PLC Controller Design of A Solar Powered Automatic Sprinkler System

by Gemmilang Surya

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PLC Controller Design of A Solar Powered Automatic Sprinkler System

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ABSTRACT— Solar energy is a renewable energy that utilizes photovoltaic (PV) to generate electricity. Solar panels are used in automatic plant sprinklers, which are strongly influenced by irradiation from the sun (w / m^2) to generate electrical power to activate the PLC device. The PLC device used in this study is the Zelio Smart Relay with type SR2B121JD which has 12 I / O and has a working voltage of 12 VDC, which functions to run the water pump in the watering system automatically. The experimental data collected in the form of solar panel power sourced from solar energy, the power that has been processed by the MPPT Controller, which supplies the PLC and water pump, PLC switching data and water discharge from the output of the solar pump. From the research that has been done, it is obtained direct power from PV with the highest average of 136.52 W and with the lowest average power of 9.25 W. The output power of the PV before becoming the power input for the PLC first passes through the controller so that the excessive or insufficient voltage does not cause damage to the PLC system. It produces the highest average power of 127.97 W and the lowest average power of 104.44 W. Automatic plant sprinklers tests are carried out with a programmable control system on PLC memory and running the water pump for 180 seconds on the tests automatically.

KEYWORDS: solar energy, photovoltaic, MPPT, PLC, automatic sprinklers.

1. INTRODUCTION

The use of renewable energy such as solar panels is not only for lighting needs, it can also be used for more applicable things, such as turning on a water pump to water plants. Solar cells or solar cells with small currents used to run a rotating machine will be overwhelmed, especially when the light as the main power is not maximal. The pump rotation of only 400 - 600 rpm will not able to carry water to the watering location. Watering plants is an important thing, especially in areas with hot climates, in order to maintain a green environment so that it is always beautiful. Whether or not a watering system that supports plant survival at the Student Council of AKIPBA Tanjung Enim, South Sumatra makes watering work done manually and using makeshift tools will be difficult and tiring. The solution that can be offered is to use an automatic watering system [6]. The equipment that supports a system so that it can run according to plan is needed to achieve design objectives according to the times, namely the automation of society. One of the devices or equipment in the electricity sector that supports the concept of automation is the Programmable Logic Controller [1], [5], before the existence of PLC, automation was also carried out by switching carried out by relays in conventional control systems. PLC is a processor or can be said as a controller capable of automating the process of automation in the industrial world. PLCs are able to run programs stored in memory to make connections with input and output devices [2]. Input and output devices are known as I / O in PLCs, the number also varies, depending on the size and type of PLC used [7], [12]. Indonesia's conditions that are traversed by the equator make the potential of this country's sunshine can be utilized as well as possible, one of which is activating Solar Panel (PV) to produce environmentally friendly electrical energy [13]. This electrical energy can activate various devices that support the construction of a system that can run independently and help various human jobs, for example, applied to watering and irrigation systems that require pumping. Pumping using automatic devices can be combined with the use of PV, provided that the voltage and current from the PV are in accordance with the needs of pumping devices such as electric motors and so on. Automation support devices such as timers and counters are added with conventional relays, microcontroller with censorship, mini PC or PLC to complement the pumping performance that can run automatically.

The control device chosen in this research is PLC, reliability in the field makes this device more suitable for use in environments that allow it to deal with extreme conditions. The advantages of PLC are concepts that can be easily applied because they are programmed based on an electric circuit or a relay circuit which is translated into a PLC ladder line. PLC can be a set of computers that can control industrial manufacturing processes, such as robotic systems, controlling electricity generation, and so on. Components attached to the PLC input, both sensors and switches, send command signals to activate internal relays and run pre-programmed processes. Prior to this research, PLC has also been used to manage the power of PV panels, namely by applying the principle of automatic transfer switch or automatic power transfer. The power consumption by PLC in this study is the result of regulated voltage by the charging controller system type MPPT 12/24 V with a maximum power of 500 W, as in several previous studies. The use of MPPT here aims to approach the maximum performance of solar panels and improve power efficiency so that it is stable when it is streamed to the PLC system with an efficiency level of up to 30% [10]. Energy storage for a standalone PV system designed to support automatic plant sprinklers with PLC mode uses a 12 V 45 Ah battery with a hybrid type [19]. The few input and output requirements are the reason for choosing a mini PLC type that has uncomplicated and straightforward programming, namely the Zelio Smart Relay 12 I / O mini PLC with the vendor type SR2B121JD working with 12 VDC direct current electricity. PV panels or solar panels used as power plants are a type of silicon with a monocrystalline type which is the highest efficiency PV on the market today. The PV power on each panel used is 100 Wp with a total of 2 units. If connected in series, the current will be constant and the voltage will increase. In contrast, if connected in parallel, the current will increase and the voltage remains, according to the needs, such as the power source circuit in general [16]. The voltage on the load and the battery is adjusted to the PV installation to be installed, 12 V at the load is the minimum voltage that the generator must supply so that the load can run optimally, here the load to be controlled and activated with the PLC program is an electric motor that has a flat voltage. The average 12 V with the power that must be received from the source is 180 Watt. Theoretically, if the power received by the load is less than the power input which is the electrical technical data listed on the name plate, if the load is in the form of a light lamp it will not be maximal or dim, and if the load is in the form of a driving force such as an electric motor the rotation that will be generated will not be maximal or slow. The purpose of the installation and the design plan will not be achieved if the load does not receive maximum power.

