Automatic Water Level and Pressure Control System Prototype Design Using Programmable Logic Controller and Human Machine Interface

Ibnu Hajar [a,1,*], Dhami Johar Damiri [a], Meyharth Torsna Bangkit Sitorus [a]

[a] Electrical Engineering Department, Institut Teknologi PLN, Jl. Lingkar Luar Barat, Duri Kosambi, Cengkareng, Jakarta Barat, 11750, Indonesia

[1] ibnu.hajar@itpln.ac.id
* corresponding author

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ABSTRACT

Water level control and pressure control are implemented in many at several industrial processing such as water dam, petrochemical processing plant, pharmacy and food processing plant, overhead tank, waste processing plant, electricity plant, etc. This study analyses a simulation and a needed components for automatically water level control system implementation using programmable logic controller (PLC). The water level control using PLC is designed to control the water level and prevent waste the water from a water tank. PLC is one of devices of automated controller which mostly used. Use of PLCs in industries are indispensable to control parameters which required high precision. In this research studies water level control system using PLC as primary controller and human machine interface (HMI) as remote controller that could visualize state of a system work (plant) in real time on computer screen and could gather field data as well. Main device for this research is Omron PLC CP2E type and touchscreen HMI Omron. At the prototype is used a water tank and a water container (to be one with the water resource), and in the HMI is showed the pages of home, control panel, and plant. From the result of the diagram ladder and the HMI design are got the system run well. The application from this research could be learning media in the system control laboratory for the subject of industrial control system and the others, related to it.

1. Introduction

Water level control systems are used to control the level and flow of water circulating system for various processes [1, 2, 3, 4, 5]. Liquid level control is essential in many production installations, but classical approaches often fail to ensure the desired performance [6, 2, 7, 3]. These processes can include water dams, petrochemical process plants, water treatment plants, pharmaceutical and food processing plants, overhead tank, sewage treatment plants, nuclear power plants, etc. [7, 8, 9, 10, 11, 12, 13, 14, 4].

To ensure safety in production and product quality, it is necessary to control the liquid level effectively and in timely manner through a fixed level switch/valve. When the liquid level reaches a certain level, the switch/valve is automatically closed or disconnected to control the liquid level [12, 13, 4].

Level control is a common type of control method in process systems [15]. It must be controlled by the right controller [9, 13, 4]. The device that performs the control action is a valve mounted on the controller that main purpose is to maintain the desired set point level and can dynamically accept the new set point value desired by the control engineer [7, 9, 16].

Water level control is equipment used to control the water level in a place/container. The water level is controlled using various components such as programmable logic controllers (PLC), sensors, motors, and valves. The sensor senses the presence of water and gives an indication to the PLC. The PLC generates control signals to run the motor. If there is no water in the container, the PLC gives a signal to start the motor and if there is enough water in the container, PLC gives a signal to stop the motor. PLC prevents dry run of the pump as well when the level in the tank drops below the inlet level [12, 13, 4].

Programmable Logic Controller (PLC) is a digital computer used for electromechanical process automation. It is used to change relay logic or wired logic used previously to automatize the industrial process into ladder logic [12]. To make it easier for operators and or control engineers to monitor and control the liquid level in real time and online, it is used what to be called *Human Machine Interface* (HMI).

Human Machine Interface or abbreviated as HMI is a system that connects humans and machine technology, or a device used to perform an interaction between the operator / control engineer and the PLC which acts as a direct controller in the field. The purpose of HMI is to increase the interaction between the machine and the operator through display/visualization on the computer screen.

Through HMI, it will provide an overview of water level conditions in real time and online, can see which part of the machine is working, can carry out direct control via a computer screen, can display an alarm if a dangerous conditions occur in the system, and can also display machine work summary data including graphically.

2. Research Method

A. Block Diagram System

An overview of the system of this study is commonly shown in the Fig. 1 of diagram block below:

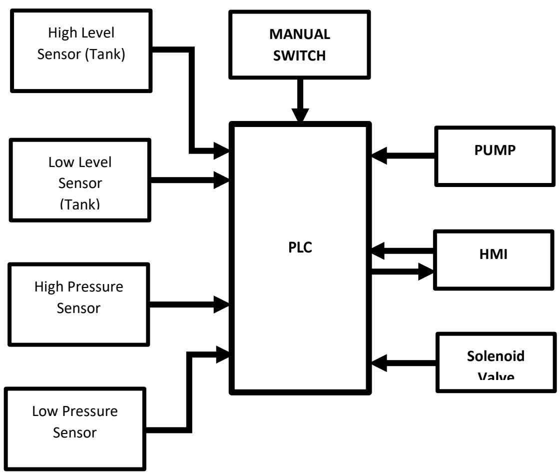

Figure 1. System Diagram Block

The water tank will be filled by a pump. The pump will automatically turn on when the water level in the water tank reaches a low level, and it stops when the water level reaches a high level. While, the solenoid valve works based on air pressure, when low pressure the sensor detects a drop in pressure according to the set point, so the air compressor will work, and it will stop when the pressure reaches the high pressure. Systems implementation can be divided into three parts [14, 17]:

