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Design of Programmable Logic Controller (PLC) on Smart Fertilizer Distribution System

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A B S T R A C T

The control system in agriculture is an important study to regulate the application of fertilizers to plants. The control system can use PLC control system which has good system robustness and easy program language. The purpose of this research is to design a simulated fertilizer irrigation system based on a programmable logic controller (PLC) system. The PLC program used is CX-program and the simulator circuit uses Fluidsim simulator. The system components used are the main reservoir, pump, solenoid valve, valve, level sensor, and light indicator. The system is organized by dividing inputs and outputs that are directly integrated into the PLC system. The components are arranged using fluidsim and the PLC control system using CX-Programmer using ladder logic language. The control system integration and system circuitry are connected using KeepServerEX. The output of this system is a successful operation function and a digital system response to the time of the system. From the results of the system response provides a fairly good timeliness so that this irrigation system can be considered in the implementation of fertilizer delivery system

INTRODUCTION

The application of fertilizer to plants plays a very important role in agriculture. The application of fertilizers provides an increase in agricultural production with the addition of supplemental nutrients (Rehman et al. 2022; Roidah 2013). However, the application of nutrients must be in accordance with the appropriate amount and concentration. Applying fertilizer to plants in inappropriate amounts and concentrations will cause adverse effects on plants and the environment. Reported in relation to world problems summarized in the Sustainable Development Goals (SDGs), the inaccurate application of fertilizers can damage environmental ecosystems (Krasilnikov, Taboada, and Amanullah 2022) (Lin et al. 2019). In addition, the utilization of clean water as a fertilizer mixture needs to be considered in order to avoid water wastage. For this reason, appropriate technology is needed to control fertilizer application efficiently and effectively.

The development of increasingly advanced technology in the era of the industrial revolution 4.0 provides increased efficiency and effectiveness in helping community activities (Dayioğlu and Türker 2021). With this technology, farmers are able to reduce the burden of performance in applying fertilizer or monitoring plants. Fertilizer application to plants can be done with an irrigation system, which is a fertilizer irrigation system to plants that are flowed through pipes. (Abashar, Mohammedeltoum, and Abaker 2017).

The irrigation process in this research is done with a dripping system. However, this irrigation system requires an automatic control system capable of working with a system that is regulated as needed.

Control systems that have been developed today are microcontrollers, such as Arduino, raspberry phi or ESP. (Eridani, Wardhani, and Widianto 2017). Each of these microcontrollers has its own advantages and has the same function, namely the control system. However, these microcontrollers have the disadvantage of being less able to integrate complex systems and a less extensive scope of use. For this reason, a possible control system is a control system with programmable logic control (PLC).

PLC is a hardware device used in industrial automation and process control (Saurav Vats, Neha Bansal, Garima Gurjar, Saurabh Kamat 2017). This system has I / O modules that are directly connected to sensor or actuator components and operated in the CPU. The advantages of PLC compared to microcontroller systems are good system robustness, flexibility of system design with young languages and equipped with data communication systems that can be monitored in the human machine interface (HMI). (Hanif, Mohammad, and Harun 2019). The disadvantage is that the price is quite expensive. For this reason, before hardware experiments are carried out, a simulation system is carried out to maximize the time efficiency of installing the system into the PLC ((Raja and Professor 2018). The purpose of this research is to design a simulated fertilizer irrigation system based on PLC control.

METHODS

System Simulator

PLC program design using CX-programmer (Omron) and CX-Simulator to simulate the ladder program. Because the PLC control system is in simulation, the irrigation system is schematically arranged in Fluidsim Hydraulic ver5 software (Festo). For integration between Fluidsim and CX-program is connected with KeepServerEX software.

Components

The selection and number of irrigation system components are based on field data in the Greenhouse of Sumatera Institute of Technology. The plants that are the object of control are melon plants. The irrigation system components consist of 1 main reservoir containing a mixture of fertilizer and water from the well equipped with 2 level sensors, 2 water pumps used for water jetting with pressure, 6 solenoid valves used to open / close the water jetting in the pipe, 1 discharge sensor and 8 indicator lights fertilizer up to the plant.