2. Design and Methods

The device design in this study consists of a PV buffer structure, a circuit in an electrical panel, and a scheme for pumping along with water piping and sprinkling. The initial design was the frame and frame for the solar panels and the posts on which the box panels were attached. Placement of MPPT, PLC, measurement media parameters, and test indicators are placed on the panel box. The configuration of the solar panel that is installed and supplies power for the PLC mode automatic plant watering system is a standalone type installation, which in this installation system must have a battery to support the performance of the automatic watering system, which must supply the PLC control system with the load of the pump drive motor. Energy storage is a primary requirement in this type of standalone solar panel installation, because in addition to backing up solar panels in system operation, batteries also play a role in storing the current and voltage received from the PV panel. Parameters of solar energy to be stored in the storage device must be on a safe scale so that the reliability of

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the energy storage device is maintained. Batteries as energy storage devices have different charging and discharging voltages depending on the type and type of battery used in the system being designed. The voltage that is applied to the battery poles as the charging voltage is 13.3 V to 14.4 V, if it is below this range it is called discharging and above or above, it will experience overcharging.

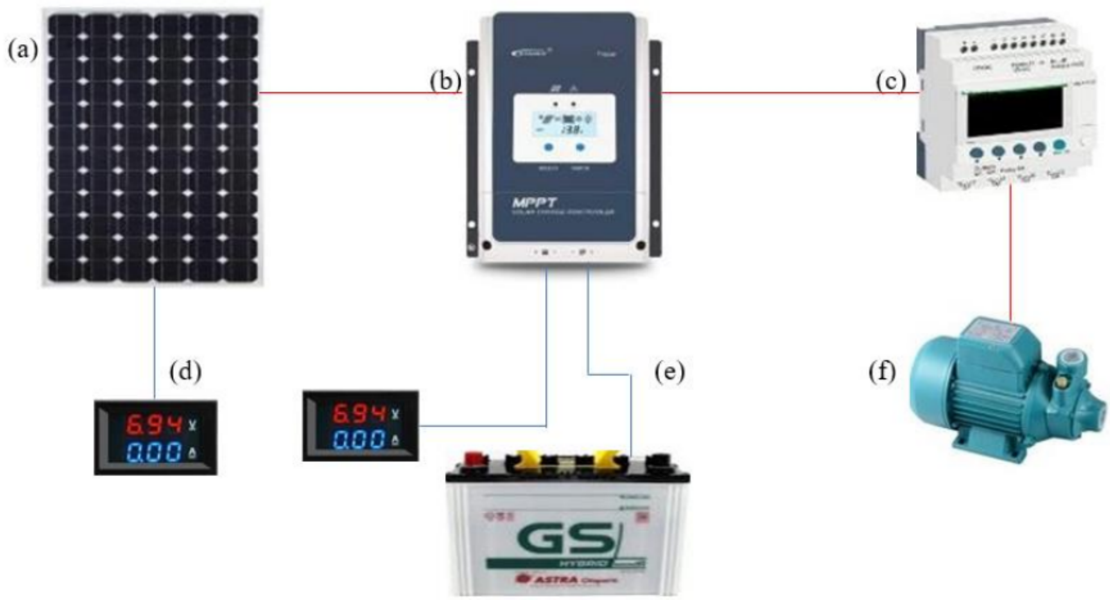

Fig. 1 Block diagram of PLC mode plant sprinkler system

Description:

(a) PV Panel
(b) MPPT Solar Charge Controller Epever
(c) PLC Schneider Zelio 12 I/O
(d) VA Meter
(e) Battery
(f) Water Pump

