Development of Solar Power Plant to Support Smart Farming 4.0 at Hubbul Khoir Islamic Boarding School Indonesia

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***Abstract*—Electricity is a very crucial thing in human life today such as for communications, education, offices, household appliances, and transportation. Unfortunately, most of the electricity in Indonesia is still generated by fossil fuels such as coal. Indonesia which is on the equator has an advantage in solar power generation. Every area in Indonesia gets sunlight for a full year. In this paper, we develop a 1.62 kWp solar power plant at the Hubbul Khoir Islamic Boarding School Indonesia. Energy generated from solar panels is used to support the hydroponic farming system owned by the Islamic boarding school. Economic analysis is used to find out whether the installed generating system is profitable or not. Power quality analysis is used to determine whether the load can be supplied with good power quality. The results obtained by the monitoring system can monitor the PV output power and the power to the load with a display on the LCD screen and on the web with overall accuracy above 96%, economic analysis results show that the system will return on investment after 6.8 years with a profit in the 25th year of Rp20,871,282, and quality the power in this system has good power quality from the PLN side and the inverter side.**

Keywords—IoT, monitoring, renewable energy, solar panel, power quality

I. Introduction

In this paper, the author analyzes the solar power plant system installed at the Hubbul Khoir Islamic Boarding School. This boarding school has a 1.62 kWp solar panel installed, a 100 Ah 48 V battery, and a 3,000 W inverter. Photovoltaic cells on solar panels can convert radiation from the sun into electrical energy. The greater the solar radiation, the greater the electricity generated.

Electricity is very crucial in human life today. Electricity is used in communication, education, offices, household appliances, and transportation. Unfortunately, most of the electricity in Indonesia is still generated by fossil fuels such as coal. These fossil fuels produce pollution and their fuel sources can run out because they are not renewable. There needs to be a transition to renewable electrical energy generation so that electricity can be produced continuously. Renewable energy with solar, wind, water and other energy sources can be an option for energy transition. Solar power plants as one of the renewable energies have advantages for the Indonesian region. Indonesia is geographically located on the equator which gets full sunlight during the year. Solar panels use radiation from the sun to generate electricity [1].

Internet of Things (IoT) is a concept where a certain object or device has the ability to transfer data automatically to an internet network without requiring human interaction. IoT is used to expand the benefits of internet connectivity. Internet of Things (IoT) refers to the use of intelligent devices and systems with internet-connected programming activities to leverage data from sensors and generate machine interactions automatically [2].

The information system is a combination of several continuous information technology components for communication within an organization in order to achieve an expected goal. Information systems are generally data relationships and methods using hardware and software to convey useful information. Information systems are useful for managing data so that the data conveyed can be clearer and more meaningful [3].

An economic analysis needs to be carried out to ensure that existing solar power plants are profitable. The main advantage is that the electricity used can be self-generated, thus reducing the amount of PLN electricity used.

Power quality is a value that shows how well electricity can supply the load. Good power quality can maximize the performance and service life of electrical equipment. One of the regulations governing power quality is "*Permen ESDM number 4 of 2009*" [4].

II. Methods

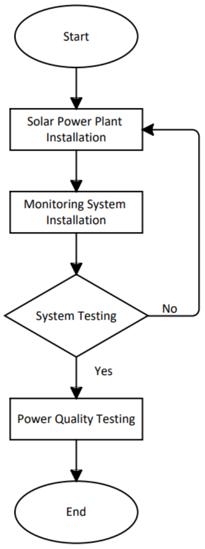

Fig. 1. Design Process

In this study the solar power plant has three main components. The main components are solar panels, batteries and inverters. Power quality testing is carried out using a power analyzer to test power quality on inverters and PLN.

A. Location

Fig. 2. Solar Power Plant Location

The existing solar power plant is located at the Hubbul Khoir Islamic Boarding School which is located in Ngentak, Bulakrejo, Sukoharjo, Central Java. Based on the Solar Global Atlas, this area has a Global Horizontal Irradiation value of 1607.7 kWh/m2. The existing solar power plant is used to supply greenhouse and student dormitory loads.

Fig. 3 Hidroponik GreenHouse

The existing hydroponic garden is used to grow vegetable and fruit plants for the activities of existing students.

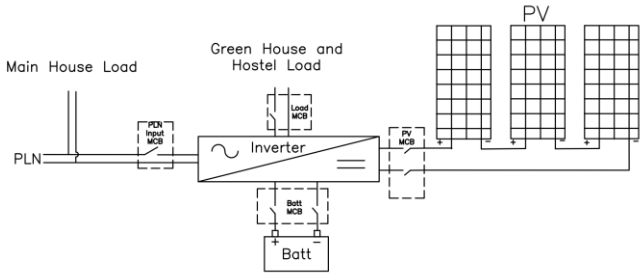

Fig. 4. Schematic Design of Solar Power Plant Electrical System Installation

This solar power generation system uses a hybrid inverter so that the source of electrical energy comes from PLN and from solar panels. Inverters can be set to determine which power source is the main power source. In the inverter there is also an ATS (Automatic Transfer Switch) system that works to move the main power source to the secondary power source according to the settings. On each component that will enter or exit the inverter there is an MCB that is used as an overcurrent protection device.

