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A Water Level and Temperature Surveillance System Contingent on Automated PLC Controller

Mohammad Aasef Azhar Khan, Md. Efatuzzaman Efat*
Department of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna- 9203, BANGLADESH

ABSTRACT
Today, in numerous industrial and residential applications, an efficient water level and temperature surveillance system is a very essential requirement. Previously it was done under human supervision which was both unsafe and expensive. Many unpleasing occurrences happened because of the absence of sufficient regulation. The paper centers around the presentation of a PLC controlled system that is commensurately reliable and cost-effective. To supervise the entire system, an available assistant tool-type device, Siemens LOGO! PLC is utilized. Sensors of two distinct types are imposed; Float Switch (Bilge Sensor) and Resistance Temperature Detector (RTD). The float switches are used to track the water to the desired level. The RTD sensor of the PT-100 model is utilized for monitoring the temperature of the water to a required value. As output devices of the PLC, a regular water heater of 1000 watts and solenoid valves are used. To program this operation, a Ladder Diagram (LAD) network of LOGO! Soft software is used. With the help of the program, the PLC will operate thus controlling the input and output devices. This automatic system can impart proficiency in detecting water levels with temperature easily and securely. This sort of delicate operations controlled by PLC is very useful within the industries as well as in domestic territories.

Keywords: PLC, Float Switch, PT-100 RTD Sensor, Solenoid valve, Automation

1. Introduction

A control system with a properly installed program can easily track and operate the characteristics of different input and output devices. The devices working as outputs are managed by the controller by getting proper signals from the sensors due to the alteration of the level and temperature of the water in a container. The introduction of PLC in level and temperature control has been seen in many different sectors. Automatic control of level and temperature using PLC, of a food manufacturing process, was presented by A. Aftab et al (2016). For persistent monitoring, the process was further modified by the interfacing of PLC with SCADA (Supervisory Control and Data Acquisition) [1]. MAZIN A. presented a similar type of water level and temperature management system where Siemens S7-200 type PLC was used. Whereas in this system a relatively cheaper, available, and user-friendly type PLC LOGO (0BA8) is used. Besides, in this proposed system a cheaper level sensor has been used wherein previous works used the LVDT sensor which is a bit more expensive [2]. In another case, P. Narkhede et al (2016) showed a PLC controlled automatic water monitoring system for the distribution of the water. Here for detecting the water level, inductive proximity sensors are used [3]. In this proposed system, a bilge type water level detector is used which is both cheap and provides accuracy. Gabriela Rata and Mihai Rata (2016) presented a temperature control system that used a PID controller with a PLC [4-5]. X. Ding et al (2015) in his design of making a water heating system for students, used two types of PLC; S7-300PLC and S7-224PLC as controller units and a pressure sensor, flow sensor, and PT-100 temperature sensor as input units while electric heating pipe and an electric control valve as output units [6]. For many industrial and domestic purposes, water level monitoring and controlling its temperature to a required value is very essential. Like in chemical industries or day to day use. In our country, we tend to use traditional water heaters which are known as geyser, for water heating. There are two types of water heating process. They are- (a) Instant water heating and (b) Storage type water heating [7]. For the instant water heating process, the rating of the heater is kept between 3000-4500watts, and the volume of water is generally kept under 6-7 liters [8]. This is done to reduce the heating time. On the other hand, in the storage type heating system, the main concept is to heat a huge amount of water where the heater is kept in a smaller rating, and heating time is not a major factor. The geysers are fixed for a certain amount of water, and the temperature control is also risky as the available ones neither show the temperature nor it can be programmed at the desired level. As a result, if the main switch isn’t turned off in due time, not only the electricity bill will surge but also the device might get damaged. From both sides, it is a big waste of money and time. In some cases, it can also happen that the heater gets turned ON by the user through a switch but a sufficient amount of water isn’t present in the container. Thus the heater loses its efficiency due to lack of heat transfer. All of the above problems can be solved easily and an efficacious result