Previous researchers have carried out various experiments using PLCs and smart relays as controllers for designing automatic drive systems, including Arduino as a microcontroller with different programming lines from PLC and Smart relays [8]. In this study, the researchers designed an automatic plant sprinkler with solar energy controlled using a PLC. The use of PLC in previous research is not only for controlling electric motors but also as an automatic transfer of two different sources of electricity generation such as hybrid power generation technology. In addition to the use of switching in other studies, it has also been carried out in monitoring systems for charging and discharging VRLA batteries in off-grid installations or standalone solar power plants [11], [15]. The difference with previous researchers in applying the PLC device configuration in this research design is in the input and output elements and, of course, the program part that makes this device run control notation lines uploaded from the computer device to the module. Electric power from solar panels or PV is very dependent on sunshine conditions since the power input from the sun to the PV panels position is set as direct power. Solar panels receive direct light from the sun to make electrons move and generate electricity. The voltage and current of the solar panel are calculated using the following simple equation:

$$P_{PV} = V \times I = V_{PV} \times I_{PV} \qquad (1)$$

PLC operation is not recommended to use the direct voltage from the solar panel because the voltage scale of the solar panel can sometimes exceed the voltage required by the module. Here the performance of the MPPT solar charge controller is highly expected. MPPT adjusts the voltage according to the load requirements, including the PLC voltage requirements in this study to achieve maximum solar panel performance. The regulated voltage from the MPPT is what will be used to activate the PLC because the voltage regulation conversion of the solar panel has been adjusted to a scale that is not harmful to the module and the load. The voltage and current to generate power for the PLC from MPPT solar are calculated by the following simple equation:

$$P_{PLC} = V_{MP} \times I_{MP} = V_{PLC} \times I_{PLC} \qquad (2)$$

Experiments were carried out to obtain current and voltage data generated by solar panels, in the end getting direct power from the PV and the power that the MPPT has regulated to supply the PLC. The value of voltage and current according to the needs of the PLC or module will make the designed system run properly, in which the PLC activates the pumping system automatically with a ladder diagram uploaded by Zelio Soft. The design begins with planning to draw the placement of tools, both MPPT and PLC modules and other supporting devices, the MPPT Solar Charge Controller used is the MPPT Epever 12/24 V 20 A with dimensions large enough for a panel size of 300 x 400 x 180 mm. The dimensions of the MPPT Solar Charge Controller Epever Tracer 2206AN 20 A 12/24 V are 180.8 x 228 x 55 mm, much larger than the dimensions of the PLC module used, namely Schneider Zelio SR2B121JD 12 VDC with a size including small among other compact PLC's.

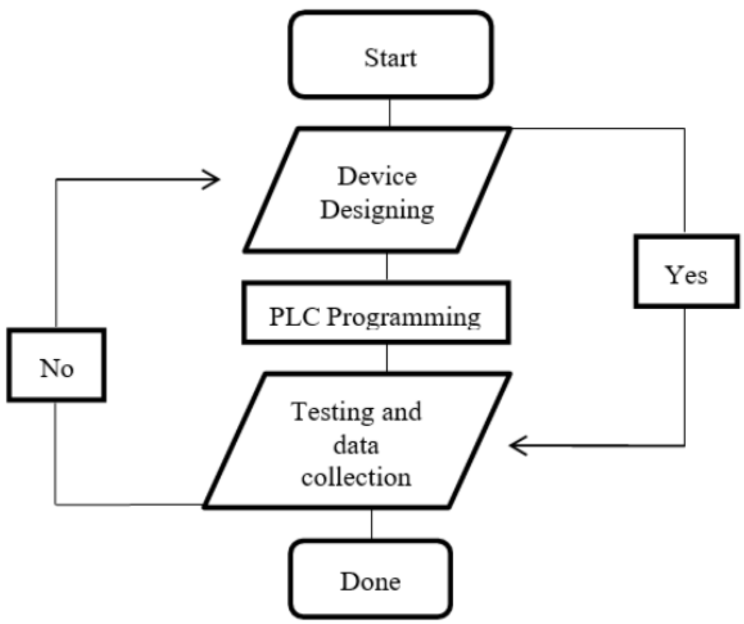

Fig. 2 System design flow

Doing something by starting to find new and innovative ideas is not easy, but with structured and organized planning, whatever will be built can be completed according to the initial plan and be successful during testing and in making an automated system design. PLC control that is applied to automatic plant sprinklers is not only about programming with computer applications and designing support structures, but the overall layout of the equipment and the electrical system must also pay attention to the function of each component, such as the water pump component and cable length. The PLC in the panel layout is positioned next to the MPPT Solar Charge Controller, which is connected directly to the solar panel. The electric panel is located under the solar panel frame to prevent the possibility of rain and not disturb the performance and reliability of the equipment inside the panel, which is full of electrical circuits.