B. Solar Power Plant

Fig. 5 Solar Power Plant and Monitoring System

1) Solar Panel

Most solar panels on the market use crystalline silicon technology. This type of solar panel is divided into two types. The first type is monocrystalline which comes from cylindrical silicon sliced with a thickness of 200-200 μm. This type has the advantage of 15-20% better efficiency and has better durability or strength. However, the disadvantage of this solar panel is the amount of production waste due to the production process when the silicon cells are cut. This also causes monocrystalline solar panels to be relatively more expensive compared to polycrystalline types. The second type is polycrystalline, which is a type of solar panel whose process is different from the previous type. The process of making polycrystalline types by melting silicon with other materials and then molding. Its thickness ranges from 180-300 μm. The efficiency of polycrystalline is not as great as monocrystalline, which is 12-14%. However, it has lower production waste and price [5].

The solar panels used are "*Longi LR5-72HPH 540 Wp*" of 3 pieces. This panel is monocrystalline which has an efficiency of up to 21.3% and can be used up to 25 years [6].

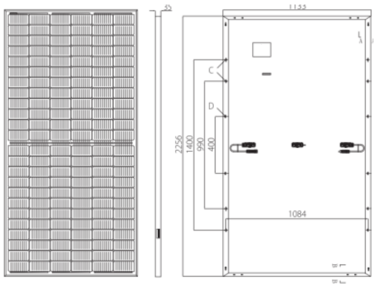

Fig. 6. *Longi LR5-72HPH 540 Wp*

2) *Battery*

A battery is a device that can convert the chemical energy contained in the active ingredients in the battery and convert it into electricity. This can occur due to reduction and oxidation reactions. A reduction reaction is one in which electrons are added and the oxidation number is decreased. An oxidation reaction is a reaction where electrons are released while increasing the oxidation number. Battery classification can be divided into primary batteries and secondary batteries. Primary batteries are disposable or non-rechargeable batteries, while secondary batteries are rechargeable batteries. Secondary batteries can be recharged because the electrochemical reactions that occur are reversible. So that chemical energy can be converted into electrical energy (discharge) and electrical energy can be converted into chemical energy (recharge) [7].

The battery used is "Sacred Sun SCIFP48100". This battery has specifications of 100 Ah 48 V. This battery is of the LiFePO4 type. This type of battery is suitable for energy backup for off-grid, on-grid, and energy storage for households [8].

Fig. 7. *Sacred Sun SCIFP48100*

3) *Inverter*

Inverter is one of the power electronics circuits which can convert DC electricity into AC. Inverters are often found in PLTS systems. This is because the electricity generated by solar panels is DC electricity and the loads used in households are AC loads. The inverter here will later play the role of converting DC electricity generated from solar panels into AC electricity so that it can be used for household loads [9].

The inverter used is "Techfine VE3848ML". This inverter has a maximum power of 3,000 W. This inverter is included in the hybrid inverter because it can supply the load with two power sources, namely from the grid and solar power plants [10].

Fig. 8. *Techfine VE3848ML*

C. *Monitoring*

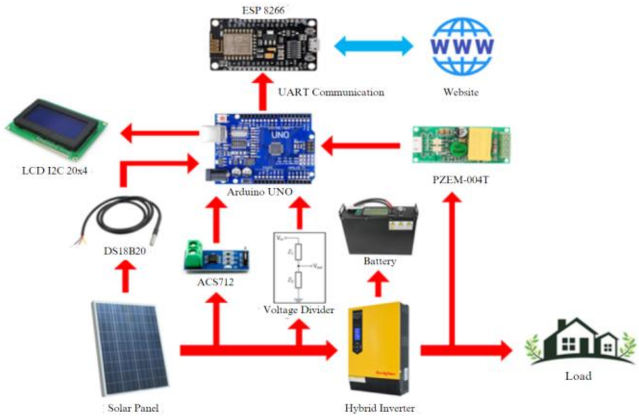

Fig. 9. Monitoring System

1) *Microcontroller*

This monitoring system uses two microcontrollers. The microcontrollers used are Arduino Uno and NodeMCU ESP8266. NodeMCU here is focused on IoT systems that are used by sending data to a website which will display monitoring results from the existing system.

