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Solar Panel Monitoring and Control System Using Human Machine Interface

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Abstract—The solar panel monitoring system based on the human machine interface is a system that can control and monitor the power generated by solar panels in the form of voltage, current, power, temperature, and solar radiation parameters in real time. PLC is used to monitor the panel work system in a long distance by utilizing PLC communication as an indicator of the reading status of the sensors used. As the interface between the PLC and the user, HMI is used. By using HMI visualization and technology a system can be made real. HMI is used to facilitate physical work and increase interaction between machines and operators through computer screen displays so that they can meet the information needed by users. The hardware used is a Programmable Logic Controller SIEMENS SIMATIC 1215C DC/DC/RL, Human Machine Interface SIMATIC KTP700 basic, ACS712, K type Thermocouple, and Pyranometer. Tia Portal software is used for programming and parameter setting of each system hardware.

Keywords: Solar Power Plant, PLC Siemens, Human Machine Interface, Monitoring System

1. Introduction

The use of New and Renewable Energy (EBT) has also started to become a trend in energy policy in all countries today. Energy has now become another need that goes hand in hand in the community, with the increasing number of people in Indonesia causing an increase in the amount of energy use. The supply of electricity in Indonesia will reach around 120 GW in 2025. To meet this demand for electricity, according to the National Energy Policy (Presidential Decree No. 5 of 2006) various alternative energies must be developed including renewable energy, including geothermal, micro-hydro, solar, wind, ocean, biomass and nuclear, which are targeted to reach more than 17% of the national primary energy share. Geothermal, hydro and micro-hydro have considerable potential to be developed, namely the maximum geothermal potential of 28.18 GWe, hydro of 75 GWe and micro-hydro of 450 MWe. To meet the demand for electricity in 2025, renewable energy resources that can provide significant support are geothermal, biomass (through waste, waste, gasification and biofuels) and solar through PLTS [7]. In the energy sector, one of the things that can be utilized from the high intensity of sunlight in Indonesia is to maximize the conversion of sunlight into electrical energy called solar panels. The solar panel consists of an arrangement of solar cells, as long as the solar panel operates under sunlight, solar radiation energy is converted into electrical energy and there is an increase in the temperature of the solar cells. Changes in the temperature of these solar cells are caused by temperature, cloud conditions and wind speed in the environment around the solar placement area. Therefore, it is necessary to use a monitoring tool to measure and monitor the current, voltage,humidity and temperature values of the solar panels [1]. Based on solar radiation data collected from 18 locations in Indonesia, solar radiation in Indonesia can be classified as follows: for the western and eastern regions of Indonesia with the radiation distribution in the Western Region of Indonesia (KBI) around 4.5 kWh/m^2/day with a monthly variation of around 10% and in Eastern Indonesia (KTI)

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around 5.1kWh/m2/day with a monthly variation of around 9%. Thus, the average solar radiation potential in Indonesia is around 4.8 kWh/m2/day with a monthly variation of about 9% [2]. *Programmable Logic Controller* or also called PLC is a *microprocessor* that is used to replace the many relay circuits that exist in conventional controls [3], [4].

The Siemens S7-1200 PLC is one of a series of controller devices that can be widely used for automation needs. The S7-1200 model is a Siemens PLC model of windows-based programming which is more flexible to use. The CPU of the S7-1200 consists of an integrated microprocessor with power supply, input and output circuits, PROFINET, and I/O controller [5]. HMI can control and monitor inputs and outputs, control modes and system indicators that will be displayed in real time through a screen interface [6]. The solar power plant monitoring system is designed using the HMI sinamic KTP900 which will display generator data in real time and as an integrated power plant control center. The data displayed on the HMI includes data on voltage, current, power, temperature and light intensity. The PLTS used for off-Grid operation is a 4KW Panel. Siemens S7 1200 PLC is used for data processing. Apart from being a monitoring center, the HMI can control the operation of the plant which is processed using a PLC. The purpose of this monitoring system is to increase system reliability, increase protection security, increase efficiency and performance of an electrical system. To carry out monitoring and control, the SCADA system has a Human Machine Interface (HMI) which functions as an intermediary between humans and machines.

