MONITORING OF WATER LEVEL AND TEMPERATURE BASED ON AUTOMATED PLC CONTROLLER

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Abstract - An automated Programmable Logic Control (PLC) is a device used in automated electromechanical processes. This paper is focused on automation control of water level and temperature in a tank using assistant tool type Siemens S7-200 PLC. Two types of sensors are used in this work; Linear Variable Differential Transformer (LVDT) and Resistance Temperature Detector (RTD). LVDT sensor is used to measure the level, while RTD sensor is used to measure the temperature of water. These sensors are connected to a PLC through transducer circuit. A PLC is used to control the motor working via linear drive circuit and control the heater working via Pulse Width Modulation (PWM) drive circuit. The Ladder Network (LN) is used for programming these tasks. Automatic control of water tank can provide a certain water level and temperature at any time. A water level and temperature control system are used in many industrial applications as well as civil and military applications.

Index Terms— LVDT Sensor, PLC, RTD Sensor, Temperature control, Water Level Control.

I. INTRODUCTION

A control system can be manage and regulate the behavior of other devices or systems. The controller is used the sensors for sensing the variation in the level and temperature of water inside a tank.

G. Alem and K. Vankdoth (2016) treated with Automatic Fluid Level Control (AFLC) using Programmable Logic Controller (PLC) in Alameda Textile Factory where it is used conventional relay control system to control level of fluid. They used conventional relay control system to control level of fluid [1]. A. Aftab et al (2016) presented an automatic control of level and temperature of a tea powder manufacturing process using PLC. The automation is further enhanced by the interfacing of PLC with SCADA (Supervisory Control and Data Acquisition) for continuous monitoring [2]. P. Narkhede et al (2016) presented a PLC automatic water system for monitoring the distribution of the water. Inductive proximity sensors are used to detect the water in the tank [3]. K.G. Bhutia et al (2016) presented the design of a PLC automatic water level controller to avoid excess over flow and wastage of water. The float and solenoid sensors are used to detect the level of the water [4].

D. Baladhandabany et al (2015) described the methods for filling more than one bottle at a time. In a conveyor system, stepper motor is used for its efficiency. It included the user defined volume selection at the desired level [5]. X. Ding et al (2015) improved the original control system of process control to provide a platform for students to learn the PLC technology. The design were used two types of PLC; S7-300PLC and S7-224PLC as controller units. The input device unit includes a pressure sensor, flow sensor, and Pt100 temperature sensor, while the output device unit includes an electric control valve and electric heating pipe [6].

H. H. Haque et al (2014) dealt with the feasibility of employing advanced control technique of PLC to linarite the input-output characteristics of control system. Also a MATLAB program is used to activate the PID controller, calculate, and plot the time response of the control system [7].

Raghavendra R., et al (2013) designed an electronic circuit used in water level indicators that controlled the storage level of water in a tank to follow water daily without any wastage. This water level controller is designed, implemented, and analysed using Multisim tool [8].

N. Dey et al (2013) used a fuzzy logic to analyze the effectiveness of water level control. In this work the transistor switching has been used to sense the water level in the tank. The level is controlled using the PIC16 microcontroller [9].

Muktha S. K. et al (2013) presented a design and of wireless controller based on microcontroller to control the level of the water. The system uses two Radio Frequency (RF) transceivers for wireless communication technique [10].

In this paper, an LVDT sensor and RTD sensor have been used to measure the level and temperature of water, respectively. The sensors are connected to PLC (type Siemens S7-200) through signal conditioning circuits. The PLC is used to control the motor by using linear drive circuit and control the heater by using PWM driver. Ladder network is used for programming the system.

II. TECHNOLOGY COMPONENTS

Brief introduction of PLC S7-200, LVDT and RTD sensors have been presented. These components are the main parts of the proposed system design.

