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*Article*

# Automatic Transfer Switch System Design on Solar Cell – Grid Hybrid Based on Android Application

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**Abstract.** The main source of electricity supply, namely PLN, greatly affects the supply of electricity and is not always continuous in its distribution. PLN power outages cause the distribution of human activities and productivity. The solution is to create a hybrid automatic transfer switch (ATS) system. The system works automatically as a hybrid power plant using a solar cell and PLN using ATS and remote monitoring using android. This type of research is classified as laboratory experimental engineering research. This study aims to determine the power savings of PLN that flows to the load after using the ATS system, work specifications, and system design specifications. In this study, a solar cell with a maximum capacity of 20 watts was used. The results of power savings after using the ATS system in sunny weather conditions for 10 hours of irradiation with an average solar intensity of 318,551 lux is 16,84%. The system performance specifications are small, portable, and easy to operate. The values of accuracy and precision in power saving are 96,13% and 95%.



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## 1. Introduction

Energy is an indispensable position for the whole world with it containing developing technology and an increasing population [1-4]. Renewable source of energy plays a vital role in full fill the demand for electrical energy generation [5-7]. In the digital age, the need for electrical energy is very large, In 2025 there will be an increase in energy demand of around 35%, especially in the transportation sector which continues to increase until 2050 by around 37 % to 42 % especially in the industrial sector[8-9]. Renewable energy sources are gaining significant research attention due to their economical and sustainable characteristic [10-11].

Based on the Indonesian energy outlook, stated that the power generation capacity until 2018 reached 64,5 GW, or an increase of 3 % compared to the capacity in 2017 [12-13]. The installed capacity of power plants in 2018 mostly came from fossil energy plants, especially coal (50%), followed by natural gas (29%), fuel(7%), and renewable energy(14%)[14-15]. Most of the electrical energy used uses non-renewable fossil energy [16-17]. Solar energy is one of the sources of renewable energy sources [18-19]. Nowadays, to maximize utilization of the solar energy, studying hybrid systems is getting more of interested [20-22].

The non-permanent supply of fossil energy causes its availability to run out, so alternative energy is needed as a renewable energy source so that the world's electrical energy needs are still met. The advantages of using this alternative energy are in terms of maintenance and pollution-ree [23-24]. This has prompted several countries to start taking advantage of the potential of renewable energy sources [25-27]. Solar energy has been considered one of the most widespread solutions to ongoing worldwide energy shortage due to its high accessibility, high energy conversion efficiency, cost-effectiveness, and pollution-free nature [28-29].

Solar cells are devices that can convert sunlight energy into electrical energy with the principle of the photovoltaic effect [30-31]. Photovoltaic technology is rapidly evolving and the current push to the increasingly efficient solar cell is leading [32-33]. Based on the characteristics of different types of photovoltaic cells, it was determined that monocrystalline silicon photovoltaic cells are mostly used in through solar energy [34-35]. Bambang Hari Purwanto in his research on the efficiency of using solar cells as an alternative energy source stated that the use of solar cells is more efficient than the use of solar cells [36-37]. In general, PLTS is one of the electrical energy [38-40]. Solar Power Plant(PLTS) is a generator that utilizes photon energy produced by sunlight and converts it into electric power. This energy conversion can occur because of the photovoltaic cells in the solar panels [41-42]. Therefore, the use of solar radiation to be converted into electrical energy can be an alternative to this problem so that the stability of electrical energy is maintained.

Hybrid energy systems are a relatively powerful technology [43-44]. A hybrid system is a combination of two or more energy sources, which when combined contain a hybrid power system or a combination of renewable energy sources with conventional sources to provide the controllable capabilities required for everyday use [45-46]. Brian Gagani in his research on the planning of a hybrid power generation system stated that using a hybrid alternative energy system can save fuel consumption and not only prioritize fossil fuels [47-49]. This hybrid system requires a switcher circuit whose job is to switch the electrical power supply to the load.

According to Sadi and Mulyati, an automatic transfer switch (ATS) is the main load connecting device with two or more power supply sources (backup source and main sources) or more that are separated to keep the supply directed to the load and function as a substitute for transfer switches and working positions automatically [50-52]. According to Adel Arshad in this research on the design and implementation of an effective automatic transfer switch, he stated that ATS can monitor, control, and switch between resources in a few seconds and has high reliability in control, making it an option compared to other system [53-54]. Efficiency in the use of electrical power can be done by using software in palnning needs[55-56].