Fertilizer Irrigation System

The schematic of the fertilizer irrigation system is shown in Figure 1. The main reservoir will be filled with a mixture of water and fertilizer with the volume of water determined by the upper limit level sensor. The fertilizer mixture is flowed using pump 1 to measure the nutrient level criteria with the fertilizer review sensor. Because this system is simulation-based, the review sensor is considered to have met the criteria so that it is directly flowed with pump 2. To regulate the discharge rate, it is measured by the discharge sensor and controlled by the opening of the solenoid valve.

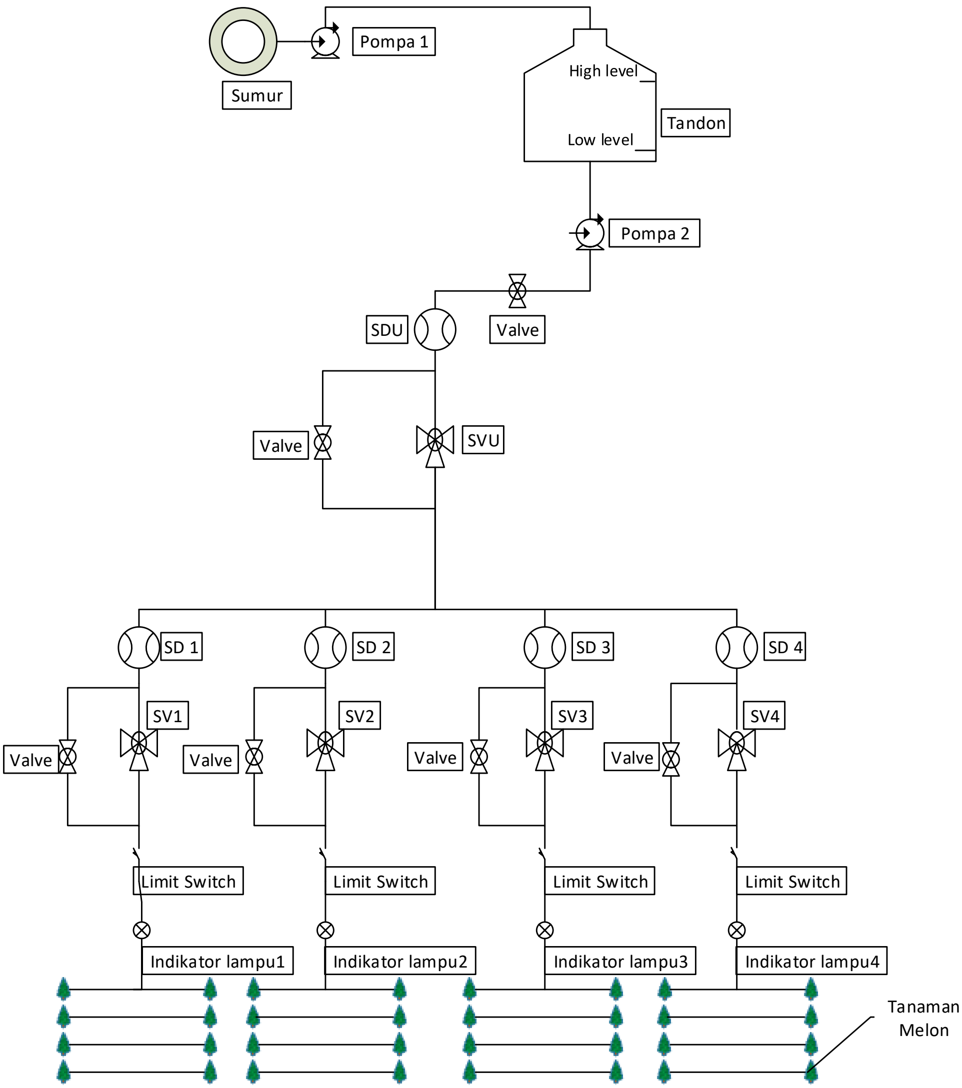


Figure 1. Design Fertilizer Irrigation System

From this system, the control concept is designed using PLC. This control system is shown in Figure 2.

