Greenhouse automation: smart watering system for plants in greenhouse using programmable logic control (PLC)

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Abstract. Automation is a technology used to carry out work processes or procedures without human assistance. Greenhouse automation is carried out related to the many operational activities in the greenhouse that involve many human repetitive activities. Some of them are related to fertilizing, watering, spraying pesticides and others. In the current era of the industrial revolution 4.0, manual activities that use human labor began to diminish and were replaced with automated systems and devices in order to streamline the operation of a work field. PLCs can be defined as a micro-computer based controllers that use instructions stored in memory that can be programmed to implement logic, sequencing, timing, counting and arithmetic functions through digital or analog input / output (I / O) modules, to control machines and processes. This PLC is commonly used in the industrial world as an automation tool for production machines. PLC can be implemented as an automation tool in a greenhouse in this case as an automatic watering system for plants. This research resulted in a prototype of an automatic watering system on a clock based and combined clock-sensor based greenhouse that can run simultaneously on the same PLC.

1. Introduction

Greenhouse is a building made of glass, is used as a place to grow plants so that the plants inside are protected from the intensity of high sunlight and high rainfall. In subsequent developments, other materials such as plastic, fiberglass and parernet have been found so that the mention is changed to a house plant. In general, the figure of a greenhouse building consists of the framework as a support for strength, the roof and walls as a protector, the interior of the greenhouse which is usually in the form of a rack or pot hangers, and greenhouse equipment in the form of climate control devices [1]. The climate control devices are still manual, especially related to watering plants. The role of the PLC here as an automation tool related to watering plants because greenhouses are designed to maintain and protect plants against climate, especially reducing the intensity of sunlight and exposure to rainfall, which means for watering plants done manually, and the frequency of watering these plants depends on the type of plant planted or dependent on the water content present in the soil of the plant.

An automatic greenhouse system using a PIC16F877A microcontroller as the main processing unit that accepts input from a temperature sensor (LM 35), a light intensity sensor LDR (Light Dependent Resistor) and a humidity sensor has already been built [2]. A smart greenhouse automation research in which in this study used an Android device, server computer and 8051 microcontroller has been conducted [3] by also designing a control system to monitor various parameters such as temperature, humidity, soil moisture content and light intensity. A greenhouse monitoring and automation system using a microcontroller. In this research using PIC16F877A microcontroller with light intensity sensor...
(LDR), Temperature Sensor (LM35), water content sensor on the ground, humidity sensor with stepper motor actuator for solar tracker, fan and water sprinkler has been researched [4]. An automated greenhouse research using a microcontroller Arduino Atmega 328 has been conducted [5], a step by step approach in measuring and controlling microcontroller based on four essential parameters of plant growth, namely temperature, humidity, water content in the soil and lighting intensity. This research also uses image processing in detecting plant health for proper and healthy growth. The results obtained from these measurements indicate that the system performance is quite accurate and reliable.

The use of Programmable Logic Control (PLC) as an automation tool has been widely applied in industry and research. We have conducted research related to automation using PLCs in smart trafficlight simulations [6] as well as in automating batik machine gripper [7] and combining them with the CNC Mach 3 program [8]. In this study, we use a PLC to automate manual activities that are still frequently carried out in a greenhouse, in this case plant watering, based on clock and sensors. Researches using PLC as an automation tool in a greenhouse has also been conducted by integrating watering with fertilizer [9], controlling [10] and monitoring system [11][12], and even comparing it with arduino [13].

This research is a part of a fully automated greenhouse scheme that will combine the use of PLC and arduino uno.

2. Method
The automatic watering of plants in the greenhouse involves 2 main steps. The first step is the process of studying literature and field surveys in which in this process a detailed study of the types of plants to be watered along with the need for watering these plants is based on literature and information generated from interviews with related parties greenhouse acquaintance.

The second step is to prepare a mini greenhouse. Based on the study above, we used water spinach (Ipomoea reptans) as our subject plant, because of its fast growth and are easily grown. We grew it manually in a mini greenhouse so that more accurate information can be obtained about the timing of watering and how to water the plants. We used two plant pots shown in figure 1, with a default watering in the morning once a day for each pot. The first pot (pot A) will only be watered once in the morning, the second (pot B) has the same default watering in the morning but with a capacitive soil moisture sensor inserted horizontally beside the pot shown in figure 2, at a depth of 4 cm [14] to detect the moisture level of the soil correlating to depth of the seed planted inside the pot (combined clock-sensor based). From the sensors attached to the second pot, it needed 7 seconds to detect the change of soil moisture. This change of soil moisture can be red in an arduino uno software serial monitor. We used an arduino uno to connect the capacitive soil sensor to the PLC.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Mini greenhouse  **Figure 2.** Capacitive soil moisture sensor inserted beside the pot
Then we conceptualize and simulate a ladder diagram using Zelio Soft 2 software on the PC based on information obtained from the first step. Ladder diagrams that are successfully simulated on the PC, are then implemented on the PLC, and tested directly on the mini greenhouse. We are using Schneider’s PLC Zelio SR2B121BD. The flowchart of this research is shown in figure 3.