With the gradual rollout of the 5G (5th- generation mobile networks) technology across the world, the role of the internet of things (IoT0 is becoming more and more essential in both industrial and commercial developments [57-58]. The rapid expansion of the internet of things (IoT) in many living environments, such as smart homes, has motivated the development of human-machine interfaces (HMIs) for the interactions between humans and machines [59-60].

Internet of Things simply means the network of physical objects defined by software modules [61-62]. The use of IoT in this system is a novelty of this research, where this switching system can also make it easier for humans to monitor, the use of electrical power in the load and harvest electrical power from solar cells and see if there is damage to the equipment remotely. Recommend a machine-controlled Internet of Things (IoT), which is an alternative energy-viewing gadget that enables automated alternative energy consumption from anywhere on the internet [63-65].

Internet of things (IoT) methodology communicates both humans and devices electronically concerning control modules [66-67]. According to Taufal Hidayat in this research, namely the design of IoT-based smart meters for solar power plant applications, he stated that the existence of a server thinger for IoT can facilitate remote photovoltaic monitoring via an internet connection [68-70]. According to A.R Al-Ali in his research, namely IoT solar energy powered smart, stating that the remote monitoring website makes the system very accessible and can be monitored via a computer or mobile phone and in the future this design can be improved and support the operating system without requiring human intervention [71-72].

Based on these problems, the researchers designed an automatic transfer switch system on a solar cell hybrid grid based on an android application to facilitate accessibility in viewing the uses of electrical energy in the load and the use of electrical energy can be effective and efficient. The novelty of this assessment is the existence of power monitoring using an android application.

This research can also help the distribution of electrical energy throughout the region and become an alternative to the use of limited fossil materials in producing electrical energy. The system is made using a Mega2560 microcontroller as a data processor, ACS712 and INA219 sensors as current and voltage sensors, and is equipped with solar cells and PLN supply as a source of electrical energy. The system also uses a relay module which is used to control the switching system for power transfer to the load and ESP8266 as a wifi module that sends data to the android application.

## 2. Experimental Section

### 2.1. Materials

The design and manufacture of an automatic transfer switch system on solar cells – grid hybrid based on an android application is made in the form of a functional block diagram. The functional block diagram can be seen in Figure 1.