A- PLC S7-200

The S7-200 Micro PLC is the smallest part of the SIMATIC S7 family of programmable controllers. The central processing unit (CPU) is an internally unit inside a PLC which connect the input devices such as switches, sensors and output devices such as motors, pumps. The Micro PLC SIMATIC S7-200 is truly in class of its own; it's both compact unit and highly powerful, fast response, and its open-ended is enough to be expanded anytime in the future.

All this makes the SIMATIC S7-200 a real economic alternative in open-loop control for the lower performance range. SIMATIC S7-200 delivers consistently economical solutions. The features of entire system are; powerful performance, optimum modularity and open communications.
In addition, the Micro PLC is very easy to program allowing fast and easy realization of applications. Figure (1) illustrates the PLC module with programming port, input and output points.

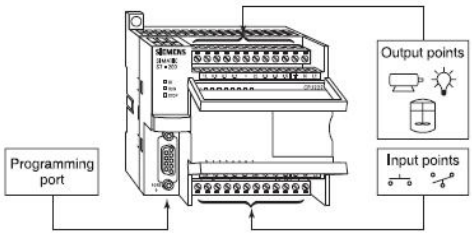


Figure 1. PLC S7-200 module.

B- LVDT Sensor

Linear Variable Differential Transformer (LVDT) is a transformer with a mechanically actuated core. The sine wave having stabilized amplitude that is driven to the primary coil and it eliminates error in the transformer that is related to harmonics [4]. In the two secondary coils, an AC signal is induced, and connected in opposite phase. When the positioned of the core in the magnetic center of the transformer, the signals of secondary output is terminate and there is no output voltage. Unbalances the induced magnetic flux ratio between the coils is happened when the core moving away from the central position which developing an output and also the reluctance of the flux path changes. The degree of flux coupling depends on the axial position of the core. The amplitude of the induced voltage is proportional, in the linear operating region, to the core displacement at a steady state. The voltage is used as measure of a displacement. The LVDT provides the magnitude and direction of the displacement [11]. Figure (2) shows the LVDT sensor in the tank.

C- RTD Sensor

The changing in the electrical resistance represents the basic of the Resistance Temperature Detector (RTD) operation . The RTD element types are platinum, nickel, copper and nickel-iron alloys. Platinum is widely used in manufacturing because of its appreciable characteristics such as temperature range, accuracy and stability. The linear positive change in resistance with respect to temperature is characteristic of RTD. Two types of RTDs used as available tools in various applications such as Thin-film RTDs and Wire-wound RTDs.
Thin-film RTDs are alloys and deposited on a suitable substrate such as a micro-machined silicon membrane or it's fabricated of thin platinum. On the other side wire-wound RTDs are platinum winding which is partially supported by a ceramic tube with high temperature glass adhesive. It's the most stability for industrial applications [11].
RTD type PT-100 is a good choice using as temperature sensor in the range from -243 °C to 600 °C. Figure (2) shows the RTD sensor in the water tank.



Figure 2. Water tank containing LVDT and RTD sensors.

III. SYSTEM THEORY

The hydraulic systems can be divided into two categories, hydraulic resistance and hydraulic capacitance.

A- Hydraulic resistance

If the liquid flows from a pipe of specific diameter to another of a different diameter, then there is a pressure difference is occurs, thereafter hydraulic resistance has been generated. If the pressures at each side are p1 and p2, then the hydraulic resistance R is defined as equation (1) [12]. Figure (3) illustrates the hydraulic resistance.

$$R_q = p_1 - p_2 \qquad (1)$$

Where q is the flow rate of the fluid

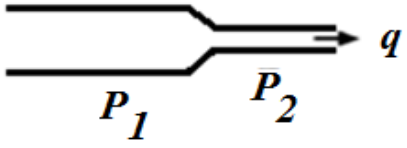


Figure 3. Hydraulic resistance.