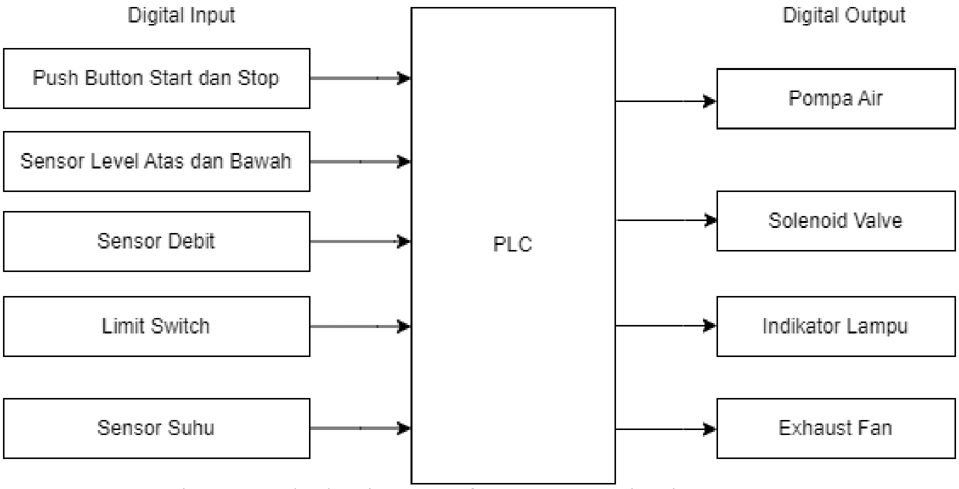
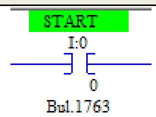
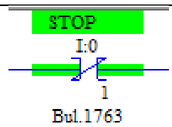
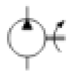
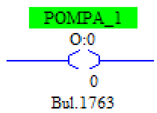
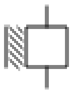
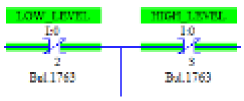
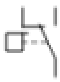


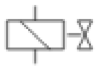
Figure 2. Block Diagram of PLC Base Irrigation System

Ladder Programming

The language system of the PLC is a ladder logic language that uses a digital base. The conversion of irrigation system components to ladder logic is shown in Table 1.

Table 1. Convert Irrigation System to Ladder Logic

No	Comp	Schematic	Ladder
1	Push button start		
2	Push button stop		
3	Pompa air		
4	Sensor level		
5	Sensor debit		

No	Comp	Schematic	Ladder
6	Selenoid valve		

This ladder logic conversion component will be assembled to PLC programming and carried out the concept of irrigation system control logic shown in Figure 3. From the system, the input and output parts are divided as shown in Table 2 along with the system address integrated into the PLC system. The results that will be shown during simulation are time domain digital signals to show the accuracy of the system response.