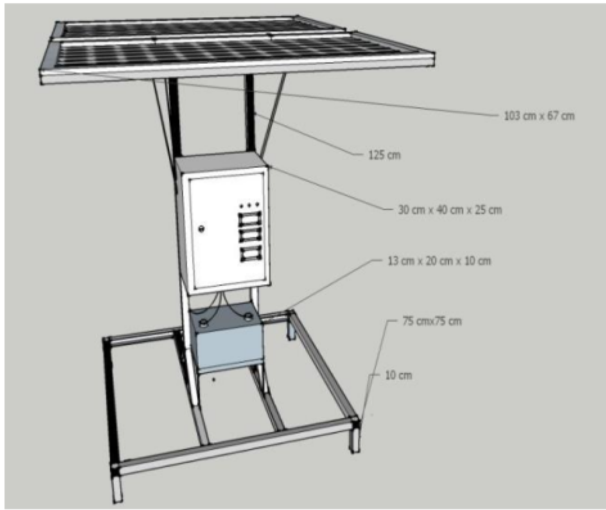

Fig. 3 The structure of the SPP system Standalone.

The construction of an automatic plant sprinkler system with PLC mode is built from a hollow steel frame 3x3 cm with a thickness of 3 mm. The part of the solar panel frame is designed and assembled with 3 x 3 cm angle iron according to the size of the solar module. The frame is made separately between modules so that the standalone PLTS configuration system can be moved easily for adjustment and improvement during testing. The overall placement of the solar panel installation and its accessories are positioned on the field close to the experimental area or watering location, except for the location of the solar pump or DC water pump, which is placed near the raw water reservoir, which will later be connected to a water channel in the form of a flexible pipe and at the end a divider is installed. Rotating water called sprinkle, which sprinkle is installed in two areas of the garden to adjust the garden area so that watering is evenly distributed. The motor that drives the watering system is the load with the largest power in this series, connecting the installation that is in the watering area and the water source on the panel cabinet, which is where the main circuit connects the pump with the PLC. The water pump is connected to the I / O PLC at the output.

The program on the PLC zelio smart relay has two choices of line models that can be transferred to the module, namely LD and PBC, LD or ladder diagram is a widely used program model, because it is almost similar to conventional electrical circuits which are easier to understand. Programming choices must pay attention to the function of the planned system, such as an automatic plant sprinkler system, which means that the program arrangement of the PLC software adapts to the installation conditions of tools and other devices. The zeliosoft application, which is compatible with zelio schneider PLC devices, has a simple interface, allowing users to be creative more freely in designing programmable control systems using I / O devices from PLCs and smart relays. The design of the ladder diagram sequence in this study is in accordance with the plan for the construction of an automatic plant sprinkler system, where the zeliosoft application will load the work sequence of the watering system when activated and can run automatically during the process and use renewable energy sources from the sun by utilizing solar panels or PV module. The PV module will supply solar energy, which has been converted into electrical energy into the solar charge controller installed in the electric panel box. The electrical energy that enters the charge controller will go through the steps of increasing efficiency and voltage regulation which will be adjusted to the needs of the PLC control device. The voltage in accordance with the specifications of the device will enable the device to be activated, including the PLC device, which will be able to run the programmed system by controlling other devices such as a water pump in the form of an electric motor attached to the output of the PLC device. The electric motor used by the water pump in the automatic watering system in this study is a 12-inch type solar pump with a working voltage of 12 V with an average power usage of 180 W.