1. Placement of Sensors
2. Ladder programming
3. Human Machine Interface (HMI) Design

B. Placement of Sensors

This study uses two types of sensors that are level sensors and pressure sensors. The level sensors are mounted and used to measure and to sense the level of water presence at the required level in the tank. While pressure sensors are mounted and used to measure and to sense high of air pressure at the required pressure on the solenoid valve. Level sensors come into the PLC input module and inlet water valve is connected to the PLC output module [14, 17]. Similarly, Pressure sensor come into the PLC input module and inlet gas valve is connected to the PLC output module.

C. Ladder Programming

Ladder logic programming for PLC Omron of CP2E type is worked using *software CX Programmer*. CX programmer is a kind of software that suitable for all types of PLC Omron series. This software is fully integrated into CX-one software suite. CX programmer also contains variety of features that can speed up development of user PLC programming [18].

D. Human Machine Interface Design

Human Machine Interface (HMI) is a tool where the operators and the users can be communicated with the systems. The systems status is sent to the operators or the users through graphical user interface (GUI). The operators or the users can be interacted with the systems by activating or inactivating various the functions of the interface. Human machine interface design using NB-Designer that is a software programming for HMI the type of NB Product series.

3. Result and Discussion

A. Wiring Diagram and Components

The research design of a water level and pressure control system simulation using Programmable Logic Controller (PLC) with its wiring shown in Fig. 2 below.

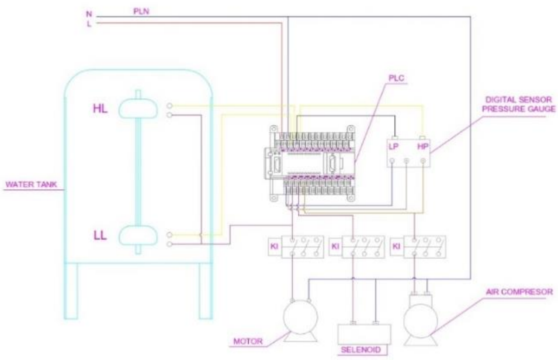

Figure 2. Water Level and Pressure Control System Wiring

In Fig. 2 can be seen the hardware needed in this simulation design, those are:

1. Double float level sensors
2. Digital pressure sensor gauge
3. Programmable Logic Controller (PLC)
4. Solenoid Valve
5. AC Motor (Aquarium Pump)
6. Air Compressor

1) Float for Water Level Sensor: *Float level sensor* is a sensor put in the water tank and used to detect water level. The float level sensor has two floats that both of which have a space to float, and the spaces have each space limit that it will send signals to the PLC. The lower float (LL) has a lower limit space and an upper limit space for the upper float (HL). The double float component that is used as Fig. 3.

Figure 3. *Float for Water Level Sensor*

The first Float is the lower float that will send signals to the PLC if the lower water level reach or push a float in space limit (LL) in the lower that sign that the water tank will empty so the PLC will process the signals given by float level sensor to run the motor (pump) to pump the water from the water container (the water resource) come up in the water tank.

The second float is the upper float that will work if the upper limit space (HL) is pushed since the water pressure on the float to up. In the limit, float level sensor sends signals to the PLC to process so that the PLC switch off the motor to pump the water come up in the water tank.

Abbreviations of LL (Low Level) and HL (High Level) refer to Fig. 2.

2) Digital Pressure Sensor Gauge: This pressure sensor is not connected directly to the water level control, but to the pressure control. It gives a signal to the PLC if the solenoid valve operates under a certain air pressure that required pressure setting given to the solenoid valve. Based on the pressure sensor signal delivered to the PLC and then PLC gives the signal to the air compressor to switch on, so that the solenoid continues to work at a certain pressure setting.

Figure 4a. Digital Pressure Sensor Gauge

Figure 4b. Digital Pressure Sensor Specification

Fig. 4a and 4b are digital pressure sensor gauge and its specification respectively.