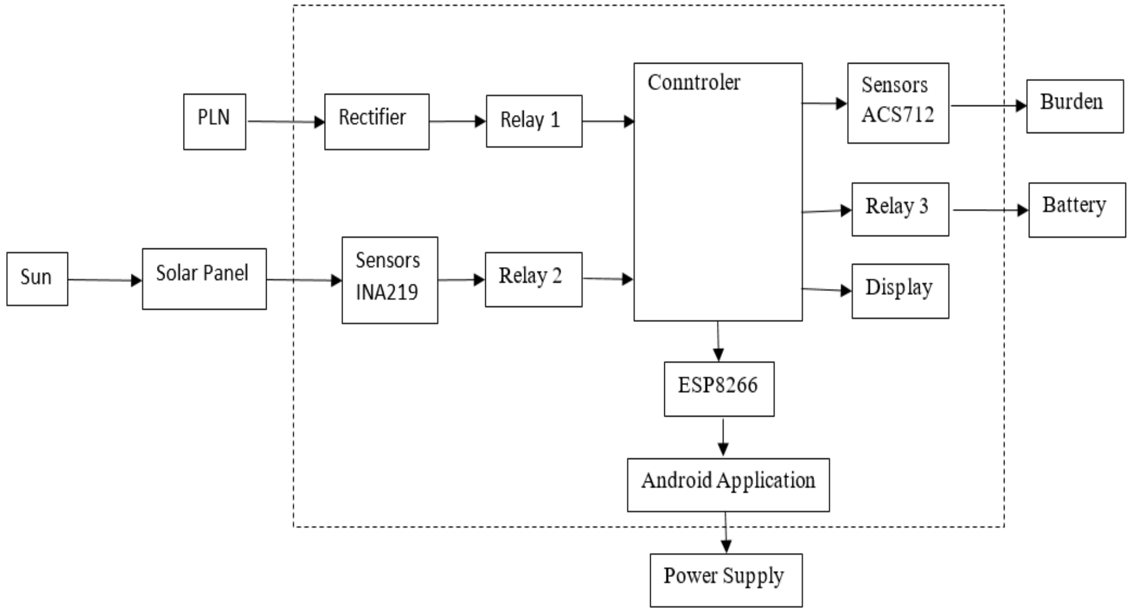


**Figure 1.** Functional block diagram of the automatic transfer switch system tool in a hybrid solar cells power plant based on an android application

In Figure 1 there are 7 parts of the system that have different roles and functions so that the system can work properly. The following is an explanation of each of these sections :

a. Solar cells function to convert solar energy into electricity.
b. The INA219 sensor functions as a current and voltage sensor so that the solar cell output power can be known.
c. The ACS712 sensor functions as a current and voltage sensor so that the power required by the load can be known.
d. ESP8266 works as a transmitter to send data to thingspeak
e. The relay module (relay 1, relay 2, and relay 3) functions as an automatic switch that controls the flow of electrical power from the solar cells to the load and PLN as well as the flow of electric power from the solar cells to the PLN.
f. Arduino mega 2560 functions as an ATS controller and the main sensor controller.
g. The power supply serves as a supplier of electric current to the components.

Photovoltaic cell absorbs light energy (photons) from the sun and converts it into electricity by the photovoltaic effect [73-75]. In this study, the system is programmed using arduinomega2560 to adjust the relay state automatically based on load conditions as a switching process from the power supply to the load. When the power required by the load is detected, the power requirement will be supplied by the solar cell as the main supply of power supply and the lack of power from the panels to the load will be supplied by PLN. When it is detected that the power required by the load is less than the power generated by the panels, the excess power from the solar panels will be channeled to the battery. The battery is suitable for storing electrical energy generated from the solar cell [76-77].

Based on the functional block diagram, there are main parts of the data processing system consisting of Arduinomega2560, INA219 sensor, ACS712 sensors, ESP8266, and relay module. The circuit schematic for the main parts of the data processing system can be seen in Figure 2.

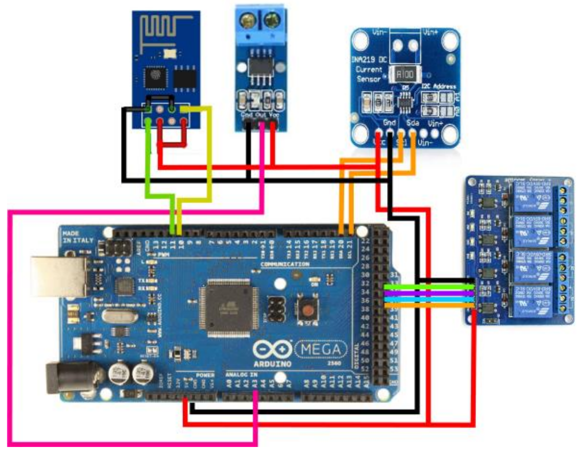

**Figure 2.** Schematic of the main parts of the system

The system works by installing current and voltage sensors on the load and solar cells so that the power required by the load and the power generated by the solar cells can be known. When power is detected on the sensors, the relay will work according to the conditions created in the system programming, so that power will flow to the load. System programming using arduinomega2560 microcontroller. Minimum system arduinomega2560 microcontroller using Arduino devices including IDE to write programs, drivers for connection witch computers [78-79].

The current and voltage sensors used in this study are the ACS712 sensor and the INA219 sensor[80-81]. ACS712 current sensor has been used for sensing the input current of the system [82-83].

**Figure 3.** ACS712 sensor module

In Figure 3. There is a pinout (analog out), a ground pin, and a VCC pin. The out pin is connected to the A3 pin on the Arduino device, the ground pin is connected to the ground pin on the Arduino device and the VCC pin is connected to the 5V VCC pin on the Arduino device.