*Md. Aasef Azhar Khan. Tel.: +88-01744622192
E-mail address: aasef2k16@gmail.com

can be elicited by the use of a PLC controller. The amount of water in the container or the heating temperature will never be a constraint if a PLC controller is used as it controls the whole process by the input signals from the sensors and thus controls the outputs such as- heater, solenoid valves, etc. In this whole system, floating switches play an important part as the higher-level floating switch controls the heater's ON and OFF state. So, the heater is only in operation when the container is filled with a sufficient amount of water. If the water level is below the higher or required level set by the floating switch, the heater will automatically turn OFF or remain OFF to avoid any kind of accidents. The position of floating switches can be changed by moving the switches along an aluminum channel to which it is attached. The use of PT-100 RTD sensor for measuring the water temperature made the whole process a lot smoother than manual measurement through thermometer which is not as precise as it is. The main controller, PLC, is used to monitor this whole function as an operator and it performs according to the program that is set in it. In the PLC, several programs can be uploaded at a time, and in different working conditions and the required program can be executed. For instance- the changed value of temperature in a different program will operate a new program. So, whenever needed, an authorized human operator can change the program according to the need and set new operating conditions like- the temperature value or switch controllers, etc. A further modification of this whole system can be done by interfacing it with an HMI (Human Machine Interface). The response time between getting the input signal and operating the output devices is very negligible (maximum 10ms) in the PLC that is used [9]. It provides a good amount of reliability in the system

2. Components and whole system:

The essential components needed for this system to build up are available and cheaper than the other equivalent systems. In Fig:2.1 and Fig:2.2, the complete layout of the system and circuit connection of the PLC is shown respectively. The name of the components and the required amount of quantities are listed below:

a) A control board with aluminum channel attached.

b) A Siemens LOGO! (6ED1-052-1MD00-0BA8) PLC module (with analog input facility).

c) Two Float Switch (Bilge type sensor).

d) One PT-100 RTD sensor.

e) One temperature transmitter (0-10v)

f) Wires

g) Two indicating lights. (Green and Red)

h) A standard-size container with a channel.

i) A solenoid valve (Two, if used with outlet)

j) The layout of the whole system and the circuit diagram of the PLC is comprehensible. The layout of the system and the input and output circuit connection of the PLC is given below:

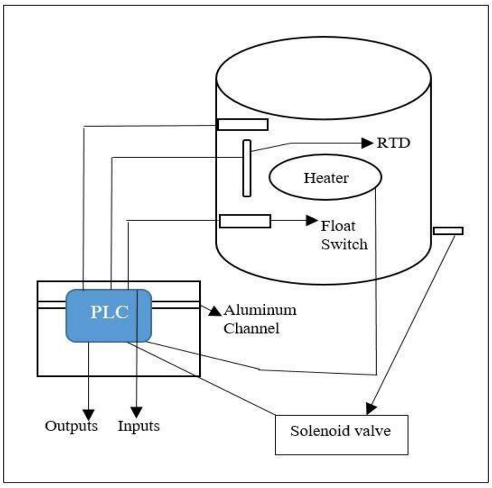

Fig: 2.1- Complete layout of the system

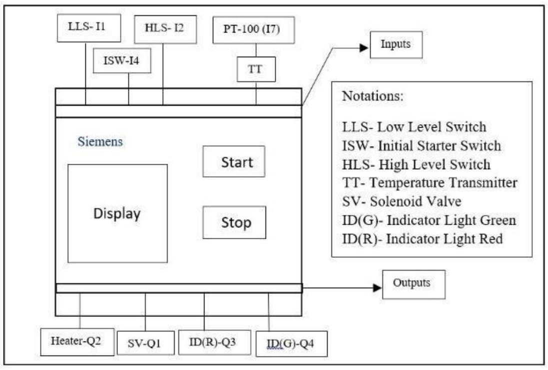

Fig: 2.2- Circuit connection of the PLC

3. Methodology:

The fundamental purpose of this system is to measure the water level to a certain height and then according to the temperature value set in the PLC program, control the heating operation and discharge the water when needed. The whole process begins with the press of a push button which turns the solenoid valve ON to intake water from the prime source. To show this intake process to the operator, a green light will turn ON and when the valve is OFF, it will also turn OFF. It must be noted that the push button, both higher and lower level float switches, PT-100 RTD sensor are connected to the PLC as input devices whose signals operate the output devices-the solenoid valve, the heater. The lower level switch is at the bottom of the container. When the lower-level switch is turned ON by the surge of water level, the effect of the push-button pressed earlier is eliminated. The lower level float switch now plays the role of the push button which keeps the valve turned ON. When the increasing water turns ON the higher level float switch, the solenoid valve is turned OFF and cuts the water supply and simultaneously the heater is turned ON. After a certain amount of time when the water gets heated at the required temperature, the PT-100 RTD sensor sends a signal to the (0-10V) temperature transmitter which converts the resistance into corresponding voltage and then supplies it to the PLC as an analog signal which turns OFF the heater at that temperature. Now from the outlet valve or tap, the water can be taken and used. If the water level gets below the higher-level float switch, the heater will never operate as it is programmed in this way to avoid any kind of accident or damage related to the heater. The whole process can be initiated again by pressing the push button that was pressed earlier. In case there is a leak in the container and the water level goes below the lower float switch, the whole system will shut down to avoid malfunctions and a red indicating light will turn ON whenever this happens to aware of the operator. The cardinal aspect of this system is to bring safety while operating this kind of quotidian risky procedures.

4. Experimental Setup:

The proper physical connection of this system to the software through the PLC is equally important as programming. In Fig:4.1 and Fig:4.2, the setup is shown. The necessary steps for constructing this system are:

a) Develop the PLC program in LOGO! Soft Comfort (V8.2) software.

b) Uploading the program in the PLC module from PC or laptop.

c) Connecting the input devices of the system, such as-the float switches, the RTD PT-100 sensors (connected to the transmitter) to the PLC input section. The temperature transmitter must be connected to the analog input block of the PLC module and the float switches can be connected to the digital blocks of the PLC (Fig:4.2).

d) The output devices need to be connected according to the program block notations i.e.- if the heater is indicated as the Q1 output in the program, then physically the heater is to be connected to the Q1 block of the PLC output section. The same goes for the other output devices.

e) The PLC itself runs by either (12-24V DC)/ (115-220V AC) corresponding to its operation criterion. So while connecting the PLC with power, the criteria must be observed.

f) Then all the devices after properly being connected is ready for operation and can be run.

(g) If the circuit doesn't run accordingly, then the program should be checked and also the physical connection.

Fig: 4.1- Top view of the experimental setup

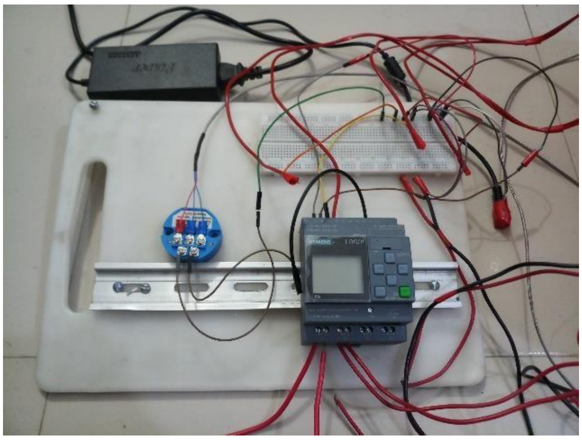

Fig: 4.2- Top view of the control board

5. Performance Test and Calculation:

5.1- Performance Test:

The following steps were done for a performance test of the system:

a) At first all the connections are checked for a safe and smooth operation. The program was uploaded via PC to the PLC and the start button of the PLC was pressed to make the system ready to run.

b) The push button was pressed once to initiate the operation. At this water started to flow inside the container through the solenoid valve and a green indicator light was turned ON. Gradually, the water level increased and when the higher float switch was ON, the valve and the green light stopped.

c) At that time the heater turned ON without any lag. The program was set for heating the water at 70℃.

d) With a 1000W heater after about 32 minutes, the heater turned OFF. With a manual thermometer, the temperature was measure and it was found around 70℃.

e) For safety purposes when the operation was completed, the STOP button on the PLC was pressed to terminate the system.