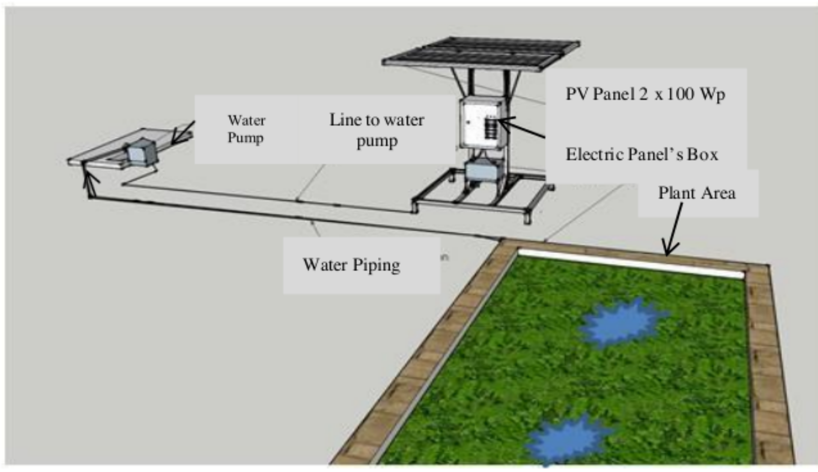

Fig. 4 Overall View of the Sprinkler System

The PLC device installed in the automatic plant sprinkler system is implanted with a program that supports the data retrieval process. The arrangement and sequence of the program lines are adjusted according to the duration and volume of recording the quantities to be obtained in this study. The quantities of electricity to be measured and used as research data in this study are the current and voltage from solar panels as the main source of electricity generation with environmentally friendly renewable energy. This data will be referred to as direct power data from PV, current and voltage from solar panels or PV are not used directly to activate the load on the circuit. Direct power from the PV is regulated in advance by the MPPT Solar Charge Controller to not interfere with the performance of the watering system with PLC mode. The voltage current from the MPPT, which is also used for charging the battery, is referred to as PLC power data. Mechanical data such as active PLC contact data and water discharge were also recorded into research data as secondary data.

3. Results and Discussion

The manufacture of the plant sprinklers begins with assembling the frame and installing all the tools, including PV. Based on the block diagram in Fig. 1, the electrical circuit from PV to the active water pump as a water carrier from the reservoir to the watering area. The system test will automatically perform watering at scheduled times according to the PLC ladder diagram line, outside of schedule the PLC will not activate the water pump to do the flushing. The whole range of tools consists of a PV connection to the MPPT Solar Charge Controller, from the MPPT connected to two important devices, namely a PLC and a battery as energy storage that will support the performance of the solar panel when solar conditions are not optimal, the electric motor used as a water pump is connected to I / O PLC with NYM cable in order to make it stronger and not easily broken due to underground installation.

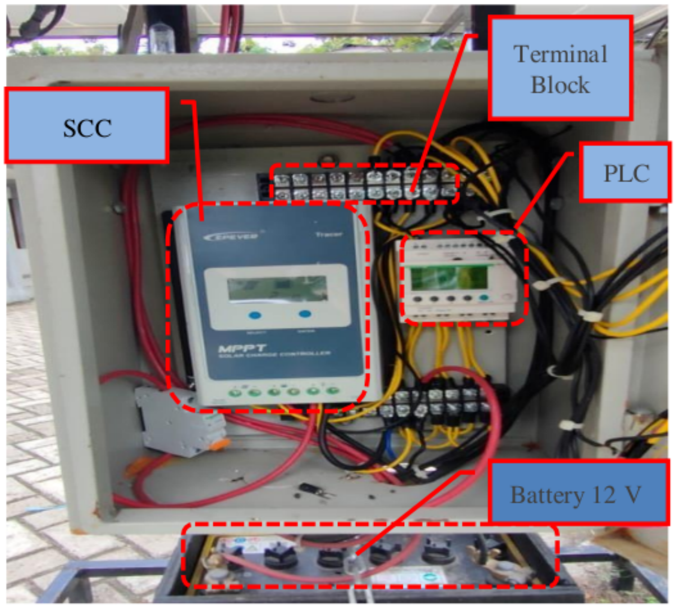

Fig. 5 The circuit in the Box Panel

Fig. 5 shows all the equipment that has been installed in the electrical panel. Before data collection is carried out, tests are first carried out on all the equipment installed. It is necessary to ensure that the circuit conditions have been connected between devices correctly in order to avoid malfunction and damage to the equipment. The test begins by activating all the equipment that is the reference in data collection. The current and voltage measuring instrument must always be ready to make measurements, whether it is direct power from the PV panel or power or current and voltage to be supplied to the PLC circuit. The data collection was carried out for 30 days. The watering system installed in the AKIPBA hostel in Tanjung Enim, South Sumatra, was active in watering with a period of 08.00 - 16.00 WIB, from morning to evening, the sun conditions were always different and it was necessary to collect data every hour to ensure performance. Solar panels in the process convert solar energy into electricity which is utilized by this automatic plant watering system with PLC mode. The solar energy indicator is measured by a solar power meter, the magnitude or sub-data of the research that is recorded is irradiance data or the ability of sunlight to affect PV to produce electricity. The maximum irradiance is when the sun's light is at its peak, which is when it's hot, low irradiance is when the sun is dim, covered in clouds and when it rains. Irradiance from the sun will affect the voltage generated by PV. High irradiance makes the voltage on the solar panel will also increase to a maximum level in conditions of open circuit or not connected to the load. A voltage that is too large will make the PLC not work because the voltage generated by the solar panel does not match its specifications, charging the battery voltage in storing energy cannot be done if the direct voltage from the solar panel exceeds the capacity or the charging voltage of the battery. on the load side, this can happen, be it lamp loads, electric motors, and others as having a limit on the ability to accept voltage from an electric power generation system including solar power plants. Any equipment that operates on electricity will experience interference if the electrical energy it receives exceeds its capacity, such as a lamp that will break or even worse.

