Design of solar power plants with hybrid systems

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Abstract. The design of hybrid power plants aims to provide alternative solutions to the community in the event of a power outage. This solar power generation system utilizes solar panels that have the function of converting sunlight energy into direct electrical energy which is used as the main source in battery charging. In a hybrid solar power plant system that is made equipped with a logger system that stores data about temperature, current, voltage on the solar panel, battery percentage, output power at the load, charging source and the power used at the load. From the results of the design and testing of the hybrid charging system, the main power source of the solar panel, if the battery power is less than 40%, the charging system moves to PLN (the state electricity company) and when the battery power is above 50%, the charging from the PLN will be turned off, at Auto Transfer Switch (ATS) system will be active if the power from the PLN goes out, the relay will move the PLN power to battery power for 3 seconds due to the start of the inverter, if the PLN power is on, the power from the inverter will move to PLN directly with no pause.

Keywords: ATS, Hybrid power, Solar panel.

1. Introduction

Electricity needs have turned into primary needs in human life. Almost every activity of human life will require electricity. When the electricity goes out, a lot of activity is disrupted. Electricity consumption in Indonesia until semester 1 of 2018 has only reached 1,050 kWh / capita, a low number when compared to Malaysia 4000 kWh / capita and Singapore which reached 8000 kWh / capita[1]. One of the factors causing the low number is due to the unequal electricity consumption in Indonesia[2]. Indonesia has a very abundant source of renewable energy but it has not been used optimally. The remote areas that have resources are left just like that and not utilized at all to become an energy source. Many areas have not been evenly distributed, so some areas still have many blackouts, one of them is in Madura.

Based on that problems, in this research build of a hybrid solar power plant with PLN electricity equipped with a data logger and ATS (Auto Transfer Switch). Solar power plants utilize solar renewable energy through solar panels as the main source of charging on batteries and PLN as backup of charging.

The system used in this study includes solar panels, electricity grids, batteries, automatic transfer switches, and data loggers.

There have been many studies on solar electricity generation. In Taufik's research entitled Prototype DC House of Jatinangor as a Source of Rural Electricity, the research produced 600 W of power where solar panels supply 300 W of power [3]. In its application, a solar power plant (PLTS) is a generator that utilizes solar panels as a photon energy converter from solar / sun to electrical energy [4]. In addition to solar panels, several other components are also needed, including: Solar Charge Controller...
is a component in the PLTS system that functions as a regulator of the electric current (Current Regulator) for the incoming current from the PV panel and the load current out [5]. DC-AC Inverter itself has a function to convert direct current (DC) into alternating electric current (AC) [6], a battery is a device that functions to store the power obtained from solar panels[7]. In addition to being used as a battery charging application, solar panels can also be used at direct loads as in the research of Kerry A. Sado which uses direct power from the panel to the DC pump in agriculture[8]. The use of solar power plants is a good thing because of Indonesia's geographical location which is located on the equator because the sun shines throughout the year[9]. Hybrid system power generation can also be applied in villages or remote areas that are difficult to reach by electricity. Electrical energy sources are obtained from renewable energy such as solar, wind[10] and water [11]. Automatic Transfer Switch (ATS) in the study which is an automatic transfer system that is used as a main power supply switch to a backup power supply when there is a problem in the main power supply [12]. In the use of mk2p Relay which is an electronic switch that can open or close the chain with control from other electronic devices. An mk2p relay consists of a coil, a spring, a switch connected to a spring and 2 electronic contacts normally close and normally open. Based on how it works, the relay works based on the presence of a magnetic field that is used to move the switch [13]. Data logger is an electronic device that is made to record data or record data integrated with sensors. Physically the data logger is equipped with a microprocessor and internal memory as a recorder and record data on the sensor. The data recorded is the current sensor data, voltage sensor, temperature sensor, with the RTC DS3231 digital timing module used for timing. Communication using I2C or two wire (SDA and SCL) [14] and microprocessors using ATMEGA 328p.

2. Hybrid System
This research concern in power engineering, and hybrid system mean in hybrid power. Hybrid power are combinations between different technologies to produce power. In power engineering, the term 'hybrid' describes a combined power and energy storage system[a]. In this system include hardware and software design. Hardware consist of hybrid charging, ATS (Automatic Transfer Switch) and logger system, software include all program that build the system.

2.1. Hardware Design

![Figure 1. Hardware design](image)

In figure 1 there are three systems. First the hybrid charging system, meaning that if the solar panel is no longer able to charge when the battery is below 40%, the adapter will charge with the power from the PLN. The second is an Automatic Transfer Switch system, meaning that if there is a power outage the Automatic Transfer Switch will turn on the inverter and when the light is on the Automatic
Transfer Switch will turn off the inverter. The third is the logger system, meaning that if the system is turned on, the data available on the solar panel voltage sensor, solar panel current and temperature on the solar panel, the current used at load, the power used, the source of charging and the percentage of the battery will be recorded and stored in memory.

2.2. Hybrid charging

![Figure 2. Hybrid charging](image)

Figure 2 shows that the voltage sensor takes the voltage data on the battery that will be used as a reference to what percentage battery. The formula used as a reference to the percentage of the battery:

\[
\text{Percentage} \; \% = \frac{\text{DT} - V_{\text{min}}}{V_{\text{max}} - V_{\text{min}}} \times 100
\]

Information:
- DT = Voltage measurement data
- \( V_{\text{min}} \) = Lower Battery Voltage
- \( V_{\text{max}} \) = Upper Battery Voltage

If the battery percentage is below 40% the relay will change the charging from the solar panel to the PLN and the charging will break if the battery percentage is above 60%.

