Conclusions

In this design there are several things that are concluded, as for the conclusions in this study are as follows.

1. PLTS is used as a substitute for PLN electricity as a whole in the room using the Off-Grid System, so that the PLTS is carried out storing electrical power in the battery and converted using an inverter so that it can be used in household electrical devices.
2. LDR absorbs light intensity of 122 lux during the day so that the lights are off and scraps light of 40 lux so that the lights are on.
3. During the day the temperature increases to 31° C so that the fan will turn on and at night the temperature decreases to 30 ° C so that the fan will automatically turn off.
4. Electric energy consumption by using sensors and control systems is smaller than without using a control system.

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