3) Programmable Logic Controller (PLC): Programmable logic controller (PLC) is the brain of controlling the work of system devices [19]. PLC is a place to store programs that have been made by programmers such as ladder diagram [19, 20]. PLC translates the signals received from sensors in the fields, and then it provides control to the devices which is ordered to work according to the settings given by the PLC programmer [19, 20].

In this project, the signals received by the PLC come from the water level sensors (float level sensors) and pressure sensors (digital pressure sensors) and provide the orders to the motor, air compressor, and solenoid valve to operate based on the value setting desired by PLC programmers.

The type of PLC used for this simulation is Omron brand, type of CP2E-N30DR-A as the Fig. 5 below.

Figure 5. PLC Omron CP2E-N30DR-A

4) Solenoid Valve: If the water level in the water tank reaches the highest level that is the float level sensor detect the water push the float and touch the upper limit space, the PLC processes the signals and switches off the motor and then switches on the solenoid valve to flow the air to push the actuator, so the valve open and the water in the tank flow down into the water container.

   The tools specification used for this simulation is airtac valve of 4V210-08 model with the DC voltage of 24 V (voltage range: 21.6 – 26.4 V) and the power is 3.0 Watt. The component is showed in Fig. 6.

Figure 6. Airtac Solenoid Valve 4V210-08

5) AC Motor (Aquarium Pump): The AC motor operates to pump the water flowing into the water tank if the float level sensor is pushed down and reaches the lower limit space (LL) dan it will not operate if the float level sensor is pushed up by water and press the upper limit space (HL). The AC motor operates based on the signals obtained by the PLC from the float level sensors.

   The AC motor used is an aquarium pump type of model of AA-103 with the voltage range of 220 – 240 volt and the power are 18 Watt. It is showed in Fig. 7.

Figure 7. An Aquarium Pump of AA-103 Model

6) Air Compressor: It is the same as the pressure sensors, the air compressor in this study is not directly related to controlling the water level, but the compressor is used to maintain the air pressure which is in the solenoid valve. Considering that the solenoid valve works during emptying the water in the water tank, it is may the air pressure which is in the solenoid valve is reduced than it should be. If the pressure in the solenoid valve decreases from the set point of the pressure so the PLC processes the signals sent by the pressure sensors to switch on the compressor. The compressor specifications used in this study are the Artix OA 10-24 silent and oil free, the voltage of 220 volt, the power of 750 watt/1.0 HP, the speed of 1450 rpm, the tank size of 24 liters, the pressure of 8 bars, and the air flow of 56.6 liters/minute.

   In Fig. 8 is showed the component of the air compressor used in this project.

Figure 8. Air Compressor

B. Prototype of Water Level and Pressure Control

In Fig. 9 below shows the prototype of the water level and the pressure control system which each of the parts of the control unit has described on section A above. Meanwhile, the steps of working of it will be described on section C in detail.

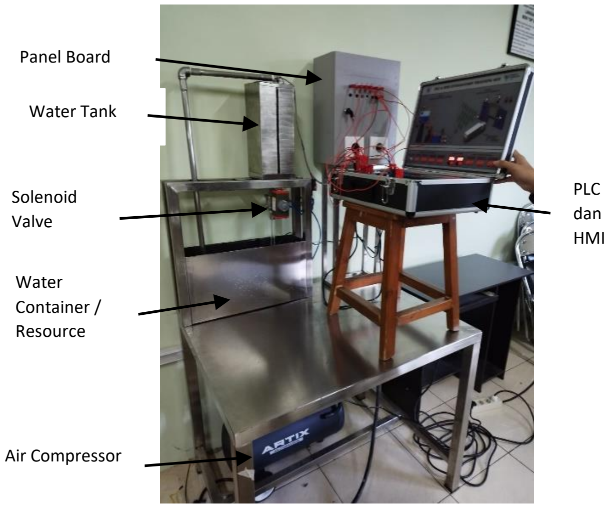

Figure 9. Prototype of Water Level and Pressure Control System

C. Ladder Diagram and Human Machine Interface

Ladder diagram is one of the programming languages used by PLC. Ladder diagram describe electricity current flow arranged from relay contacts structured [21, 20]. Fig. 10 below is ladder diagram to control the level water when must filling in (the pump run) and when must switch off so that the water in the tank is not overflow from the tank.

The working principal of the ladder program in Fig. 10 below is that in the rung 0, the program runs by activating the program with an indication that the start light is on and immediately starts the pump in the rung 2 and fill the water from the water resource (the water container) into the water tank. After the water reach the upper setting value (high level), the water state stops for a moment according to the set value on the timer in the rung 3, and then the solenoid valve opens the valve, and the water falls into the water container (the water resource). So that the water reaches the lower setting value (low level) and immediately the solenoid valve closed, and the pump starts. This process continues be repeating until deactivating the program with the stop light indication turning on in the rung 1.