2. Method

The tool design method in the final project is carried out in several stages, consisting of hardware design and software design. The purpose in designing this tool is to determine the constituent components of a tool or system that will be made so that it can solve problems during tool manufacture and get results that are in line with expectations. In Figure 1. The block diagram of the solar panel monitoring consists of a Human Machine Interface (HMI) and Programmable Logic Controller (PLC) which requires an input 24 Volt DC. The HMI used is the Simatic KTP 700 Comfort type, for the PLC using a Siemens S7 1200 1215 DC/DC/Relay PLC, for the connection between the HMI and the PLC using a LAN cable. The PLTS parameters that will be monitored include voltage, current, power, solar radiation on the surface of the solar panel and the temperature on the solar panel. The data of the parameters to be monitored is obtained from the sensor which is processed by the PLC and then displayed on the HMI screen. Monitoring these parameters can be used as a reference in designing a control system, but in this study the discussion is focused only on the monitoring system.

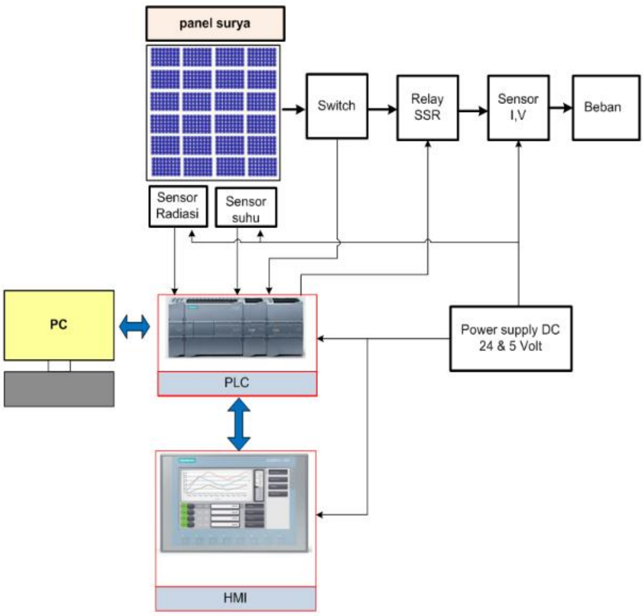

Figure 1. Solar panel monitoring block diagram

a. The solar panel is the object that will be monitored in this study. The solar panels used are 50 Wp polycrystalline solar panels, 6 units.
b. Current Sensor, which functions to detect the amount of current flowing from the solar panel to the load and is read by the PLC to display the data on the HMI. The current sensor used is ACS712 30A. This sensor generates an analog signal and is connected to the PLC analog pin.
c. Power supply, serves as a resource for all equipment used in this monitoring system. The power supply used has two output voltage levels, namely 24 VDC for PLC, HMI and irradiation sensors and 5 VDC for voltage, current and temperature sensors. The power supply source is taken from a 24 Volt battery which is regulated to remain constant at 24 Volt and 5 Volt.
d. Voltage Sensor, the voltage sensor functions to detect solar voltage and becomes input for the PLC to display its data on the HMI screen. The voltage sensor used is a voltage divider circuit with a measurement range of 0-25 VDC and this circuit will produce an analog voltage signal, so it will be connected to the PLC analog pin.
e. PC, is a medium used to intermediary Tia Portal software and PLC.
f. Temperature Sensor, a sensor that functions to measure the temperature around the solar panel. The temperature sensor used is a type K Thermocouple, where this sensor will produce an analog voltage signal and will be connected to the PLC analog pin to display temperature data on HMI.
g. The solar radiation sensor is used to obtain data on solar radiation that hits the surface of the solar panel. The radiation sensor used is PYR20 which will produce an analog current signal and will be connected to the PLC analog input.
h. PLC, functions as a data processing center in the monitoring system created in this study. PLC used is PLC S7 1200 type 1215C DC/DC/RL.
i. HMI, serves to display the data that will be monitored in this study. The HMI used is the KTP700 Basic HMI.
j. Solid State Relay (SSR), functions as circuit protection from overcurrent and also as circuit breakers and connectors ordered from the PLC. To activate this SSR, the activation terminal is connected to the PLC output digital pin.
k. Switch, Used to disconnect and connect the circuit. This switch is connected to the PLC input digital pin.