2) *Sensors*

There are three types of sensors used in this monitoring system. The first sensor is a sensor for monitoring the output AC power from the inverter. This sensor is the PZEM-004T sensor which has an AC voltage sensor with a reading capability of up to 240 V and a ring-shaped current sensor with a reading capability of up to 100 A [11].

The second sensor is the ACS712 current sensor sensor, which is a sensor capable of measuring current values in DC and AC electricity based on field effects. This sensor is equipped with an operational amplifier circuit so that the current measurement becomes more sensitive. The sensor used can take readings up to 30 A [12].

The third sensor is the DS18B20 temperature sensor. This sensor is used to measure the temperature on the PV. This sensor can measure temperatures from -55ºC to +125ºC with an accuracy of up to 0.5ºC [13].

D. *Power Quality Analysis*

1) *Power Analyzer AEMC 3945-B*

A power analyzer is used for power quality analysis. *AEMC 3945-B* is a power analyzer that can be used on 1-

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phase and 3-phase electricity. The data that can be retrieved through this tool are electric waveforms, frequency, voltage, current, power, power factor, current THD, and voltage THD. Based on these data it can be determined whether the existing power quality is good or not [14].

Fig. 10. *AEMC 3945-B*

2) *Power Pad Application*

This application is an application used to monitor, control, and transfer data from the power analyzer to the laptop.

III. Results and Discussion

There were three analyses carried out in this study. The first analysis is economic analysis, the second is power quality analysis, and the third is power quality impact analysis.

A. *Economic Analysis*

Economic analysis requires data such as annual electricity production from solar power plants, PLN electricity costs, the total cost of solar power plants, interest rates, and inflation rates. The inflation rate from Bank Indonesia data from 2010-2022 was 4.29% [15] dan and the interest rate from 2010-2022 from the Central Bureau of Statistics was a discount of 10.29%.[16].

TABLE I. Economic Analysis

Revenue	**Value**
The First Year's Electricity Production	3,717 kWh/Year
PV Degradation Factor	0.70%/Year
First Year Savings	Rp5,369,950
Savings from Solar Power Plant Generation	Rp1,444.7/kWh
Cost	**Value**
Capacity	1.62 kWp
Investment costs	Rp15,555,556/kWp
Total Investment Cost	Rp25,200,000
Operating Costs	Rp504,000/Year
Percentage OnM	2.00%
General	**Value**
Interest Rate	10.29%
Lifetime	25 Years
Inflation	4.29%/Year
Replacement Cost (Inverter + Battery/10 years)	Rp12,100,000
NPV (Net Present Value)	Rp20,871,282
IRR (Internal Rate of Return)	19.86%
DPP (Discounted Payback Period)	6.8 Years

From this table, it can be seen that the return on investment will be obtained after 6.8 years. In the 25th year, the profit to be obtained is Rp20,871,282.

B. *Monitoring System*

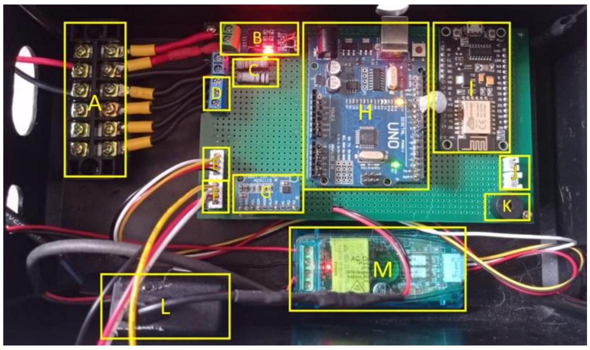

Fig. 11. Hardware Monitoring System

Testing the accuracy of the DS18B20 temperature sensor is done by comparing the temperature value of the DS18B20 sensor with the UNI-T Clampmeter. The average accuracy of the DS18B20 sensor is 98.7%.

Testing the accuracy of the PZEM-004T AC electricity sensor is done by comparing the value of the PZEM-004T sensor with the UNI-T Clampmeter and Kyoritsu Multimeter. The average sensor accuracy on voltage is 99.36% and the average sensor accuracy on current is 96.72%.

Testing the accuracy of the voltage divider by comparing the recorded voltage value with the voltage value generated by the power supply and testing the accuracy of the ACS712 current sensor by comparing the recorded value on the sensor with the current value on the load tester. The DC voltage accuracy value obtained is 97.23% and the DC current accuracy obtained is 96.26%.

The system is set to send data with a delay of 30 seconds. With some sample data where sending data to the website server has an average time of 52 seconds. The delay difference between the program code and the actual delivery is 22 seconds. The error value and delay difference in each data transmission occurs due to the programming looping system and signal interference that occurs when sending data.

Fig. 12. First Mode Display on LCD

The first display displays from the output side of the inverter (AC). In this display mode there are PV voltage, current, power, energy, frequency, power factor, and PV temperature.

