COMPARISON OF MONOCRYSTALLINE TYPES OF SOLAR CELL MODULES TO POLYCRYSTALLINE TYPES IN REVIEW OF THE POWER GENERATED BY APPLYING REAL-TIME MEASUREMENTS

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ABSTRACT
The solar cell module is the main device in the solar power generation system. There are two types of solar cell modules that are commonly used, namely monocrystalline and polycrystalline types. The selection of the better type of solar cell module for a particular area, condition, and time can increase the effectiveness of solar power plants. This study aims to compare the performance of monocrystalline solar cell modules against polycrystalline solar cell modules in terms of the power generated when each solar cell module obtains the same intensity of sunlight. Measurements were carried out in two different weather conditions, namely when the sun was shining brightly and when the weather was cloudy or foggy. The measurement method was carried out by applying an automatic electronic data logger system. Data is retrieved in real-time and stored in the memory card. In addition to measuring the voltage, light intensity and surface temperature measurements were also carried out for each type of solar cell module. The results showed that the monocrystalline solar cell module produces a higher power than the polycrystalline type.

Keywords: Monocrystalline, Polycrystalline, Sunlight, Power, Data Logger

INTRODUCTION
The solar cell module is the main device in the Solar Power Generation system. The performance of a solar power plant is strongly influenced by the characteristics and specifications of the solar cell panels used. While the performance of solar cell panels is influenced by the intensity of sunlight received by the surface of the solar cell panel. In addition to the intensity of sunlight, the surface temperature of the solar cell module is also known to affect the performance of the solar cell module.

Two types of solar cell modules are commonly applied to solar power plants, namely: monocrystalline and polycrystalline types. When compared, monocrystalline and polycrystalline certainly have several different characteristics.

The purpose of this study was to compare the performance of monocrystalline and polycrystalline solar cell modules, in terms of response to changes in light intensity and surface temperature. The benefit of the results of this research is to provide a reference for the designers of solar power plants. in determining the choice of the module to be used, according to the conditions that affect it. Two things that will be compared in this study are:
1. The influence of the orientation of solar cell panels on the energy produced by solar cell panels, both monocrystalline and polycrystalline types
2. The influence of the surface temperature of the solar cell panel on the energy produced by the solar cell panel for monocrystalline and polycrystalline types.

LITERATURE REVIEW
The sun provides the earth with 16x1018 units of energy every year, which is 20,000 times the amount of energy required by people on the planet. On a sunny day, the sun emits

roughly 1 kW/m2 of energy. "The International Energy Agency projects that by 2050, solar energy will provide nearly one-quarter of renewable energy, or 11% of global electricity," as stated in. [1]

The solar power plant is one of the renewable energy that has the potential to be developed in Indonesia. The potential for solar energy in Indonesia is very large, around 4.8 KWh/m2 or equivalent to 112,000 GWp, but only about 10 MWp has been implemented. Currently, the government of the Republic of Indonesia has issued a roadmap for the use of solar energy which targets the installed solar power capacity by 2025 to be 0.87 GW or around 50 MWp/year. This number is an illustration of the fairly large market potential for the development of solar energy in the future.[2]

The solar cell module is the main device in the solar power system. The function of the solar cell module is to convert the received light energy into direct electrical energy (DC). There are two types of solar cell modules based on their construction, namely: monocrystalline and polycrystalline. It is necessary to know how the influence of the intensity of sunlight and the surface temperature of the solar cell module on the power generated. The efficiency of silicon solar cells is the most important parameter which shows the performance on temperature and FF of Silicon Solar cells between 0.75 to 0.85 on standard solar irradiation 1kw/m2 in equation [3]

Polycrystalline and monocrystalline modules are currently utilized mostly in rooftop and ground photovoltaic systems. Monocrystalline modules have a high power generation yield and save land or rooftop costs with the same installed capacity. With the same number of modules, the real power generation yield of monocrystalline is higher than polycrystalline. When monocrystalline modules are utilized in solar energy projects, more power is generated than when standard modules are used.[4]