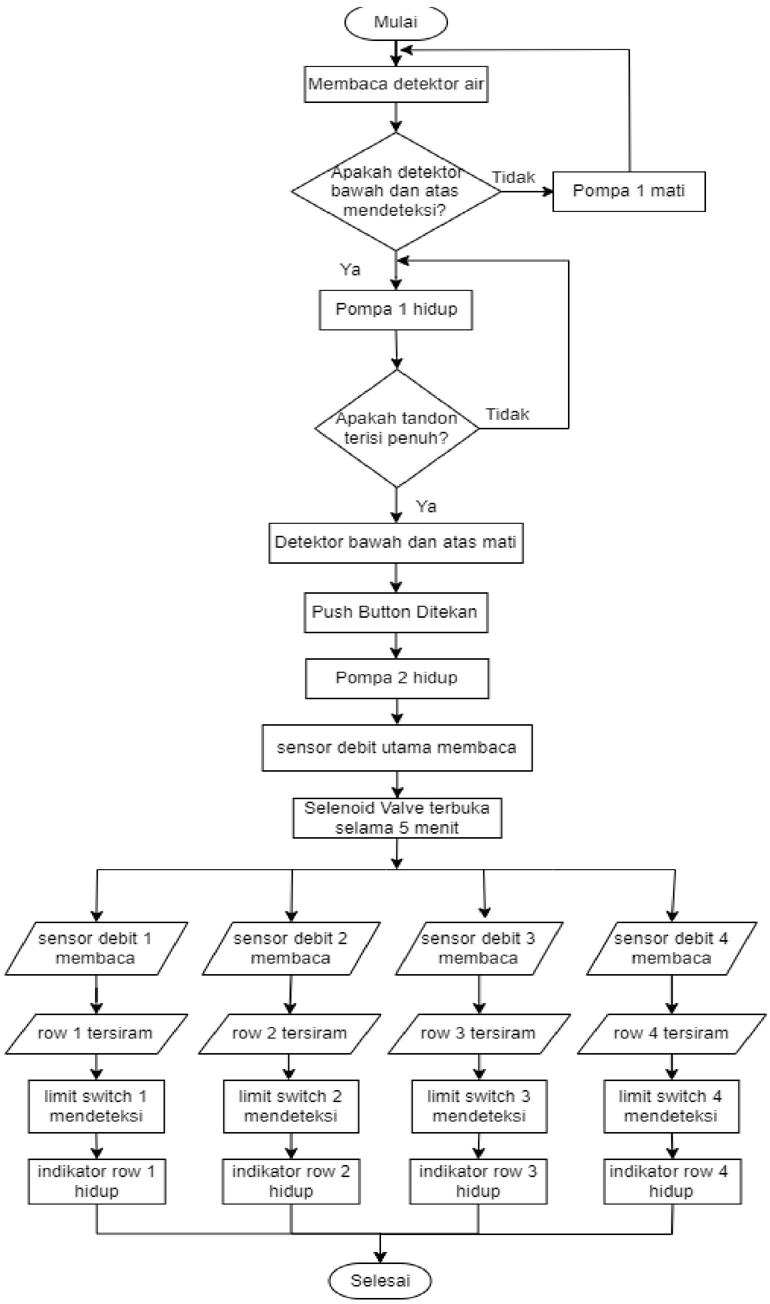


Figure 3. Flow Chart of Irrigation System

Table 2. Address of Input Components on a PLC

No	Input	Addresing	Captions
1	*Push Button Start*	I:0.00	Turn on system
2	*Push Button Stop*	I:0.01	Turn off system
3	Low level sensor	I:0.02	Monitors the water level in the reservoir when it is at a low water level or minimum limit and as a condition to start pump 1 to fill the reservoir.
4	High level sensor	I:0.03	Detects the reservoir is at a high water level or maximum limit and as a condition to turn off pump 1 so as not to drain excessive water.
5	Debit Sensor 1	I:0.04	To measure the flow rate and deliver nutrient water with a precision of 12000 ml in order to open and close the solenoid valve on row 1.
6	Debit Sensor 2	I:0.05	To measure the flow rate and deliver nutrient water with a precision of 12000 ml to open and close the solenoid valve on row 2.
7	Debit Sensor 3	I:0.06	To measure the flow rate and deliver nutrient water with a precision of 12000 ml to open and close the solenoid valve on row 3.
8	Debit Sensor 4	I:0.07	To measure the flow rate and deliver nutrient water with a precision of 12000 ml to open and close the solenoid valve on row 4.
9	Main Debit Sensor	I:1.00	To measure the flow rate and deliver nutrient water with a precision of 48000 ml so as to open and close the main solenoid valve of the irrigation system.
10	Limit Switch 1	I:1.01	Limit switch 1 detects the final position of the nutrient water in row 1 and initiates the system to turn on the SV1 indicator light.
11	Limit Switch 2	I:1.02	Limit switch 2 detects the final position of the nutrient water in row 2 and initiates the system to turn on the SV2 indicator light.
12	Limit Switch 3	I:1.03	Limit switch 3 detects the final position of the nutrient water in row 3 and initiates the system to turn on the SV3 indicator light.
13	Limit Switch 4	I:1.04	Limit switch 4 detects the final position of the nutrient water in row 4 and initiates the SV4 indicator light.
14	Main Limit Switch	I:1.05	Main Limit switch to detect nutrient water that has reached the SDU setpoint to initiate turning on the SVU indicator light.