**Figure 4.** (a) INA219 sensor module (b) Relay Module (c) ESP8266

The INA219 sensor is a sensor module that is used to measure current, voltage, and power in a circuit with a good level of precision[36]. The INA219 contains a precision amplifier that measures the voltage drop across a 0.1-ohm sense resistor with a 1 % gain error [37]. In Figure 4. (a) There are I2C/SCL and SDA pins, ground pins, and VCC pins. The I2C/SCL and SDA pins are connected to pins 20 and 21 on the Arduino device, the ground pin is connected to the ground pin on the Arduino device and the VCC pin is connected to the 5V VCC pin on the Arduino device.

The switching system on the automatic shift switch in this study was designed using a relay module. The relay module is a switch that is operated automatically by an electric voltage and is an electromechanical component consisting of two main parts, namely electromagnets and mechanics. Relay uses the electromagnetic principle to move switches with low power voltage to conduct high-voltage electricity [84-85]. In Figure 4 (b) There is a pin 1 relay, pin 2 relays, pin 3 relays, pin 4 relays, ground pin, and VCC pin. Relay pin 1 connected to pin 39 on the Arduino device, relay pin 2 connects to pin 37 on the Arduino device, relay pin 3 connects to pin 35 Arduino device, relay pin 4 connects to pin 33 Arduino device, and the ground pin connects to the ground pin on the Arduino device and the VCC pin is connected to the 5 V VCC pin on Arduino device.

So that power measurement data can later be sent to thing speak which will then be displayed in the android application, a wifi module is needed. In this study the wifi module used is ESP8266. The ESP8266 has powerful features and simultaneously a reduced footprint [86-87]. The ESP8266 has onboard processing and storage capabilities that allow the chip to be integrated with sensors or with specific tool applications via input-output pins with only short programming [88-89]. In Figure 4 (c). There are Rx pins and Tx pins. The Rx pin is the receiver used to receive data from the Arduino to the ESP8266 which is connected to pin 10 on the Arduino device and the Tx pin is the transmitter used to send data from the ESP8266 to the Arduino which is connected to pin 11 on the Arduino device.

### 2.2. Tips

The solar cells harvesting power data and the power supplied from PLN to the load both after the equipment is installed and before the equipment is installed will be displayed in graphical form on thing speak and the android application. The high-efficiency solar cell depends on optical concentration to achieve high conversion efficiency [90-91]. So that it can be seen the power used by the load before and after the device connected to the solar cells is installed can save the power supplied by PLN to the load after the tool is installed.

The level of accuracy of the sensor measurement results on the system is done by comparing the measurement results that are read in the application with the measurement results manually using standard measuring instruments so that the percentage error is obtained. Data processing is also carried out to see the power savings supplied by PLN to the load after using the automatic transfer switch system on a hybrid solar cell grid based on an android application.

To facilitate the research, a diagram of the research steps was made. The research diagram can be seen in Figure 5.

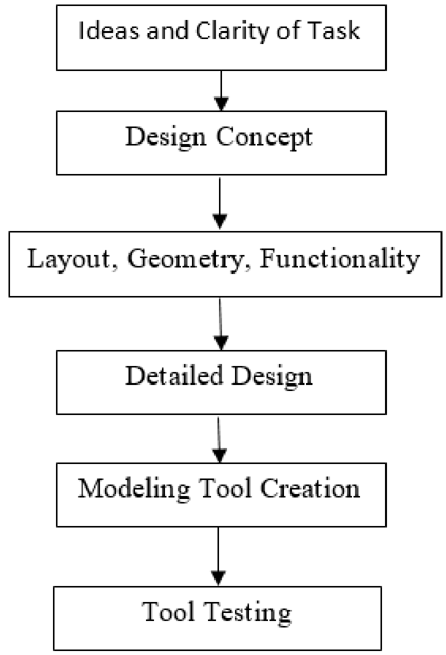


**Figure 5.** Diagram of research steps

## 3. Results and Discussion

The design of the ATS system on a hybrid solar cell grid based on an android application is a black acrylic box with a size of 32 cm x 22 cm x 11 cm which contains an electronic circuit. The electronic circuitry in the acrylic case has been programmed to perform power switching. The following results from the design of the ATS system can be seen in Figure 6.