Mono crystalline solar cell are made using a single crystal of silicon (Si) by the Czochralski process [5]. Polycrystalline PV modules (figure 3) are formed from various crystals, joined together in a unit cell [5]
Solar cells are made of semiconductors, and every type of semiconductor has a property called a band gap that is different from that of other semiconductors. The band gap defines the longest wavelength of light a semiconductor can absorb (it is transparent to longer wavelengths). It also fixes the maximum amount of energy that can be captured from photons of shorter wavelength. The result is that long-wavelength photons are lost and short-wave ones incompletely utilized.[6]

The most important parameters that describe the operating conditions of a solar cell are the total irradiance,the spectral distribution of the irradiance and the temperature. Usually the solar cell designer asses their devices by evaluating the efficiency at standard reporting conditions (SRC: illumination =1000 W/m2, temperature=25°C and AM1.5 reference spectrum). [7]

Maximum power output from the solar cells decreases as the cell temperature increases,[8]
By using the PV/T technique, the experimental result has shown the significant improvement on the electrical efficiency of PV module[9]
In the field of photovoltaic, a photovoltaic module or photovoltaic panel is a packaged interconnected assembly of photovoltaic cells, also known as solar cells. An installation of photovoltaic modules or panels is known as a photovoltaic array[10]

The purpose of this research was to compare the ability of monocrystalline and polycrystalline solar panels to generate electrical power with changes in the intensity of sunlight and the surface temperature of each. each solar cell. The results of the research can be used as a reference for the public to choose the type of solar cell module that will be used as a solar power generation device.

METHODS

This research was conducted in stages:

Preparing the object of research

The research object used is shown in the following table

Table 1. The Research Object

Device	Specification	Quantity
Solar cell module	Monocrystalline, 100 Wp,	1 unit
Solar cell module	Polycrystalline, 100 Wp	1 unit
Dummy load	88 ohm (4 x 22 ohm in series), 20 W	2 series circuits

Preparing the measurement system

This real-time automatic measurement consists of several main components as shown in the following table:

Table 2. The Main Components

Component	Specification	Used for	Quantity
The infrared temperature measurement sensor	Name : Module GY-906 MELEXIS MLX90614ESF Range : -70+380 C	solar cell module temperature measurement	4 pieces
Voltage Sensor Module	range : 0.02445-25v DC	Solar cell module voltage measurement	2 pieces
Current sensor Chip	Name : ACS712ELC-20A; Range : 0-20 Ampere	Dummy load current measurement	2 pieces
Light intensity sensor	Name : GY – 302-BH1750 Range : 0-65535 lux	ambient Light intensity measurement	1 piece
Wind sensor	Name/ Model : JL-FS2 Range : 0-60 m / s	Wind movement speed	1 unit

microcontroller	Arduino mega	Controlling	1 unit
multiplexer	Name : CJMCU-9548 TCA9548A	Multiplexing analog data from each Infrared Temperature measurement sensor	1 piece
Display Module	Dot Matrix LCD Display Module Character : 16 x2	Display monitoring	1 unit
SD Card Module	Standard	Data logger	1 piece
Power supply DC	12 Volt with step down to 5 volt	Power supply for all system circuit	1 unit

Designing the Measurements Circuit

The measurements circuit in real-time based on this data logger is shown in the following block diagram:

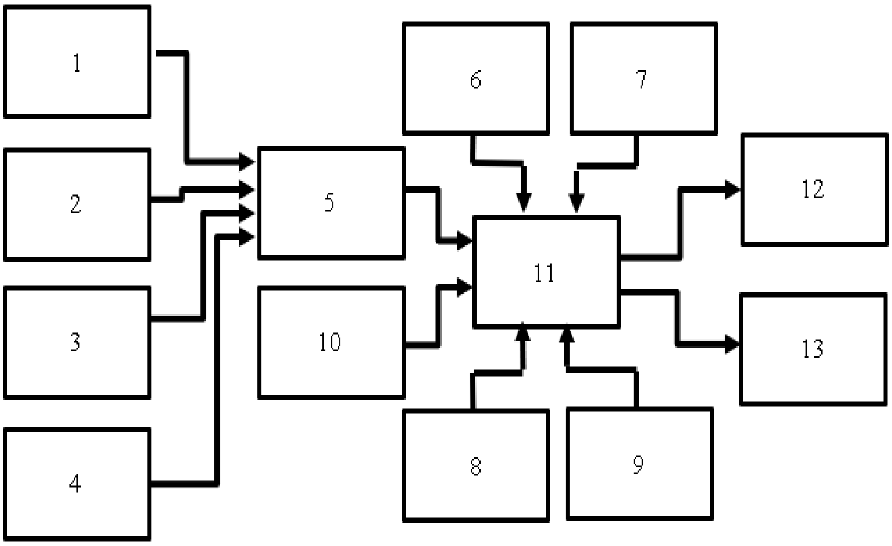

Figure 1. Block Diagram Of Measuring Real-Time Measurement Circuit

Each sub blok 1 to 13 are :