Table 3. Address of Output Components on a PLC

No	Comp	Address	Caption
1	Pump 1	Q:100.00	As a motor to drain water from the well to the reservoir
2	Pump 2	Q:100.01	As a motor to drain nutrient water from the reservoir to the plants
3	*Selenoid Valve* 1	Q:100.02	To regulate the flow by opening and closing the water flow to the irrigation drip based on the setpoint on the row 1 discharge sensor.
4	Selenoid Valve 2	Q:100.03	To regulate the flow by opening and closing the water flow to the irrigation drip based on the setpoint on the row 2 discharge sensor.
5	*Selenoid Valve* 3	Q:100.04	To regulate the flow by opening and closing the water flow to the irrigation drip based on the setpoint on the row 3 discharge sensor.
6	*Selenoid Valve* 4	Q:100.05	To regulate the flow by opening and closing the water flow to the irrigation drip based on the setpoint on the row 4 discharge sensor.
7	*Selenoid Valve* Utama	Q:100.06	To regulate the flow by opening and closing the water flow to the irrigation drip based on the setpoint in the overall irrigation system.
8	SV1 Indicator	Q:100.07	To signal that the nutrient water has flowed to the end of row 1.
9	SV2 Indicator	Q:101.00	To signal that the nutrient water has flowed to the end of row 2.
10	SV3 Indicator	Q:101.01	To signal that the nutrient water has flowed to the end of row 3.
11	SV4 Indicator	Q:101.02	To signal that the nutrient water has flowed to the end of row 4.
12	SVU Indicator	Q:101.03	To signal that the nutrient water has drained the entire row.

RESULTS AND DISCUSSION

The results of the irrigation system electrical circuit are depicted in Fluidsim on a PLC basis. The most important thing is to connect the input and output pins with the irrigation system components. Figure 3 shows the display of the PLC-based irrigation system in Fluidsim.

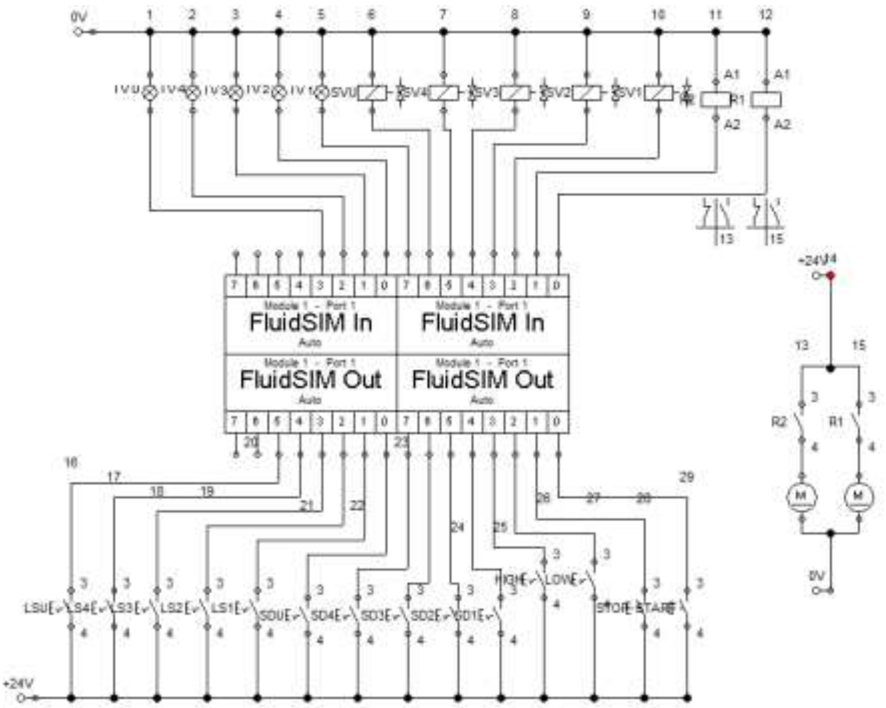


Figure 3. Schematic of PLC Base Irrigation System

Ladder Logic Visualization

The results of the irrigation system design on the PLC are given by dividing each system procedure as follows:

1. Filling well water to liquid fertilizer in the reservoir. To know the volume of fertilizer mixture, a level sensor is given. This system is shown in Figure 4.