5.2- Calculation:

For the performance test, a 1000W-220V heater was used to heat 10 kg of water. The ambient temperature was 26°C and the target temperature was 70°C. The PT-100 RTD sensor had a range of -20°C-200°C.

The required time for heating the water can be calculated by non-flow or batch heating formula-

$$T = \frac{L*(T_2-T_1)*S}{P}$$

Where,

T= Time required for heating (min.)

L= Amount of water in Kg

T_1=Ambient Temperature (°C)

T_2=Target Temperature (°C)

S= Specific heat of water=4200 $J.Kg^{-1}.K^{-1}$

P= Power of heater= 1000W

So, using equation (1), required time,

$$T=\frac{10*(70-26)*4200}{1000}$$

=0.51hr

=30.6 minute

Table-1: Heating Time required for various target temperature.

Volume of water (KG)	Target Temperature (°C)	Heater Rating (Watts)	Time (min.) (Theoretical)	Time (min.) (Experimental)
10	70	1000	30.6	32
10	60	1000	23.8	25
10	50	1000	16.8	18

Table-2: Heating time required for various volume of water.

Volume of water (KG)	Target Temperature (°C)	Heater Rating (Watts)	Time (min.) (Theoretical)	Time (min.) (Experimental)
10	70	1000	30.6	32
08	70	1000	24.6	25.5
05	70	1000	15.4	16.8

From Table-1 and Table-2, we can see that the heating time is less when the volume of water is less and the target temperature is low. So, for instant heating process, generally used in household activities where the temperature demand is between 50-60°C, we can reduce the heating time by adding a high rated heater [10]. For storage heating needed in industrial sectors, we can lessen the heating time with the help of closed vessel and high rated heater.

6. Results and Discussion:

6.1- Results

With the help of the program done in LOGO! Soft software, the results are explained. The results of this automated surveillance system are described in a few steps:

a) The initial starting of the valve:

In this step, the start button is ON and the valve turns ON and when the water level goes above the lower level switch, the start button's effect turns OFF and the valve stays ON due to the signal of the lower-level switch. (Fig:6.1.1 and Fig:6.1.2)

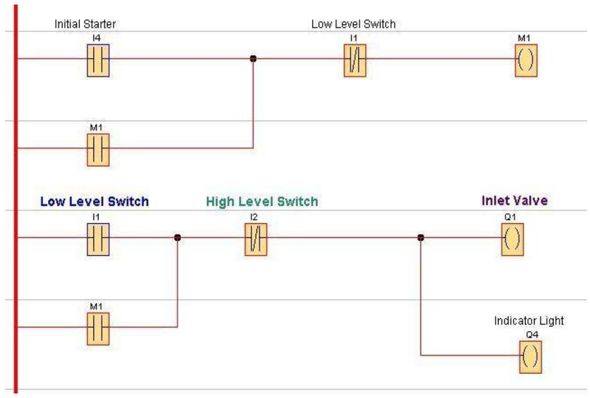

Fig: 6.1.1- Push button activating inlet valve

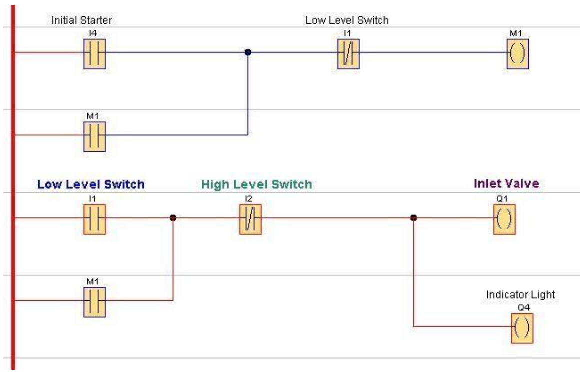

Fig: 6.1.2- Low level switch keeping the valve ON though start button's effect is OFF.