**Figure 6.** ATS system on a hybrid solar cell grid hybrid

The power saving on the load is a comparison of the PLN power that flows to the load before and after using the automatic switching switch system. The test result was carried out on February 11, 2022, when the weather conditions were sunny, for 10 hours of sunlight starting at 07.00 am until 5.00 pm in a period of every 30 minutes. The research was carried out in the physics laboratory of the faculty of mathematics and natural sciences UNP West Sumatra from June 2020 until February 2021. Data collection on the harvesting and switching system of solar panels was carried out at the shelter of one of the buildings on the coast of Jambak Padang. This measurement is not affected by water parameters and solar cell materials used. The result obtained after conducting these tests are as follows :

**Table 1.** Data on PLN power savings flowing to the load on the ATS solar cells hybrid system grid system

| Time | Light Intensity (Flux) | Power Before Attachment (Watts) | Power After Plug-in (Watts) | Power Saving Percentage (%) |
|---|---|---|---|---|
| 07.00 – 09.00 | 148 | 31.04 | 29.46 | 6.89 |
| | 144 | 31.13 | 29.78 | 4.34 |
| | 147 | 31.12 | 29.31 | 5.82 |
| | 149 | 31.06 | 29.15 | 6.15 |
| 09.30- 11.00 | 153 | 31.12 | 29.62 | 4.84 |
| | 158 | 31.12 | 29.07 | 6.59 |
| | 163 | 31.39 | 29.86 | 4.88 |
| | 184 | 31.13 | 29.24 | 6.07 |
| 11.30 – 13.00 | 358 | 3117 | 24.99 | 19.83 |
| | 403 | 31.22 | 24.74 | 20.89 |
| | 444 | 31.12 | 22.46 | 27.83 |
| | 542 | 31.12 | 20.61 | 33.78 |
| 13.30 – 15.00 | 627 | 31.02 | 18.73 | 39.70 |
| | 509 | 31.14 | 19.53 | 37.29 |
| | 445 | 30.50 | 23.33 | 23.51 |
| | 461 | 31.09 | 24.05 | 22.65 |
| 15.30 – 17.00 | 494 | 31.31 | 20.77 | 33.89 |
| | 222 | 30.69 | 27.99 | 8.80 |
| | 313 | 31.02 | 26.99 | 12.99 |
| | 307 | 31.18 | 27.34 | 11.99 |
| **Total** | | **621.69** | **517.02** | **338.71** |

From Table 1. It can be seen that the lowest power saving is found in the 2nd measurement at 08.00 am with a power saving percentage of 4,34% and the light meter shows intensity of 144 lux. This is because the intensity of sunlight in the morning is not too high or hot. The highest power saving is found in the 13th measurement at 1.30 pm with a power saving percentage of 39,7 % and the light meter shows intensity of 627 lux. This is because the intensity of the sun's light at that time was high or scorching. Figure 7. is a graph of PLN's power savings flowing to the load before using the automatic transfer switch system on the hybrid solar cell grid and after on February 11, 2022.