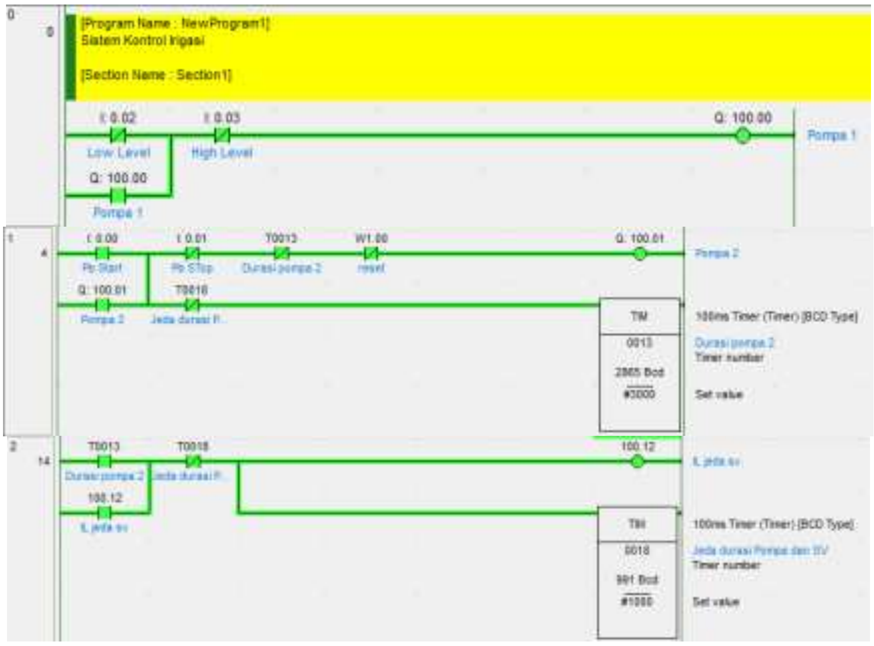


Figure 4. Ladder logic for level sensor on well

1. When the mixture is ready, pump 2 will flow the fertilizer into the pipe and measure the discharge rate with a discharge sensor. This system is shown in Figure 5.

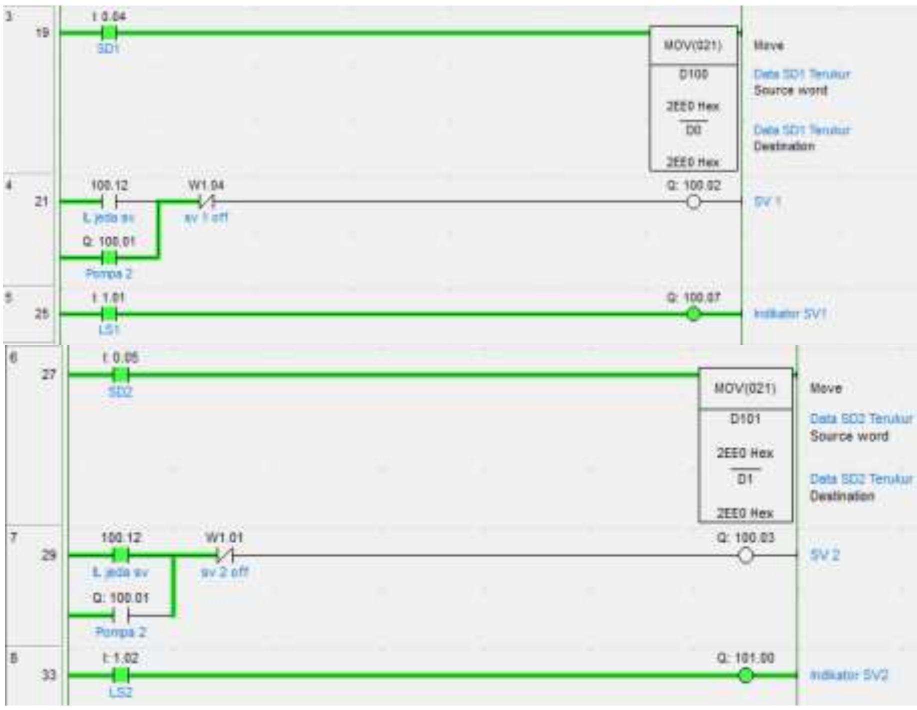


Figure 5. Ladder Logic for Water Flow to the Pump

2. Row 4 has a debit sensor input 4 with address I:0.07 and MOV output with address D103. Where MOV contains the setpoint of 12000 ml serves to move the data generated by the discharge sensor 4. by the discharge sensor 4. From the specified setpoint value, it can turn off the solenoid. valve 4 with address Q: 100.05 and when the nutrient water has flowed to all plants, the limit switch 4 with address I: 1.04 will be detected. plants then the limit switch 4 with address I: 1.04 will be detected and turn on the light indicator on SV4 with address Q:101.02. This system is shown in Figure 6.