Based on data analysis that has been obtained during the study, which took place from September 10 to October 9, 2020, the direct power of the solar panels is regulated by the charge controller and has been proven to activate the PLC to control automatic plant sprinklers that operate for 180 seconds each hour during the data collection process. The water pump can carry water from the reservoir to the watering area with electricity from the PV via the MPPT charge controller which is also powered by battery power.

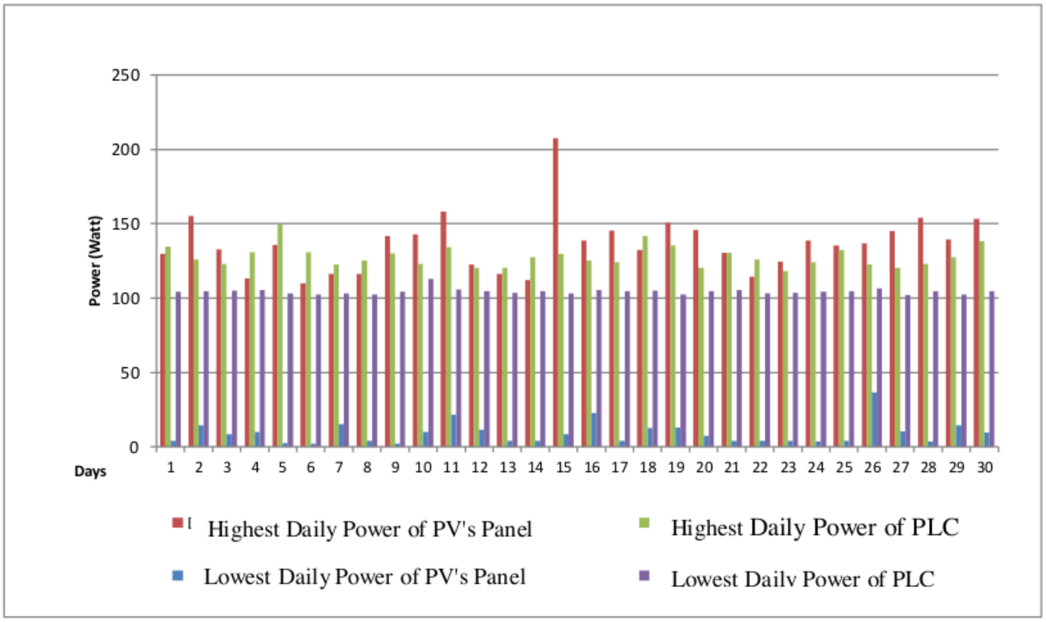

Fig. 6 Solar panel power production September 10th - October 9th, 2021.

For 30 days of observation and experiment, it was found that the conditions were changing in the power generated by the solar panels. The intensity of the sun affects the power production of solar panels, on a day when the sun is so hot on the 15th day of the study. It can even exceed the input power of PV, which is at 207.48 W, and the power that MPPT can maximize to activate the PLC is always stable above. 100 W. The lowest solar panel power was recorded on the 6th day of data collection, in rainy conditions in the number 2 W only.