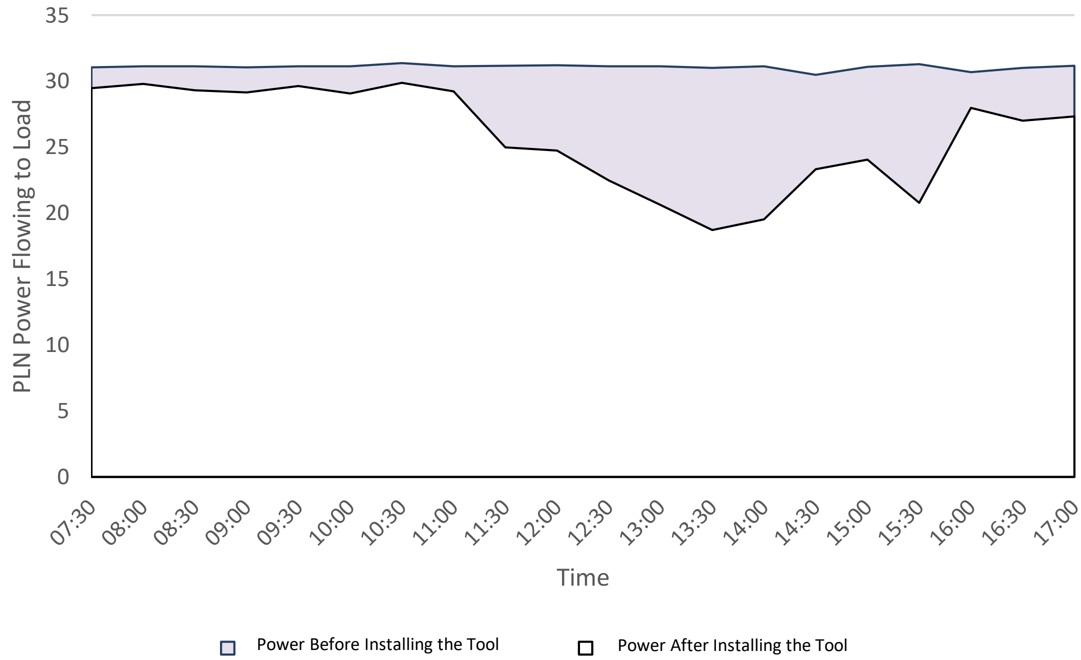


**Figure 7.** Graph of power savings on February 11, 2022

From the graph in figure 7, it can be seen that the red line represents the PLN power that flows to the load after the tool is installed, the blue line represents the PLN power that flows to the load before the tool is installed and the gray zone represents the savings in PLN power that flows to the load after using automatic transfer switch system. From the graph, it can be concluded that the highest power savings occur from 11.00 am to 3.30 pm, where the intensity of sunlight is high so that the harvesting of solar cells is maximized. The higher the intensity of the sun, the higher the power harvested by the solar cells, so the greater the power savings on the load.

From the test results in table 1, the total power obtained for one day before being installed is 621.69 watts. When the automatic transfer switch system on the hybrid solar cell grid is used, the total power usage is 517.02 watts. This results in a decrease in power or power savings in the load. To calculate power savings for one day as follows :

$$\text{Savings} = \frac{\text{Power before installing the tool} - \text{power after installing the tool}}{\text{Power before plugging in the appliance}} \times 100\,\%$$

$$\text{Savings} = \frac{621.69 \text{ watt} - 517.02 \text{ watt}}{621.69 \text{ watt}} \times 100\,\%$$

Saving = 16.84 % (1 day with average sun intensity = 318.55)

So, with the installation of an automatic transfer switch system on a hybrid solar cell grid, the power savings for one day is 16.84 %. These power savings can affect the cost of electricity bills. If the weather is cloudy, the power savings will be smaller below 16.84%. The measured power is the power on the load before and after the tool is installed. This power saving can affect your monthly billing costs [93-94]. This system is very suitable for urban communities.

Performance specifications are specifications related to the performance of a tool. The results of the automatic transfer switch system on the hybrid solar cell grid can be seen in Figure 9. In the series of automatic transfer switch systems, an acrylic box measuring 32 cm x 22 cm x 11 cm is used. The power supply used is 12 volts, which is used to convert the AC PLN voltage to 12-volt DC. This system also uses a step-down transformer to lower the voltage from 12 volts to 5 volts to supply power to the circuit.

Solar cells are a system that can be used to convert sunlight energy into electrical energy. Solar cells produce DC electric current (direct current) [95-96]. The combination of several solar cells is referred to as solar panels or solar modules [36][97]. In this study, solar cells with a length of 64 cm, a width of 29 cm, and a height of 2 cm was used with a maximum harvesting capacity of 20 watts. The specifications and front view of the solar cells can be seen in Figure 8.