Fig. 13. Second Mode Display on LCD

The second display shows the electricity generated by PV (DC). In this display mode there are PV voltage, current, power, energy, and PV temperature.

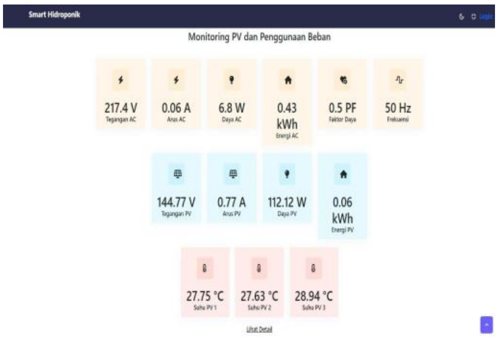

Fig. 14. Display on the Web

On this website you can monitor the condition of the existing solar power system. With this system monitoring can be done from anywhere. The data displayed on the website is a combination of the data displayed on the LCD.

In previous research conducted by Putera, Andhika Rizkita, the power monitoring system on the existing ATS system uses the Blynk application. This application has an attractive appearance but to do monitoring requires installing the Blynk application on the device. With a website-based monitoring system, monitoring can be done with any internet-connected device without the need to install a specific application [17].

C. Power Quality Analysis

In this section, three tests are carried out. The first test is testing the power quality on the inverter with the PLN source on, the second test is testing the power quality on the inverter with the PLN off, and the third test is testing the quality of the PLN electric power. The test was carried out for 3 minutes and data taken every second. The total data in each experiment is 180 data.

Fig. 15. Power Quality Testing

In "Permen ESDM number 4 of 2009" there are parameters that regulate good power quality. These parameters are frequency, voltage, voltage THD, current THD, and power factor. The frequency that is considered good is 49.5 Hz to 50.5 Hz. A good voltage is 198-231 V. A good THD voltage and current is below 5%. The value of a good power factor so as not to be fined is at a value of 0.9 [4].

TABLE II. INVERTER POWER QUALITY (PLN ON)

	F (Hz)	*V rms (V)*	*V THD (%)*	*V CF*	*A rms (A)*	*A THD (%)*	*A CF*	*PF*
Min	49,99	217	0,90	1,41	3,30	14,2	1,76	0,97
Maks	50	218,2	1,60	1,42	4,80	20,7	1,95	0,99
Rata-rata	49,99	217,67	1,40	1,41	4,44	15,65	1,81	0,98

TABLE III. INVERTER POWER QUALITY (PLN OFF)

	F (Hz)	*V rms (V)*	*V THD (%)*	*V CF*	*A rms (A)*	*A THD (%)*	*A CF*	*PF*
Min	49,98	217,2	0,80	1,41	3,20	10,7	1,73	0,96
Maks	50	218,4	1,70	1,41	5,30	21,2	1,96	0,99
Rata-rata	49,99	217,82	1,10	1,41	3,74	17,52	1,86	0,98

TABLE IV. PLN POWER QUALITY

	F (Hz)	*V rms (V)*	*V THD (%)*	*V CF*	*A rms (A)*	*A THD (%)*	*A CF*	*PF*
Min	49,96	226,7	2,4	1,4	1,7	4	1,51	0,94
Maks	50,02	227,9	2,6	1,4	3,1	19,6	1,8	0,99
Rata-rata	49,99	227,19	2,48	1,4	2,64	6,41	1,57	0,99

Based on the three tests that have been carried out, all the frequencies tested have a good value. The three results have an average frequency of 49.99 Hz, 49.99 Hz and 49.99 Hz respectively.

Based on the three tests that have been carried out, all the tested voltages have a good value. The three results have an average voltage of 217.67 V, 217.82 V and 227.19 V respectively.

Based on the three tests that have been carried out, all the THD voltages tested have a good value. The three results have an average THD voltage of 1.40%, 1.10% and 2.48%, respectively. The current THD is not an assessment material because in the applicable regulations it is the harmonic value under total load conditions.

Based on the three tests that have been carried out, all the power factors tested have a good value. The three results have an average power factor of 0.98, 0.98, and 0.99, respectively.

IV. CONCLUSION

Based on the research that has been done, a solar power plant with a hybrid system with PLN can supply the load properly. From an economic standpoint, the existing system can return on investment after 6.8 years and in the 25th year it will receive a profit of Rp20.871.282.

Monitoring that has been made can be observed directly on the LCD and can be observed on the website. The data displayed is in the form of voltage, current, frequency, power factor, power, energy, and PV temperature with overall accuracy above 96%.

Based on the power quality testing carried out, it was found that the condition where the PLN is on or off does not affect the power quality of the inverter, this indicates that the PLN and the inverter work separately. Power quality from inverters and PLN have good power quality based on applicable regulations.

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