Experimental analysis of temperature, light intensity, and humidity on rooftop standalone solar power plant

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Abstract. Rooftop standalone solar technology is a new renewable power generation solution worldwide and can reduce carbon dioxide levels in the environment. However, several factors affect the performance of the power plant; it is highly influenced by weather parameters. This paper shows the design of the rooftop standalone solar power plant and the influence of temperature, light intensity, and environmental humidity on it. The designed system consists of a 200WP photovoltaic, 1260Wh LiFePO4 battery, and an MPPT solar charge controller 40A. This standalone power plant was applied to supply the energy of the home lighting, with 20Watt the total of power. The result shows the design of the rooftop standalone solar power plant. Furthermore, there is an influence of temperature, light intensity, and environmental humidity on the LiFePO4 battery input power.

1. Introduction
Indonesia is a country located in the equator that gets abundant sunshine throughout the year, which has a very large potential for solar energy with average daily insolation of 4.5-4.8 KWh/m²/day [1]. Solar energy is a renewable source of energy that is gaining ground because of the benefits it offers [2]. A Photovoltaic (PV) system is a power generation system that produces electrical power by harnessing solar radiation and converting it into electricity [3]. Sunshine is a renewable energy source of solar electricity that can provide electricity continuously. Furthermore, it is also a clean and environmentally friendly energy, to reduce gas emissions and greenhouse [4–7].

The off-grid system is a stand-alone system that not relating to the grid facility [8,9]. Especially, the system that are not connected to the main electrical grid are referred as an off-grid photovoltaic system. Off-grid system can generate the power and run the appliances by itself, it was called a mini-grid or a standalone system. If the distinct living and spread population in the vast area or in the the districts where they do have no access to the electricity, the off-grid electrification system is viable for the remote areas [10]. Electrical energy in the stand-alone photovoltaic system produced through the Solar photovoltaic panels needs to be stored or saved on the battery bank because the requirement from the load can be different from the solar panel output [11].

A rooftop solar power plant is a photovoltaic system that has its electricity-generating solar panels mounted on the rooftop of a residential or commercial building [12]. A photovoltaic (PV) system consists of a photovoltaic, MPPT Solar Charge Controller, battery bank, and some electronic elements for power conditioning. The urban environment provides a large number of empty rooftop spaces and can inherently avoid potential land use and environmental concerns. The space on the rooftop can
harness solar radiation and converting it into electricity by applying the A rooftop photovoltaic power station [13]. On the other hand, the owners of rooftop photovoltaic power station have the authority to incorporate the solar electricity into the home grid electricity [14].

The output power generated by photovoltaics on the rooftop standalone power plant depends on many aspects [15]. There are from environmental weather condition, such as air temperature [16,17], relative humidity [18,19] and light intensity [20]. Moreover, PV material, parasitic resistance, inverter efficiency, dust, module orientation, geographical location, cable thickness also give affect the performance of photovoltaic [21].

2. Methodology

Weather parameter: light intensity, relative humidity, air temperature, were measured intermittently and simultaneously with solar illuminance and output voltage from solar charge controller to storage energy system. The development of a rooftop standalone solar power plant and data logger monitoring system consists of some parts and software. The rooftop standalone power plant consists of 1) polycrystalline Photovoltaic 200WP, 2) MPPT Solar Charge Controller 40A, 3) LiFePO4 Battery 12V 100Ah. Then, the data logger monitoring system consists of microcontroller ATMEGA 328 (Arduino UNO), current sensor ACS758 50A, voltage sensor, DHT11 sensor, BH1750 sensors, RTC DS3231, and SD Card module. Figure 1 shows the experimental layout of the rooftop standalone solar power plant and data logger monitoring system.

![Experimental design of rooftop standalone solar power plant and data logger monitoring system.](image)

2.1. Microcontroller

Microcontroller ATMEGA 328 (Arduino UNO) has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It was used to develop the data logger and monitoring system in this rooftop standalone power plant [22].
Figure 2. Location to applied rooftop standalone power plant.