2.1 Hardware Design

Hardware design is very important in making this final project. Because with the hardware, it can be tested for real whether this tool can work properly or not. Figure2 shows the PLC mechanical design for the PV mini-grid monitoring system that will be made in this study.

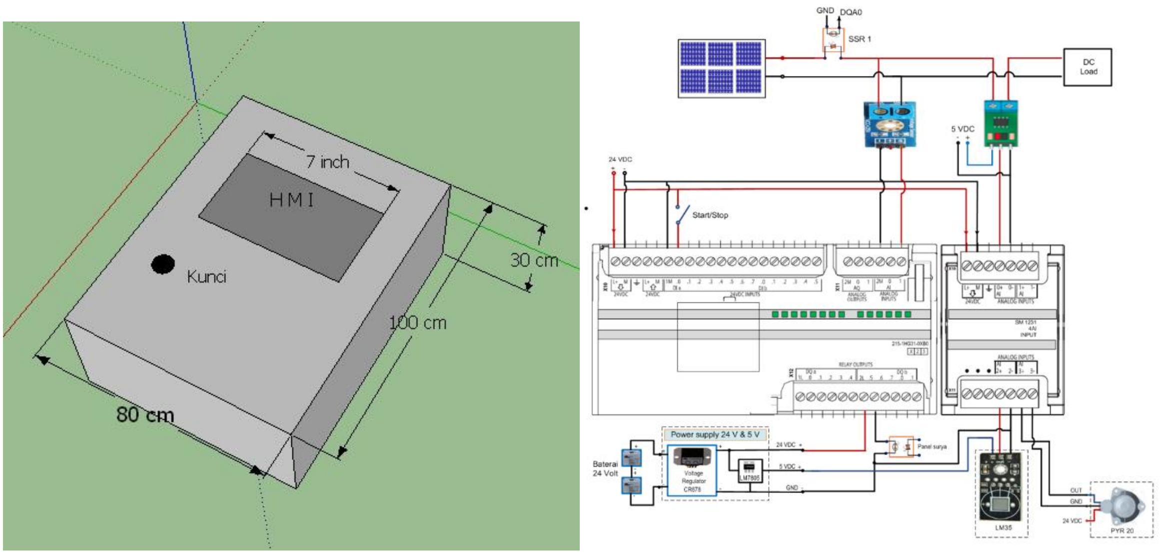

Figure 2. Mechanical and circuit design

Power supply, serves as a resource for all equipment used in this monitoring system. The power supply used has two output voltage levels, namely 24 VDC for PLC, HMI and irradiation sensors and 5 VDC for voltage, current and temperature sensors. The power supply source is taken from a 24 Volt battery which is regulated to remain constant at 24 Volt and 5 Volt. Solid State Relay (SSR), functions as circuit protection from overcurrent and also as circuit breakers and connectors ordered from the PLC. To activate this SSR, the activation terminal is connected to the PLC output digital pin. Switch, Used to disconnect and connect the circuit. This switch is connected to the PLC input digital pin.