- 1, 2 are temperature sensors for the polycrystalline module
- 3, 4 are Temperature sensor 2 for monocrystalline module
- Multiplexer
- Ambient light intensity sensor
- Wind speed sensor
- Microcontroller
- LCD
- Datalogger module/ SD card module

Designing Measuring circuit schematic

The measurement circuit schematic is shown in the following figure

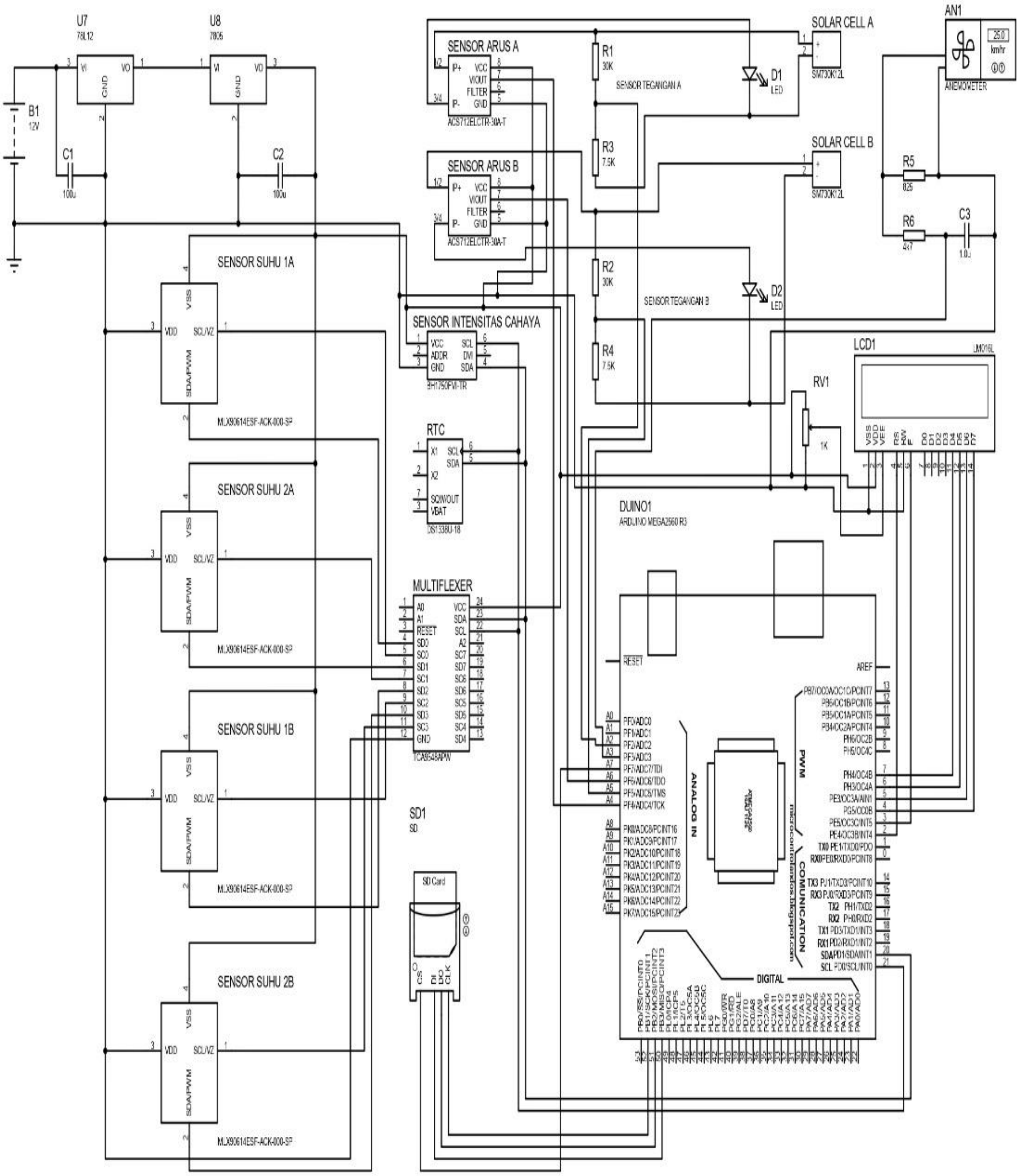

Figure 2. Measuring Circuit Schematic

Creating and compiling program code for Arduino Mega

Some libraries are needed for this, as shown in the code below :

```
#include <Bildr-MLX90614.h>
#include <BH1750.h>
#include "RTClib.h"
#include <SPI.h>
#include <SD.h>
#include <LiquidCrystal.h>
```

Place and date of measurement

Measurements were carried out two times as shown in the following table

Table 3. Place And Date Of Measurement

No	Name of Place	Coordinate of place	Date	Weather of place
1	Berastagi city	3.1709228819793656, 98.51497111158453	October 10, 2021	sunny
2	Berastagi city	3.1709228819793656, 98.51497111158453	October 20, 2021	cloudy

Measurement process

The measurement is carried out in the following steps:

1. Placing both types of solar cell modules, monocrystalline and polycrystalline in parallel side by side to get the same lighting intensity.
2. Connect the output terminals of both types of solar cell modules to the measuring device.
3. Running measurement system in real-time.
4. Processing the measurement data

RESULTS AND DISCUSSION

Result