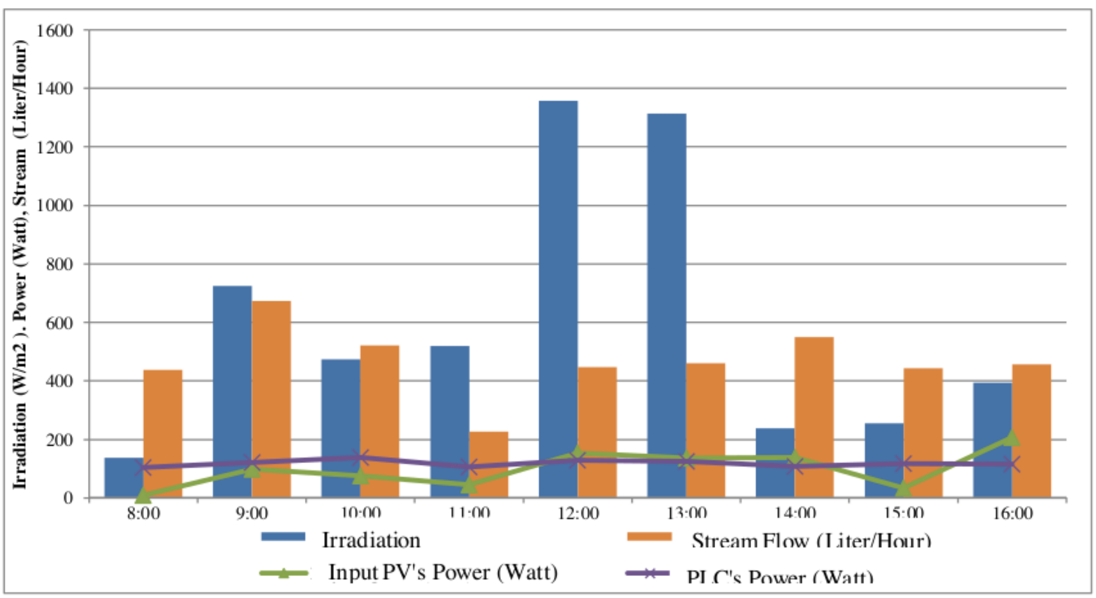

Fig. 7 Data of the automatic sprinkler system October 9th, 2020

The description of the analysis of the research results shown in Fig. 7 shows the comparison when the automatic watering system with PLC mode operates, as a whole, the solar irradiation value shows that at midday it is indeed the peak of the sun's light intensity. The blue bar in figure 7 is an indication that every hour of the sun always emits a different irradiation, if the day is always sunny from 08.00 to 16.00 it will show a normal curve, but cloud conditions always move at any time which at certain hours also cover the sun and affect the W/m2 conditions of solar irradiation. The power produced during the solar power generation system is direct current power which is measured using a VA meter installed on the panel door with a number of 2 units, measuring the current and voltage generated by PV directly and measuring the voltage current, which is the result of regulation from MPPT Solar Charge Controller and is used by the PLC to activate the automatic control system on the watering system. The voltage generated by the solar panel is monitored always to fluctuate even drastically every hour the recording of research data can be seen in the graph in Figure 7, the power generated when a water pump burdens the system shows a line pattern that always curves downward when irradiation is at a low point and curves upwards at when the sunlight is hot at midday, in contrast to the power to be used by the PLC it looks stable and does not fluctuate drastically as long as the solar power generation system used as power supply for this automatic plant sprinkler system operates. The stream flow of water (Liter/Hour) is generated by the water pump attached to the output side of the PLC using the power from the MPPT solar charge controller the same as the power used by the PLC, in Figures 7, you can see the stream flow of water coming out of the hose connected to it. The sprinkle sprays water on the plants with a different flow rate at each operating hour.

The program on the PLC contains the work process of an automatic plant sprinkler system, the ladder diagram in this study uses an internal input from the PLC Schneider Zelio SR2B121JD, which is a clock input that can schedule an active watering system every hour according to the data retrieval plan. After the clock activates the circuit, the next step is the timer and internal relay that will turn on the water pump system for 3 minutes every hour from 08.00 - 16.00 WIB. The output side of the PLC is active alternately, namely Q1 and Q2 every hour which is regulated by the input clock as shown in table 1 below.

Table 1. The work process on the PLC ladder diagram

No	Input	Clock	Output	Explanation
1	Clock (C1)	08.00	Q1	The pump is active for 3 minutes
2		09.00	Q2	The pump is active for 3 minutes
3		10.00	Q1	The pump is active for 3 minutes
4		11.00	Q2	The pump is active for 3 minutes
5		12.00	Q1	The pump is active for 3 minutes
6		13.00	Q2	The pump is active for 3 minutes
7		14.00	Q1	The pump is active for 3 minutes
8		15.00	Q2	The pump is active for 3 minutes
9		16.00	Q1	The pump is active for 3 minutes

Table 1 provides an overview of a PLC-controlled process, where the output will only be active when the contact gives a signal to the I / O to work. The PLC input in table 1 is an internal input contained in the PLC memory without hardware connected to the input side from outside the PLC. PLC input settings in this study, as shown in Fig. 8, are set according to the watering schedule carried out by this automatic sprinkler system.