![Figure 3. Research flowchart](image)

3. Results and Discussions

PLC programming starts with programming simulation on Zelio Soft 2 software, a Zelio PLC default software. In this software we create and simulate ladder diagrams that have been concepted before. The following is a ladder diagram made based on watering needs and has been successfully simulated.

3.1 Diagram ladder clock based

The following is a clock based ladder diagram, or ladder diagram that uses a clock base as a watering reference shown in figure 4. In this ladder diagram uses 1 Clock (H1) setting where Clock H1 is set to do the first watering every day at 07.00 am as shown in figure 5.

![Figure 4. Clock based ladder diagram](image)
3.2 Timer T1 setting
The timer setting T1 here functions as a timer for the duration of watering by the pump connected to the PLC output in Q1. For this setting watering is set every time watering for 7 seconds as shown in figure 6. The flow process of these settings are shown in figure 7.

3.3 Diagram ladder combined clock-sensor based
The following is a sensor based ladder diagram, or ladder diagram that uses a sensor base as a reference for watering, shown in figure 8. In this ladder diagram, it uses one Clock (H3) setting and one I2 sensor input. Where the Clock H3 is set to do the first watering every day at 07.00 am as shown in figure 9,
and the second watering based on input I2. Sensor I2 is a soil moisture based sensor, where this sensor will trigger the I2 switch and turn on the pump to water the plants in the mini greenhouse.

3.4 Timer T2 setting
The timer setting T1 here functions as a timer for the duration of watering by the pump connected to the PLC output in Q1. For this setting a watering is set every time watering for 7 seconds as shown in figure 10. The flow process of these settings are shown in figure 11.
The clock and timer configuration of all the settings above can be seen as shown in figure 12, below.

![Figure 12. Overall configuration of clock and timer settings](image)

### 3.5 Diagram ladder program implementation in PLC
Programming on the PLC is done manually by using the button on the PLC interface. The ladder diagram is made exactly the same as the settings that were simulated in the previous software as shown in figure 13, and figure 14, below.

![Figure 13. Clock based setting](image) ![Figure 14. Sensor based setting](image)

### 3.6 Automatic plant watering wiring system
This wiring watering system connects the PLC as an automation processor with its sensors and actuators. The sensor here uses a soil moisture sensor that is connected to an arduino uno. Analogue signals will be sent from the sensors to the arduino, the arduino will read this signal. If the signal is in the drought level, the arduino will send a digital signal to the PLC which is connected to the I3 input on the PLC. The actuator here uses two 5 VDC pumps which are connected with PLC outputs Q1 and Q2. Clock based output is on pump Q1, output on combined clock-sensor based is on pump Q2. The output of this pump will actively follow the activeness of the input. In clock based, Q1 pump output will only be activated by the H1 clock that has been previously set. The combined clock-sensor based, Q2 pump output will be activated by clock H3 and sensor I3. This I3 input signal if triggered, will turn on the Q2 pump to water the plant in pot B. PLC wiring is shown in figure 15. Where the sensor location has been shown in previous section.

![Figure 15. Wiring PLC](image)
Both clock based and combined clock-sensor based have clock settings which will activate the pump output with the same duration of 7 seconds every morning every day. Based on this, the water supply for watering will decrease with the same volume in each water tank. In watering using combined clock-sensor based, there are additional inputs included in the watering other than the clock, which is based on the sensor. This allows additional watering outside the clock which can occur if the soil moisture in pot B is indicated to be dry. Additional watering outside the based clock wareing will cause a difference in water supply in water storage tanks. This automatic watering system was run for 10 consecutive days from July 14, 2020 to July 24, 2020. At the beginning of the test, the volume of water in the clock based tank (A) and the combined clock-sensor based water tank (B) were equally regulated with a volume of 2 lt as shown in figure 16, below:

![Figure 16. Water volume 2 lt, before beginning the automated watering system](image)

On July 24, 2020, the water difference that occurred was as follows as shown in figure 17.

![Figure 17. Difference in volume of water after system testing begins](image)

The volume of water tank A shows 900 ml, the volume on water tank B shows 450 ml. The difference off water level in water tanks A and B of 450 ml shows the existence of an additional watering on tank B (combined clock-sensor based) outside the watering hours set at clocks A and B. The decrease in the volume of water in water tanks A and B as shown in figure 18. proves that watering based on the clock and combined clock-sensors can be done simultaneously using PLC, the difference in volume of water in tanks A and B shows that watering using sensor based is also running.
4. Conclusion

Automatic watering in greenhouse can be done simultaneously using a Programmable Logic Control (PLC) based on clock and sensor. The parameters that need to be considered in automating the watering system of a greenhouse using PLC in this study are the clock settings for watering (clock based) and the soils moisture (sensor based). Timer (H) can be adjusted to the need of the time to water and the number of frequency of watering in a day. In this study, Timer (H) is set to water once a day. Sensor based watering can also be done using Programmable Logic Control (PLC). This sensor reads drought that will trigger a switch on the PLC to do the watering. Sensor-based watering is based on soils moisture, constant monitoring in this kind of watering cannot be done directly, the only indication is by observing the difference in water reduction in the water tank between clock-based watering and combined sensor-clock based watering. Further research needs to be done regarding this combined sensor-clock based watering notification system and in many points in this research to achieve a fully automated greenhouse.

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