2.2 Sofware Design

In designing this PLTS monitoring system using PLC as a microcontroller and HMI as an interface that will be programmed using software, namely Tia Portal. Tia Portal is the latest software from SIEMENS where PLC and HMI programming have become one in this software. By using the drags and drops feature of a tag that is in the PLC, the tags will be automatically generated into the HMI display. In designing this final project there is an interface using HMI (Human Machine Interface). There are 2 displays on the HMI, namely in the form of graphics and digital which will display the parameters of voltage, current, temperature, and light intensity. The HMI display as shown in Figure 3 is an HMI display design, but only graphic and digital parameters will be used.

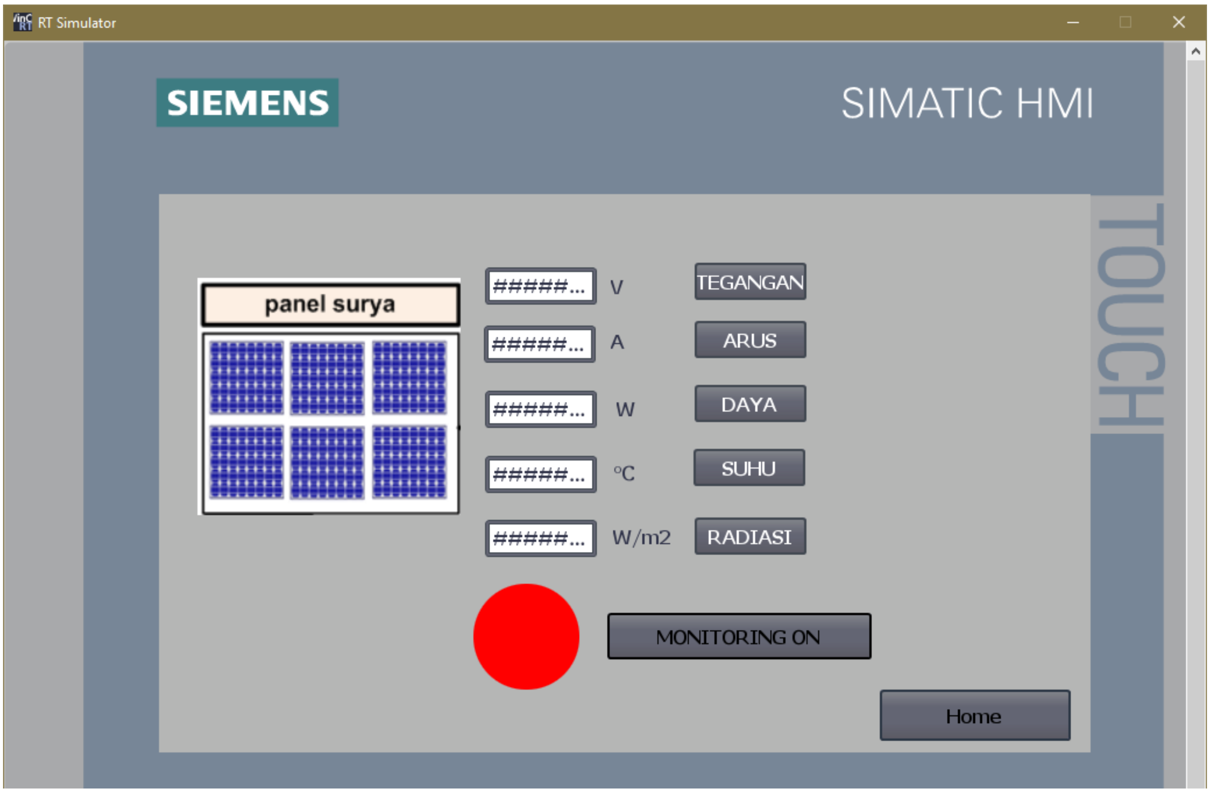

Figure 3. TIA Portal software HMI display

2.3 Flowchart

The design of software or microcontroller programming algorithms to monitor and protect PV mini-grid is presented in the form of a flow chart as shown in Figure. 5. This monitoring system will start working when the switch is activated and the start button on the HMI screen is pressed. Solid state relay (SSR) is also added to the circuit which functions to disconnect and connect the circuit. SSR will be active if the start button on the HMI is pressed and will disconnect if the OFF button on the HMI screen is pressed or if there is an overcurrent. Later the value of the overcurrent will be set according to the value of the short current from the solar panel.