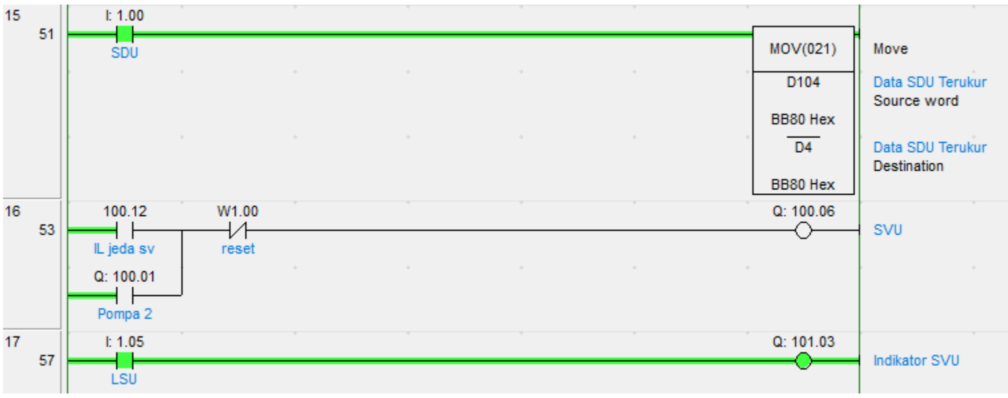


Figure 6. Ladder Logic for Water Flow to the Pump to Plant

Sensor Data Reset there is a greater than (GRT) sensor data main discharge sensor, discharge sensor 4, discharge sensor 3, discharge sensor 2, and discharge sensor 1. This GRT is a comparison between the actual value and the specified setpoint value, source A is the actual value read on the discharge sensor and source B is the setpoint value. The GRT in the rung above produces a reset output with address W1.00 which functions to reset the sensor data every day. This system is shown in Figure 7.

Figure 7. Ladder Logic for Reset System on Sensor

The signal response of the components is shown in Figure 8. The response results show that the system of each component provides a good function with accurate timekeeping. The accuracy of each component is shown in Table 5.