b) Start of Heating Process:

In this stage, the higher-level switch turns on when the required water level is achieved and the valve goes OFF while the heater turns ON. (Fig: 6.1.3)

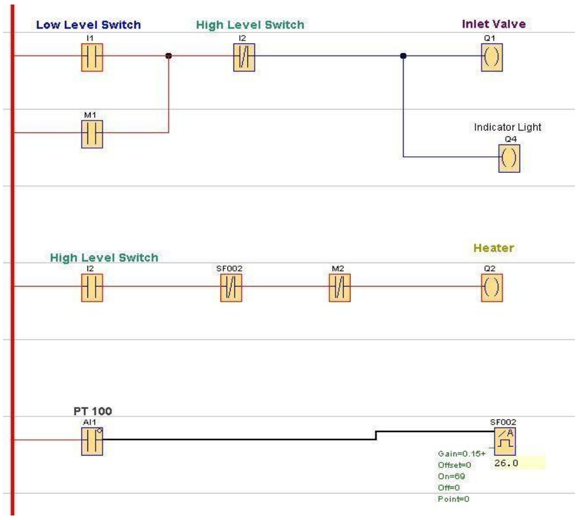

Fig: 6.1.3- Valve is OFF and heater is ON due to the turning ON of high-level switch.

c) Temperature Measuring:

At this step, the PT-100 sensor reads a temperature of 70°C and turns OFF the heater by providing a signal to the PLC. (Fig: 6.1.4)

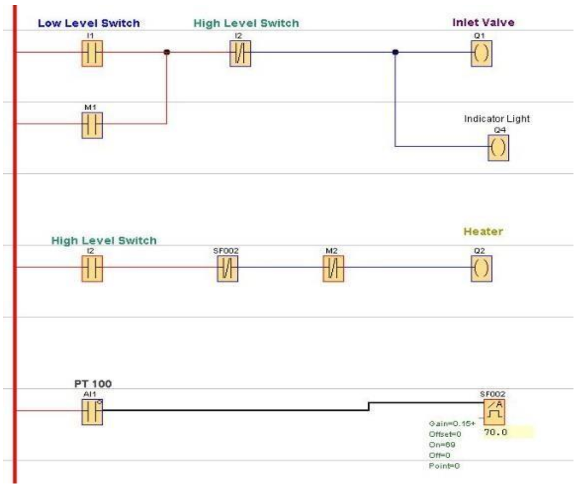

Fig: 6.1.4- Heater turns OFF at 70°C

d) Safety Issues:

When the water was at around 50°C, the STOP button is pushed and the whole system turned OFF. This was done for checking the security option. At any moment this emergency stop button can terminate the whole system (Fig: 6.1.5-6.1.6). Also, the whole water of the container was drained deliberately and when it went below the lower-level switch, a red indicating light turned ON to show the container emptied. It is done to reveal any leakage in the container. (Fig: 6.1.7)

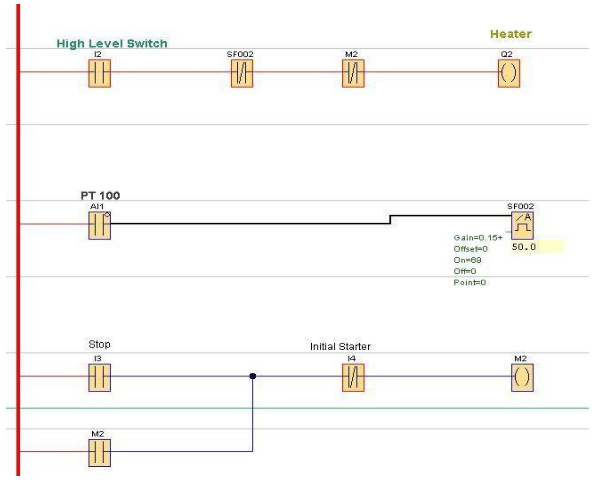

Fig: 6.1.5- Water at 50°C and STOP button is OFF.