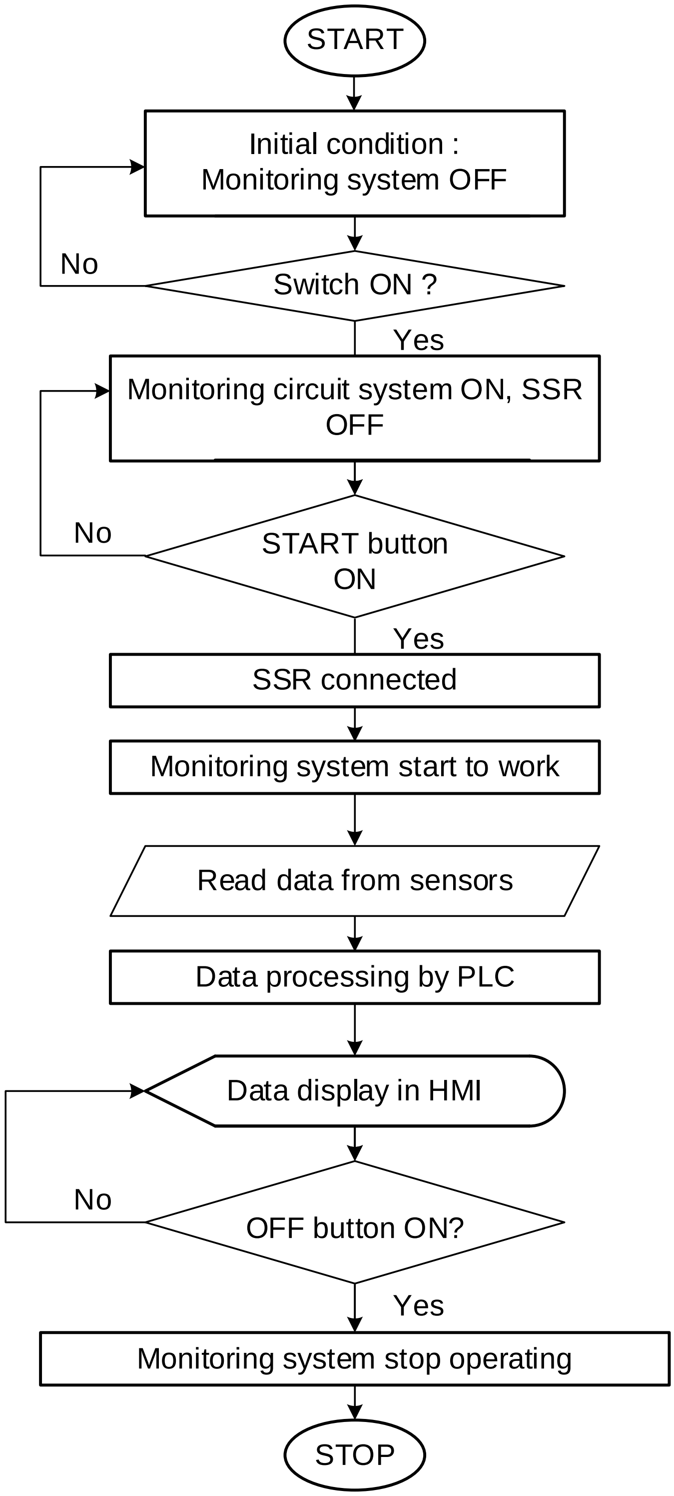

Figure 4. Flowchart

3. Result and Discussion

Testing the monitoring system for using PLTS based on Human Machine Interface which uses 4 sensors to detect voltage, current, temperature, and solar radiation. Tool testing is done manually to find out whether the tool is running well, with good reading accuracy. To compare the accuracy of the tool readings, a multimeter is used so that it can get the percentage error from the monitoring system that is made. The device consists of 4 sensors, where the current sensor and the voltage sensor is assembled in the Box Panel along with the CPU and Power supply. Meanwhile, the temperature sensor uses a thermocouple and the radiation sensor uses a pyranometer is assembled in the solar panel area. For the box panel device, see Figure 5 below.