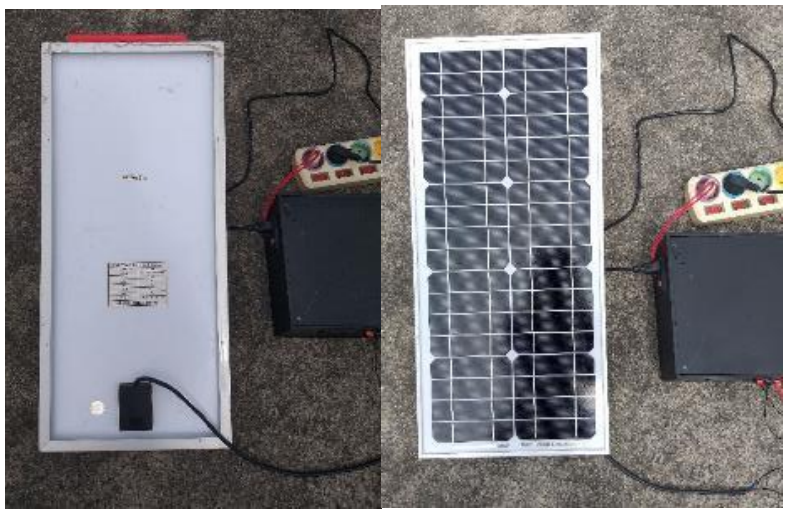

**Figure 8.** (a) specification of solar cells (b) front view of solar cells

In the ATS system, the hybrid solar cell grid uses a relay module that functions as an automatic power flow regulator. The uses of ATS can save flowing to the load [98-99]. The power flow will be controlled by Arduino which gets a signal from sensors mounted on the load and solar cells. The detected power on the solar cell will have flowed automatically to the load so that the power supply to the load does not use the full PLN power but is assisted by the power generated by the solar panels so that there is a saving in the use of PLN power by the load. The relay modules working actively low. Programmed using ESP8266, which functions as an experimental link with the internet so that data detected on the device can be monitored using the android application. ATS to switch electrical energy sources from PLN to solar energy sources from solar panels [100-103]. The results of ATS monitoring on the hybrid solar cells grid hybrid can be seen in Figure 9.


**Figure 9.** Monitoring the android ATS system on a hybrid solar cell network

The design specifications include the results of the precision and accuracy of the experiment. Accuracy is stating the degree of similarity in a group of measurements or several instruments. Accuracy is related to a person's desire to give direction to the target with certain aims and objectives. The modeling results of the automatic transfer switch system based on the solar cell grid hybrid as a whole can be seen in Figure 10.

**Figure 10.** ATS system modeling results

Accuracy of power measurements data generated by solar panels is obtained by taking as many as 10 data with sunny weather conditions on February 11, 2022, and comparing the result of power reading on the applications by the sensor on the system with a standard measuring instrument, the wattmeter, which has fairly good accuracy. The measurements made obtained an average accuracy of 96.132%. The data obtained is close to accurate because the ATS system on the hybrid solar cell grid hybrid designed as a result that is close to wattmeter readings.

Measurements accuracy is the similarity of the price of a group of measurements. The data accuracy of the ATS system on the hybrid solar cell grid with 10 times the power measurement has fairly good accuracy. Measurements made obtained power saving accuracy of 95.01%. Measurements made from reading the system as much as 10 times the data transfer is close to accurate because it has a small percentage of error.

Based on the research results obtained, the automatic transfer switch system on the hybrid solar cell grid can be used to save power flowing to the load. The automatic transfer switch system on the hybrid solar cell grid is controlled by a relay module using a microcontroller, so the system is simpler. This research has been equipped with an internet of things (IoT) system where the results of system monitoring can be displayed on the android application and graphs of harvest and power flows can be seen on the thing speak display. This monitoring can be done remotely anytime and anywhere as long as it is connected to the internet network.

## 4. Conclusion

Based on the research results obtained, it can be concluded as follows: in sunny weather, the total power at the load before the automatic transfer switch system is installed with time intervals from 07.00 am until 5.00 pm is P=621.29 watts. In sunny weather, the total power at the load after the automatic transfer switch system is installed with time intervals from 07.00 am until 5.00 pm is P=517.02 watts. The power saving after the appliance is installed is 16.84% with an average solar intensity of 318.55. The results of the ATS system design on a hybrid solar cell grid based on an android application have small dimensions, a potable, compact display on android, and an LCD on the system and uses solar panels with a maximum harvest capacity of 20 watts. The ATS tool on the hybrid solar cell grid has an accuracy of 96.132% and an accuracy of 95.01 % power saving. An automatic transfer switch system on a hybrid solar cell grid based on an android application used can save power flowing from PLN to the load and reduce electricity bill costs.

## 5. Acknowledgement

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