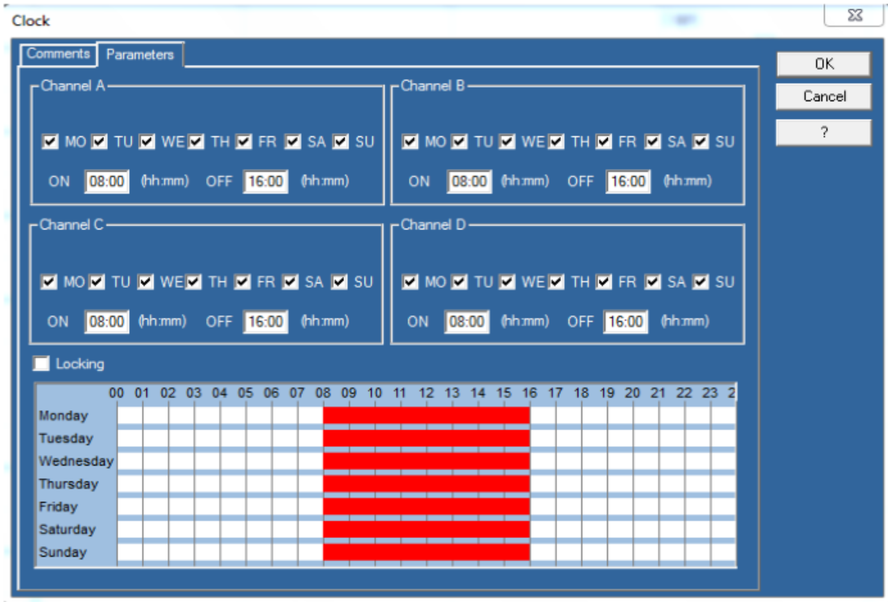

Fig. 8 Setting the Clock Input on the PLC

The purpose of the active pump for 3 minutes is to give the researcher time to record all data components, given that the distance between the generator to the water pump is quite far, which is about 30 m, and the flow meter is close to the pump. The timer will calculate the operating time of each output, both Q1 and Q2. For 3 minutes, the timer will provide an opportunity for Q1 to be active first, the next hour, the timer will do the same thing on Q2 output to be active for 3 minutes, and so on until 16.00 WIB and actively repeats the same process at 08.00 WIB the next day. The work process of the automatic sprinkler system in PLC mode using this solar energy as the timing chart in Fig. 9.

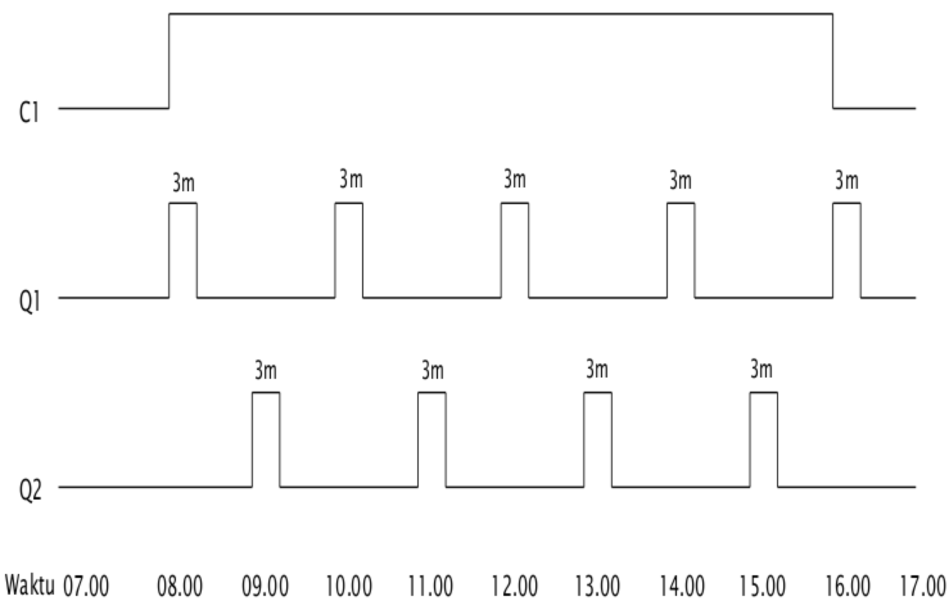

Fig. 9 Timing Chart on the watering system work process

4. Conclusion

The actual use of PLC in control systems is to replace systems that cannot run automatically. Renewable energy is very attractive to be developed and used for generation in automatic plant sprinklers. The data in this study were taken and recorded from 10 September - 9 October 2020. This watering system that utilizes a PLC device is installed on the front page of the AKIPBA Tanjung Enim student mess, South Sumatra. As long as it is installed and operating, the automatic plant sprinkler system had carried out and replaced watering tasks that were not necessarily done routinely when this tool was not installed. The results showed data regarding the importance of sunlight with sufficient irradiation for PV to generate useful electrical energy in an automatic plant sprinkler system with PLC mode to operate optimally.

5. Acknowledgments

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