On the first day of measurement, the SD card saved about 17853 real-time measurement data. The data were taken and recorded from 8.18 AM to 3.00 PM. On the second day of measurement, the SD card saved about 9811 real-time measurement data. The data were taken and recorded from 1.31 pm to 2.25 PM. The data were collected and filtered to find the specific conditions. There are 11 specific conditions to be analyzed, from data table number 4 and data table number 5. The data tables are shown below.

Table 4. Measurement Data On The First Day

No	Specific Condition	Time	Ambient Intensity (lux)	Polycrystalline Module			Monocrystalline Module		
				Temperature (^{0}Celcius)	Voltage (volt)	Dummy load current (Ampere)	Temperature (^{0}Celcius)	Voltage (Volt)	Dummy load current (Ampere)
1	Average		20306.18	28.77	16.12	0.18	28.89	17.67	0.20
2	when the ambient light intensity is minimum	14:24:24	1135	19.15	13.25	0.15	18.64	13.37	0.15
3	when the ambient light intensity is maximum	11:26:45	54612.5	33.94	20.94	0.24	35.27	22.56	0.26
4	when the temperature of polycrystalline is minimum	14:31:48	25180.83	18.55	21.27	0.24	18.64	22.42	0.25
5	when the temperature of polycrystalline is maximum	11:44:17	25197.5	48.06	20.21	0.23	48.61	21.92	0.25
6	when the temperature of monocrystalline is minimum	14:29:31	2797.5	18.63	13.29	0.15	18.5	13.42	0.15
7	when the temperature of monocrystalline is maximum	11:44:26	26715	47.86	20.19	0.23	48.98	21.87	0.25
8	When the voltage of polycrystalline is minimum	14:23:50	1210.83	19.16	13.22	0.15	18.68	13.37	0.15
9	When the voltage of polycrystalline is maximum	10:39:10	8157.5	26.51	21.65	0.24	31.08	21.99	0.24
10	When the voltage of monocrystalline is minimum	14:24:07	1159.17	19.13	13.25	0.15	18.72	13.34	0.15
11	When the voltage of monocrystalline is maximum	13:31:03	23603.33	24.16	14.88	0.17	24.67	23.12	0.26