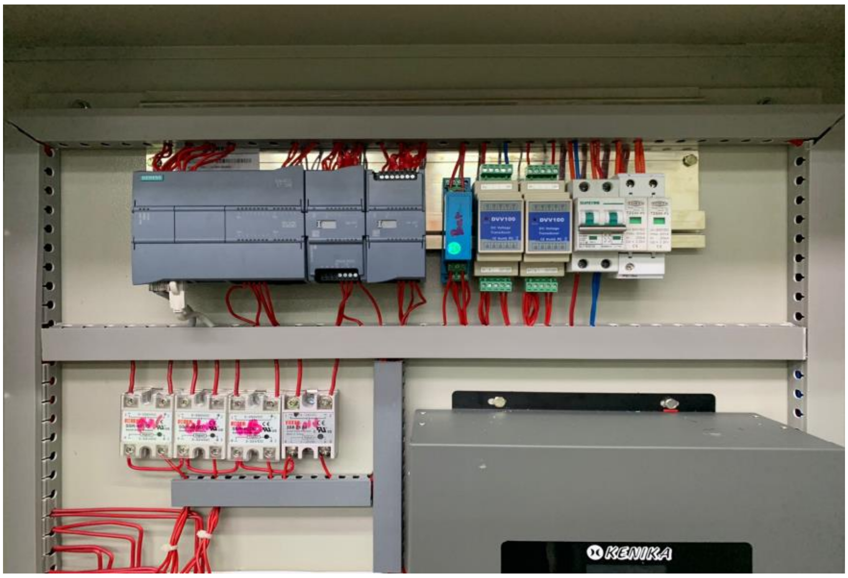

Figure 5. PLC wiring

The monitoring system testing is carried out in real time, in this study the Human Machine Interface is used which is designed with the Tia Portal application which can be simulated. The first step is to install the Tia Portal application, then run the PLCSIM Simulation after the program and ladder diagram have been created. After the PLC and HMI connections are successfully executed, the next step is to make HMI monitoring by utilizing serial communication between devices, each device has a different address. The following is the addressing of the tag on the PLC that will be used in this study can be seen in Table 1 below.

Tabel 1. PLC tag has been created

No	Name	Tag Table	Data Type	Address
1.	Start1	Default tag table	Bool	%I0.0
2.	Stop	Default tag table	Bool	%M0.1
3.	Running	Default tag table	Bool	%Q0.0
4.	Voltage	Default tag table	Int	%IW98
5.	Current	Default tag table	Int	%IW114
6.	Temperature	Default tag table	Int	%IW16
7.	Radiation	Default tag table	Int	%IW100
8.	AnalogTemp	Default tag table	Real	%MD104
9.	ScaledTemp	Default tag table	Real	%MD80
10.	AnalogVoltage	Default tag table	Real	%MD110
11.	ScaledVoltage	Default tag table	Real	%MD114
12.	AnalogCurrent	Default tag table	Real	%MD118
13.	ScaledCurrent	Default tag table	Real	%MD122
14.	AnalogRadiation	Default tag table	Real	%MD126
15.	ScaledRadiation	Default tag table	Real	%MD130
16.	ScaledEnergy	Default tag table	Real	%MD134

Interface that has been created will be online using the Tia Portal application. The designed interface utilizes the PROFINET PN/IE connection by making adjustments according to the selected process variables and also being able to read and write data to the PLC.