2.3. Data Logger

![Figure 3. Data Logger](image)

In Figure 3, the current sensor takes the charging current data used in the solar panel system, the voltage sensor takes the charging current data used in the solar panel system, the ds18b20 sensor takes
temperature data on the solar panel, the current sensor on the battery takes data on the power usage used, voltage sensor is used as a determination of battery capacity. The process is carried out on the microcontroller, the results of the sensor data retrieval and the results of the sensor readings will be displayed on the LCD and stored on the sd card memory.

2.4. Automatic Transfer Switch (ATS)

MK2p relay is used as a controller to turn on the inverter in case of a power outage. In this process the relay will turn on the inverter when the power goes out and when the power is on will turn off the inverter. The inverter will turn on or turn off according to the state of electricity from the PLN. If the PLN electricity goes out the inverter will turn off and if the power is on the relay will turn off the inverter.

![Figure 4. ATS system](image)

Figure 4. ATS system

All components are arranged as shown in Figure 5. These components include:

1. Solar Charger Controller 30 A is used as a controller of charging from the solar panel so that charging on the battery is maximum.
2. DC to AC 600W PSW inverters are used as converting DC to AC energy so that it can be used on AC electronic devices.
3. The adapter is used when the battery capacity is below 40%.
4. MK2P-I relays are used as a transfer of PLN power to the battery in the ATS system.

3. Result
The results of the study are used to find out whether the work system is functioning properly or not. Tests carried out for 1 week to find out the pattern of battery charging from the sun and PLN. From
data battery (Figure 6) showed that percentage battery fluctuating because of solar charging and power loss due to load.

\[
\text{Percentase Batray:}
\]

\[
\text{In determining the percentage of the battery using the formula (1):}
\]

\[
\text{Percentase} = \frac{DT - V_{\text{min}}}{V_{\text{max}} - V_{\text{min}}} \times 100\%
\]

\[
\text{13.53 - 10 \quad 14 - 10} \times 100\% = 88\%
\]

\[
\text{Comparison Output power, Power panel and Battery Percentage}
\]

From Figure 7 shows that the capacity of the battery can follow the voltage released during the process of charging the battery and discharging power.
3.1. Hybrid charging

Table 1. Hybrid Battery Charge Table

| Date       | Battery (%) | Battery Charge |
|------------|-------------|----------------|
| 03.01.2020 | 20.01.00    | 30.24 PLN      |
| 03.01.2020 | 20.02.00    | 54.34          |
| 03.01.2020 | 20.03.00    | 54.95          |
| 03.01.2020 | 20.04.00    | 40.69          |
| 03.01.2020 | 20.05.00    | 39.98 PLN      |
| 03.01.2020 | 20.06.00    | 39.77 PLN      |
| 03.01.2020 | 20.07.00    | 40.09          |
| 03.01.2020 | 20.08.00    | 54.84          |
| 03.01.2020 | 20.09.00    | 54.97          |
| 03.01.2020 | 20.10.00    | 39.99 PLN      |
| 03.01.2020 | 20.11.00    | 40.28          |
| 03.01.2020 | 20.12.00    | 40.18          |
| 03.01.2020 | 20.13.00    | 53.96          |
| 03.01.2020 | 20.14.00    | 54.42          |
| 03.01.2020 | 20.15.00    | 42.08          |

From table 1 it can be seen that PLN will conduct charging when the battery power is below 40% and will disconnect charging power from PLN when battery over 40%.

3.2. Automatic Transfer Switch

Table 2. Automatic Transfer Switch Table

| Date       | Battery (%) | Output Power | Source | Battery Charge |
|------------|-------------|--------------|--------|----------------|
| 03.01.2020 | 22.09.00    | 38.7         | Bat    | PLN            |
| 03.01.2020 | 22.10.00    | 38.07        | Bat    | PLN            |
| 03.01.2020 | 22.11.00    | 38.37        | Bat    | PLN            |
| 03.01.2020 | 22.12.00    | 53.45        | Bat    | Solar          |
| 03.01.2020 | 22.13.00    | 53.83        | Bat    | Solar          |
| 03.01.2020 | 22.14.00    | 56           | 0      | PLN Solar      |
| 03.01.2020 | 22.15.00    | 56.22        | 0      | PLN Solar      |
| 03.01.2020 | 22.16.00    | 56.42        | 0      | PLN Solar      |
| 03.01.2020 | 22.17.00    | 56.44        | 0      | PLN Solar      |
| 03.01.2020 | 22.18.00    | 56.5         | 0      | PLN Solar      |
| 03.01.2020 | 22.19.00    | 56.61        | 0      | PLN Solar      |
| 03.01.2020 | 22.20.00    | 56.59        | 0      | PLN Solar      |
| 03.01.2020 | 22.21.00    | 56.61        | 0      | PLN Solar      |
| 03.01.2020 | 22.22.00    | 56.7         | 0      | PLN Solar      |
| 03.01.2020 | 22.23.00    | 56.64        | 0      | PLN Solar      |
From table 2 it can be explained when the light goes out the relay will move power from the PLN to the battery, using timer its count delay about 3 seconds, and if the power is on the relay will move the power source from the battery to the PLN. If the power used is PLN, the output power will be 0.

4. Conclusion
In the hybrid charging system the main power source of the solar panel, if the battery power is less than 40%, the charging system switches to PLN and when the battery power is above 40%, the charging from the PLN will die. In the Auto Transfer Switch system will be active if the power from the PLN goes out and the relay will move the PLN power to battery power for 3 seconds due to the nature of the inverter. If the PLN power is on, the power from the inverter will switch to PLN directly. If no power outages occur, the main power used is PLN power.

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