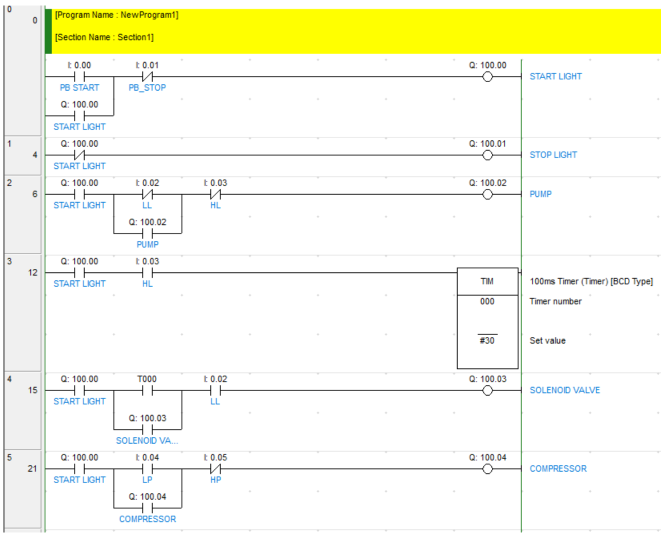

Figure 10. Ladder Diagram Water Level Control

The term of water resource and water container is same term for the prototype in Fig. 9 because the water resource and the water container are used in the same time and the same component, but in the HMI is showing the two different components.

Human Machine Interface (HMI) is programmed using NB-Designer which is a software programming for HMI the type of NB product series. In HMI, it is necessary to describe the start and stop buttons as well as system status, namely the system is run, stop, pump, valve, and compressor which are described in one panel board. In Fig. 11 shows HMi of the water level control panel board, meanwhile in Fig. 12 show the HMI of the plant system.

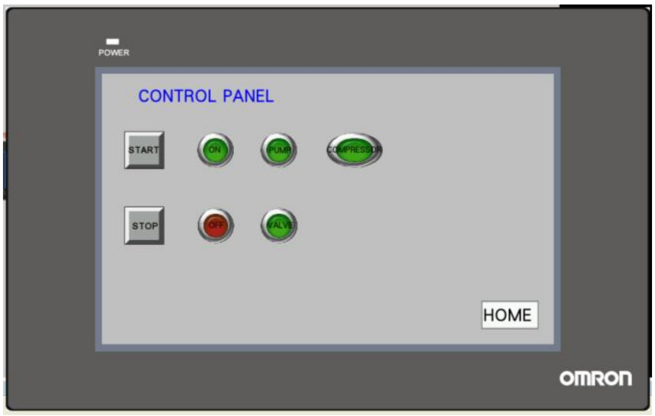

Figure 11. HMI of the Water Level Control Panel Board

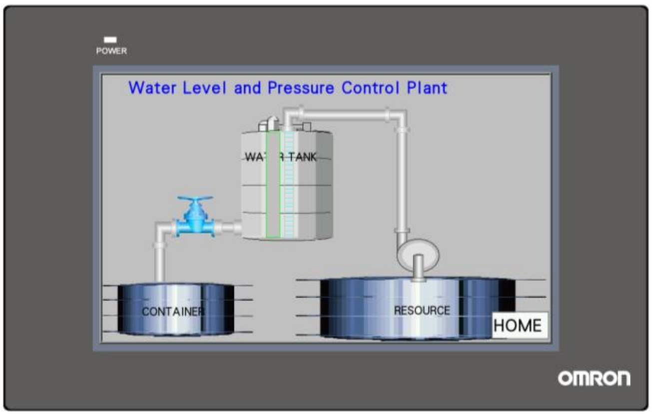

Figure 1.2 HMI of the Water Level and Pressure Control Plant

In Fig. 11 and Fig. 12 above show the HMI which are used for simulation of the automatic control system of the water level and the pressure, where the set value of the lower level is according to the lower level sensor that if the water is at that height, the pump will run automatically to fill the water into the water tank, and if the water reach the higher level that is according to the higher level sensor, then the pump stops and the valve will open to flowing the water into the water container.

4. Conclusion

From the simulation results of this study, namely the automatic water level and pressure control design using programmable logic controller (PLC) and human machine interface (HMI) can be concluded that:

1. The ladder diagram program on programmable logic controller (PLC) runs well
2. The human machine interface program using NB-Designer also runs well.

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