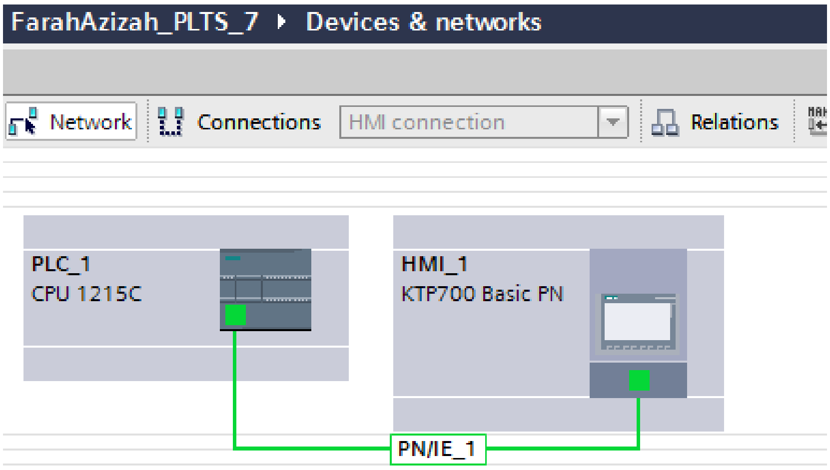

Figure 6. PLC and HMI connection

The solar panel control and monitoring system that has been made in the research is tested through PLC and HMI in the energy conversion laboratory. In the trial, monitoring data in real time is carried out, for the units of voltage and current on the HMI interface system are V and A. For the validity of the solar panel monitoring data, a multimeter and digital ammeter are used which are connected to a load resistor.

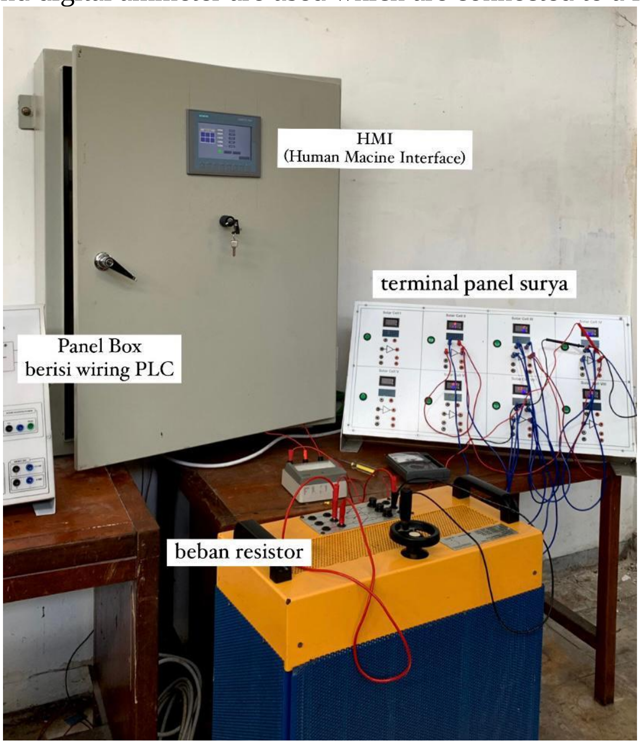

Figure 7. A series of PV mini-grid control and monitoring systems

Testing the PLTS monitoring system with HMI is carried out in real time at 4 pm with cloudy weather showing each input voltage, current, power, temperature, and solar radiation produced, which can be seen in Figure 8 below.