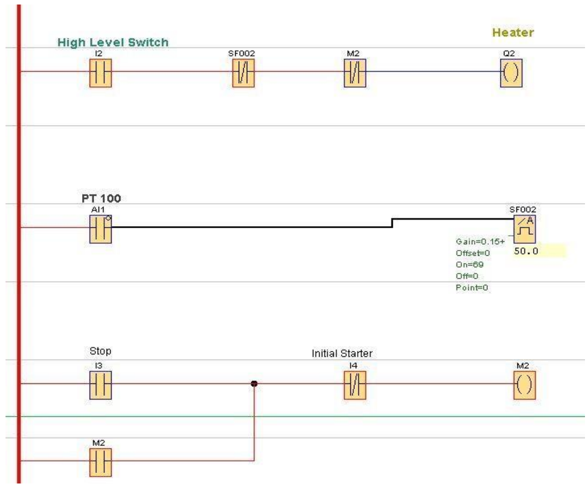

Fig: 6.1.6- STOP button pushed and heater turns OFF.

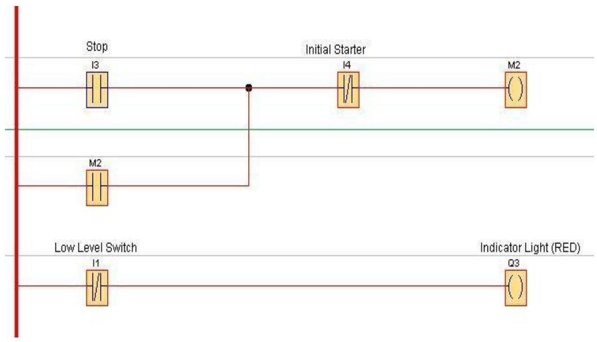

Fig: 6.1.7- Water is below low-level switch and red indicating light turns ON.

From the performance point of view, it was observed that the above-mentioned steps were done precisely. All the input devices such as the float switch and temperature sensor provided almost accurate signals which were then processed and executed by the PLC.

6.2- Discussion:

A prototype of a water level and temperature surveillance system with PLC was designed, constructed and a performance test was conducted in this project. The PLC module works with a 12/24V DC power source so there is no huge extra power consumption in the project. In the case of response time from the input of the PLC to the output of it is less than a second so there is almost no chance of lag in response [9]. This system underscores the safety of the operation and this is where PLC plays a huge part by controlling the whole system solely. So manual dependency is reduced by a profuse amount. Using a PLC enables the operator to use any output device regardless of power rating but in the case of input devices, the power rating of the device matters. It is expected that this automated system will improve the performance of the operation and also will efficaciously provide efficiency. This system is cost-effective also because unlike the regular geysers if the system fails with any component, only that component can be changed without altering the whole system. Besides a PLC can easily be used with several programs so, for different uses, only one PLC can provide the desired output. There are some drawbacks to this system. The float switches used here have an operational temperature restriction (about 80℃). If a more heat-sustaining switch is used then it can provide service in the long run. Besides, the use of HMI (Human Machine Interface) can heavily increase the facility of user-friendliness of the system. It can be then controlled by anyone who doesn't know PLC programming or others.

7. Conclusion:

In recent times, there have been a lot of accidents occurring in both domestic and industrial sectors due to the lack of proper maintenance. An automated water level and temperature management system by PLC can undoubtedly reduce this rate of accidents by ensuring proper safety and providing the required operation. This project shows how water level in a container can be measured and also how precisely the required temperature can be obtained with minimal human effort. In domestic and small industrial sectors, it can easily be used as required.

8. Acknowledgment:

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9. References

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