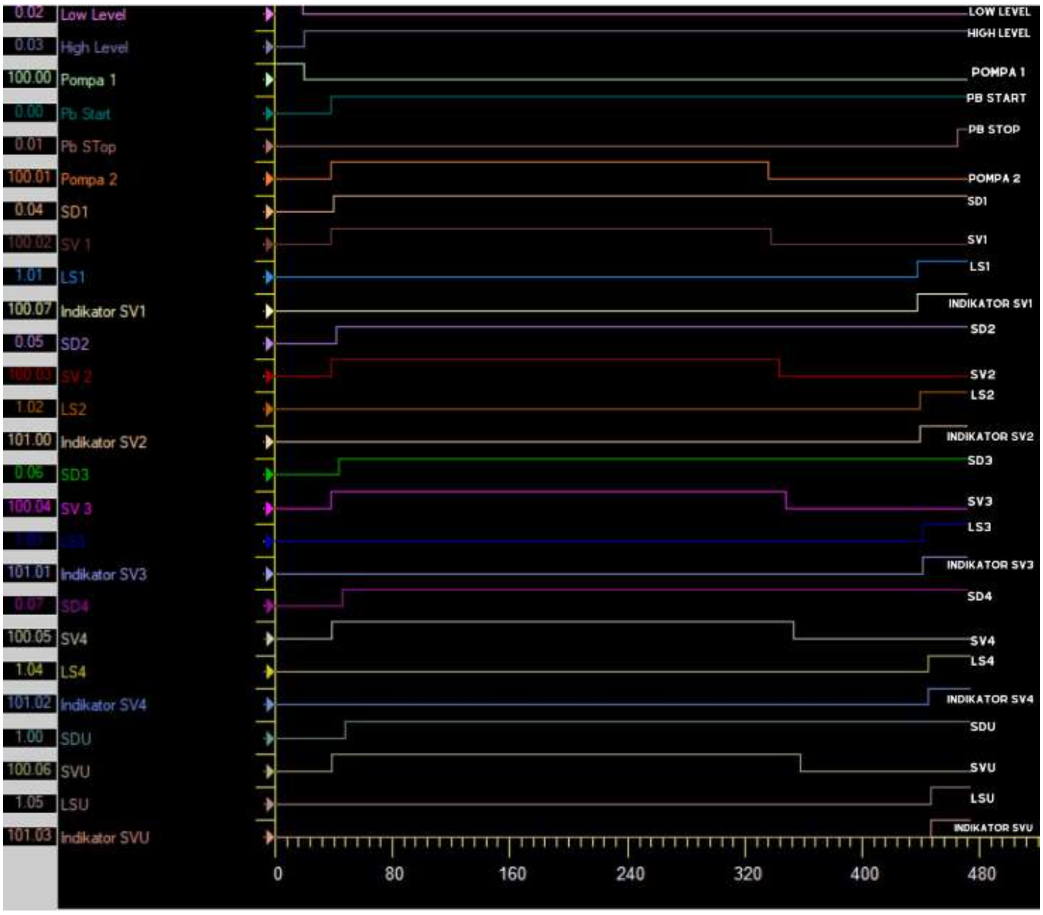


Figure 8. Digital Output Against Time on Irrigation System Components

Table 4. Time Response of Each Irrigation System Component

No	Comp	Address	Active time (seconds)	Durations
1	Low level sensor	0.02	0s - 18,6s	18,6s
2	High level sensor	0.03	19,8s – 474,6s	454,6s
3	Pump 1	100.0	0s – 19,2s	19,2s
4	Push button start	0.00	38,4s – 474,6s	436,2s
5	Push button stop	0.01	466,8s – 474,4s	7,6s
6	Pump 2	100.01	38,4s – 337,2s	298,8s
7	Sensor Debit 1	0.04	40,8s – 474,4s	433.6
8	Selenoid Valve 1	100.02	38,4s – 339s	300,6s
9	Limit Switch 1	1.01	439,2s – 474,4s	35,2s
10	Indikator SV 1	100.07	439,2s – 474,4s	35,2s
11	Sensor Debit 2	0.05	42,6s - 474,4s	431,8s
12	Selenoid Valve 2	100.03	38,4s – 339s	300,6s
13	Limit Switch 2	1.02	441s – 474,4s	33,4s
14	SV2 Indicator	101.00	441s – 474,4s	33,4s
15	Sensor Debit 3	0.06	44,4s – 474,4s	430s
16	Selenoid Valve 3	100.04	38,4s – 339s	300,6s
17	Limit Switch 3	1.03	442,8s – 474,4s	31.6s

No	Comp	Address	Active time (seconds)	Durations
18	SV 3 Indicator	101.01	442,8s – 474,4s	31.6s
19	Debit Sensor 4	0.07	45,6s – 474,4s	428.8
20	Selenoid Valve 4	100.05	38,4s – 339s	300,6s
21	Limit Switch 4	1.04	444,6s – 474,4s	29.8s
22	SV Indicator 4	101.02	444,6s – 474,4s	29.8s
23	Main Sensor Debit	1.00	48s – 474,4s	426,4s
24	Main Selenoid Valve	100.06	38,4s – 339s	300,6s
25	Main Limit Switch	1.05	447s – 474,4s	27,4s
26	SVU Indicator	101.03	447s – 474,4s	27,4s

CONCLUSION

The PLC-based irrigation system in this study provides maximum function results with a precise time even though it is still simulation-based. In the process of assembling the electrical system, PLC has the advantage, and the program language is easy to understand. For further development, it can be done experimentally to find out the obstacles that occur. In addition, supporting the industrial revolution 4.0 technology, an application system can be made on the devise for monitoring the system.

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