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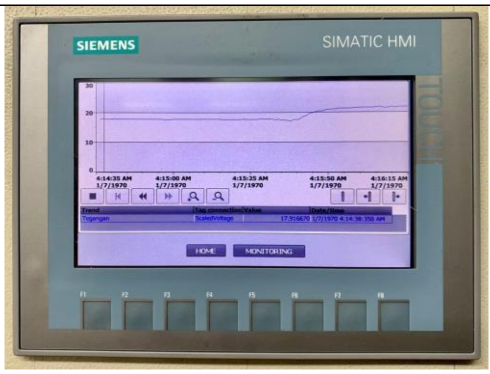
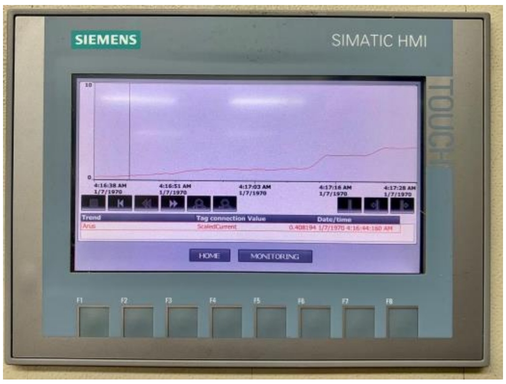
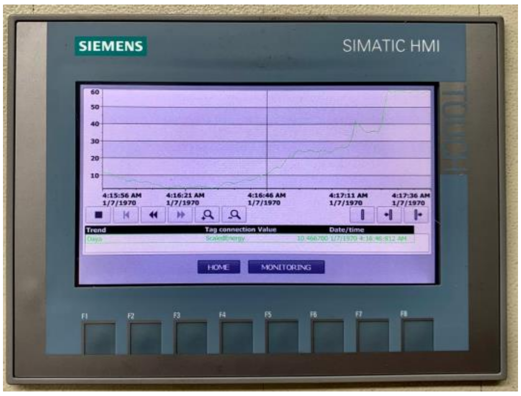
Figure 8. Real time monitoring PLTS

In the first test results using the HMI simulation shown in Figure 8, the results of the voltage, current, power, temperature, and solar radiation at 4 pm. The results of monitoring the voltage on the HMI are 15.5 V, current 2.9 A, power 45.12 W, temperature 49 °C. In the conversion of solar radiation, the result is that the current 3.3 A solar radiation at that time is 155 W/m2. After being measured using a multimeter, there is a difference between the output value the result is current 0.4 A and the voltage 0.9 V , the result of this difference may be caused by sensor error during communication delay between HMI and PLC. On the HMI monitoring screen the user can see a graph of each sensor used. With a click command on the HMI symatic screen, the interface will change to a graphic form, it can be seen in Tabel 1 below.

Tabel 2. Interface graphic HMI

No	Photo	Test Result
1		Based on the calculation of the analog signal given by the voltage sensor, the reading of the voltage value at 04:14 pm is 17 V
2		Based on the calculation of the analog signal given by the current sensor, the reading of the current value at 04:16 pm is 0,4 A

3		Based on the calculation of the analog signal given by the pyranometer sensor, the reading of the solar radiation value at 04:17 pm is 185.300 W/m2
4		Based on the calculation of the analog signal given by the sensor, the reading of the power value at 04:16 pm is 10.4 W.
5.		Based on the calculation of the analog signal given by the thermocouple sensor, the reading of the temperature value at 04:16 pm is 50 °C.

4. Conclusion

The design of the HMI-based PV mini-grid monitoring system is also controlled via PLC. This system is designed using a Siemens S7 1200 1215 DC/DC/RL PLC with interface a KTP700 Comfort HMI. The HMI can provide input voltage, current, power, temperature, and solar radiation sensors that are displayed in real time. In testing the control and monitoring of PV mini-grid, a multimeter is used for data validity. The test was carried out for 5 minutes. The results of the data obtained are that the control and monitoring of PLTS using HMI can run well, as evidenced by the sample data showing that the results of the sensor output displayed are close to the data generated by the multimeter measuring instrument. With the tool testing and getting data results, it proves that the HMI-based PLTS control and monitoring tool has been successful in controlling and monitoring PV mini-grid in real time and accurately.

Acknowledgment

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