The development of this rooftop standalone power plant is focused as a source of energy for home lighting. The selected location for applied this rooftop standalone power plant is on KH. Hasyim Asyhari Street, Gg. Bandar Kidul, Mojoroto, Kediri (Figure 2), which has coordinates -7.831849, 112.002152. Measurement of all parameter tests was taken at an interval of 24 hours for a 10 days 22-31 July 2020. During the measurements shown in figure 1, the relative humidity and air temperature were measured using the DHT 11 sensor. The light intensity was measured using the BH1750 sensor. The output voltage from the MPPT solar controller to battery was measured using a voltage sensor that consists of a voltage divider. Then, the current from the MPPT solar charge controller to the battery was measured using current sensor ACS758 50A. All data measurements were real-time recorded, therefore RTC DS3231 and SD card module were added into the data logger system.

Figure 3. Real-time data recorded of relative humidity, air temperature and light intensity from microcontroller 1.

Figure 4. Real-time data recorded of voltage and current from microcontroller 2.

The example of data recorded that recorded on the SD card is shown in Figure 3 and Figure 4. From figure 3, the data real-time of relative humidity, air temperature, and light intensity was recorded on microcontroller 1. Furthermore, figure 2 is a real-time data from microcontroller 2 that were recorded the voltage and current from the MPPT Solar Charge controller to the battery. All of the data recorded were saved in a micro SD card with a txt extension. Subsequently, data were converted to excel and analyze using origin software.
3. Result and discussion

Figure 5. Graph of the relative humidity.

Figure 6. Comparison of the rate of the relative humidity and voltage.

Figure 5 shows the relative humidity as long as 10 days. The data were recorded by real-time using the data logger. From the data can be seen that the humidity during the test is fairly good and in normal condition. At night day, the highest humidity can reach to be 80%. While during the day it can reach 18% of humidity. Then, Figure 6 shows the comparison of the rate of humidity and the rate of voltage from the MPPT solar charge controller into the battery as long as a 10-day test. During the test, the lowest humidity and the maximum voltage occur between 10.20 AM to 14.10 PM.

Figure 7. Graph of the air temperature.

Figure 8. Comparison of the rate of air temperature and voltage.

Figure 7 shown the air temperature as long as a 10-day test. The air temperature during the test is fairly good and in normal condition. The maximum air temperature during the test is 57.5°C, then the minimum air temperature during the test is 21.8°C. Figure 8 shows the comparison of the rate of the air temperature and the rate of voltage. The graph shows that temperature has a significant effect on the power production of photovoltaic.
Figure 9. Graph of light intensity.

Figure 10. Comparison of the rate of light intensity and voltage.

Figure 9 shown the graph of the light intensity as long as the 10-day test. The maximum light intensity during the test is 55765 Lx that occur between 10.46 AM to 14.38 PM. Figure 10 shows the comparison of the light intensity and the rate of voltage. The graph show that light intensity has a significant effect on the power production of photovoltaic.

Figure 11. Comparison of the light intensity and current.
Figure 12. Comparison of the air temperature and current.

Figure 13. Comparison of the relative humidity and current.

Figure 11 shows the comparation of the rate of light intensity and current. The maximum current that produce by photovoltaic occur between 11.12 AM to 14.18 PM. Figure 12 shows the comparison of air temperature and the current. From the graph, a direct correlation is observed between air temperature rise and current increase. Figure 13 shows the comparison of the of relative humidity to changes the current from the photovoltaic. The graph shows if the relative humidity increase, so the current that produce will be decrease.

4. Future work
Future work will focus on:
- Wireless data logger software
- The specific lithium ion battery (LiFePO4) with cooling system
- Smart BMS that include on the battery
- The rooftop standalone power plant connects with smart home system

5. Conclusion
The real-time performance and monitoring of rooftop standalone solar power plant located on the rooftop of a boarding house in Kediri district are carried out by developing a hardware model of 200WP
polycrystalline photovoltaic, MMPT solar charge controller 40A, and LiFePO4 battery 12V 100Ah. Moreover, the data logging monitoring system was developed using microcontroller Arduino UNO (Arduino UNO), current sensor ACS758 50A, voltage sensor, DHT11 sensor, BH1750 sensors, RTC DS3231, and SD Card module.

The light intensity affects the energy output of the rooftop standalone solar power plant. If the light intensity increases by 100 Lux, the energy output will increase by 4Wh assuming a constant temperature. During the day, the temperature affects the energy output of the rooftop standalone solar power plant. If the temperature increases by 1 degree, the energy output of the rooftop standalone solar power plant will increase 0.321 Wh, assuming constant light intensity. In the morning, afternoon, and evening, humidity does not affect the energy output of the rooftop standalone solar power plant.

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