Table 5: Measurement data on the second day

No	Specific Condition	Time	Ambient Intensity (lux)	Polycrystalline Module			Monocrystalline Module		
				Temperature (^{0}Celcius)	Voltage (volt)	Dummy load current (Ampere)	Temperature (^{0}Celcius)	Voltage (Volt)	Dummy load current (Ampere)
1	Average		51210.17	40.71	20.65	0.23	41.043	22.23	0.25
2	when the ambient light intensity is minimum	8:21:19	21182.5	29.57	20.55	0.23	30.07	21.75	0.25
3	when the ambient light intensity is maximum	9:19:54	54612.5	35.64	20.94	0.24	35.74	22.41	0.25
4	when the temperature of polycrystalline is minimum	8:22:17	31599.17	28.48	21.04	0.24	30.18	22.34	0.25
5	when the temperature of polycrystalline is maximum	12:11:24	54612.5	50.08	20.26	0.23	50.02	21.92	0.25
6	when the temperature of monocrystalline is minimum	8:18:57	31014.17	30.17	22.48	0.26	28.9	23.73	0.27
7	when the temperature of monocrystalline is maximum	12:11:45	54612.5	49.94	20.26	0.23	50.31	21.92	0.25
8	When the voltage of polycrystalline is minimum	14:24:28	30081.67	42.57	19.04	0.22	43.35	20.65	0.23
9	When the voltage of polycrystalline is maximum	8:18:36	30657.5	29.22	22.48	0.26	29.16	23.73	0.27
10	When the voltage of monocrystalline is minimum	8:55:52	42598.33	31.94	20.09	0.24	31.53	20.11	0.22
11	When the voltage of monocrystalline is maximum	8:18:36	30657.5	29.22	22.48	0.26	29.16	23.73	0.27

Discussion

Refers to the two data tables above, Each module received the same light intensity, it is known that :

The electrical power average of the monocrystalline module is higher than the electrical power average of the polycrystalline module. (row data number 1). The average temperature of each module is less than the same.
When the ambient light intensity is minimum, the power of the monocrystalline module is higher than the power of the polycrystalline. The surface temperature of monocrystalline is higher than the surface temperature of polycrystalline (row data number 2).

When the ambient light intensity is maximum, the power of the monocrystalline module is higher than the power of polycrystalline. The surface temperature of monocrystalline is higher than the surface temperature of polycrystalline. (row data number 3).
Refers to the three points above, when Each module receives the same light intensity, the electrical power of the monocrystalline module is higher than the electrical power of the polycrystalline module, although the surface temperature of the monocrystalline module is higher than the surface temperature of the polycrystalline module.

Then let's compare the data shown in row data number 4 versus row data number 5. it is about the electrical power that is produced by the polycrystalline module.
the module produces higher electrical power when its surface temperature is lower (row number 4), and the module produced lower electrical power when its surface temperature is higher (row number 5). The ambient light intensity is different. The ambient light intensity (row 4) is higher than (row 5).

Row data numbers 6 and 7 are shown the electrical power that is produced by the monocrystalline module. The surface temperature of monocrystalline gives the effect as same as the surface temperature of polycrystalline. The row data numbers 6 and 7 that are used are just from table number 4 because row data number 6 from table number 5 is not valid, the ambient light intensity is too small.

Then, .it is needed to know how the effect of the surface temperature of the module on the electrical power that is produced when it received the same light intensity. The filtered data had to be found that shows the different surface temperatures but the light intensity is less than the same. The filtered data is shown in row number 8 and number 9 of table number 4 for the polycrystalline module. The filtered data is shown in row number 10 and number 11 of table number 4 for the monocrystalline module.

CONCLUSION

1. The average power that is produced by polycrystalline and received by the dummy load is 4,74 Watt. The average power that is produced by monocrystalline and received by the dummy load is 5,55 Watt. This happens when the ambient light intensity is high, the weather is sunny. The power of monocrystalline is higher about 0,81 watts than the power of the polycrystalline module.
2. When the surface temperature is increased, the power that is produced is decreased, when the surface temperature is decreased, the power that is produced is increased. This happens on both types of modules.
3. The maximum voltage that is produced by polycrystalline is 22, 48 Volt. It happens when the ambient light intensity is high, and the weather is sunny. The surface temperature is 29,22 ^{0} Celcius.
4. The maximum voltage that is produced by monocrystalline is 23, 73 Volt. It happens when the ambient light intensity is high, and the weather is sunny. The surface temperature is 29,16 ^{0} Celcius.

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