$$q_i - q_o = A\frac{dh}{dt} \quad (2)$$

Since

$$q_i = A\frac{dh}{dt} + q_o \quad (3)$$

$$q_o = \frac{p_1 - p_2}{R} \quad (4)$$

And the pressure difference is given by:

$$p_1 - p_2 = h\rho g \quad (5)$$

where ρ is the density of water (Kg/t) and g is the gravitational constant (9.8 m/s2) then,

$$h = \frac{Rq_o}{\rho g} \quad (6)$$

Substituting in equation (3) gives:

$$qi = A\frac{d(\frac{Rq_o}{pg})}{dt} + q_o \quad (7)$$

The Laplace transform of equation (7) is:

$$q_i(s) = \frac{AR}{pg} sq_o(s) + q_o(s) \quad (8)$$

And the transfer function can be written as:

$$\frac{q_o(s)}{q_i(s)} = \frac{1}{1 + \frac{AR}{pg}s} \quad (9)$$

On the other hand, hydraulic capacitance is a measure of the energy storage in a hydraulic system, such as tank stores energy in the form of potential energy. In figure (4) the liquid enters a tank at rate qi and leaves at rate qo, that is related to tank cross section area (A) and liquid height inside tank with respect to time (dh/dt) [12].

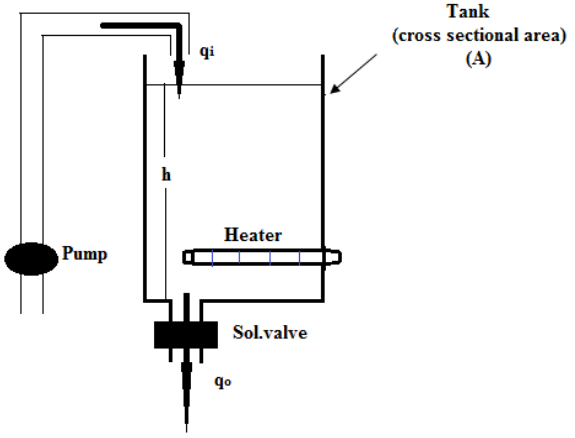


Figure 4. Liquid heated and level system.

B- **Thermal System**

As a real thing obvious in figure (4), it is possible to write an equation describe the system for balance of flows in the tank as follows [15].

$$q_i(t) - q_o(t) = A\frac{dh(t)}{dt} \quad (10)$$

Where; $q_i(t)$ water flow in the tank, and qo(t) water leaving the tank through the valve.

The Bernoulli's equation can be applied to the tank system as follows [15].

$$h = \frac{v^2}{2g} + \Delta h \quad (11)$$

where v represents the local velocity of the water, g is the local acceleration of gravity, and Δh is the system loss and can be written as:

$$\Delta h = \frac{v^2}{2g}\left(\xi t + 2\xi_k + \xi_i\frac{1}{d}\right) \quad (12)$$

Where; ξ_t is the resistance coefficient, ξ_k is the local loss coefficient of the curved tube, ξ_i is the local loss coefficient at the entrance of the tube, and d is the diameter of the discharge pipe.

Substitute equation (12) in equation (11) gives:

$$h = \frac{v^2}{2g}\left(1 + \xi t + 2\xi_k + \xi_i\frac{1}{d}\right) \quad (13)$$

The flow q_o leaving the tank is given by:

$$q_o = \frac{d^2\pi}{4}v = C\sqrt{2gh} \quad (14)$$

Using (13) and (14), the flow q_o can be expressed as:

$$C = \frac{d^2\pi}{4}\frac{1}{\sqrt{1 + \xi t + 2\xi_k + \xi_i\frac{1}{d}}} \quad (15)$$

Combining equations (15) and (10) to get:

$$qi(t) = A\frac{dh(t)}{dt} + C\sqrt{2gh} \quad (16)$$

where C represents the discharge coefficient of the valve.

Equation (16) represents mathematical model of system.

IV. METHODOLOGY

A- **Proposed System Parts**

The water level controller system consists of :

1- S7-200 PLC
2- LVDT transducer
3- Water pump driver
4- Water tank
5- Lap top computer for programming
6- RTD sensor
7- PWM driver for heater
8- ON-OFF driver for sol. valve

B- **System Design**

Figure (5) shows the block diagram of the proposed system design.

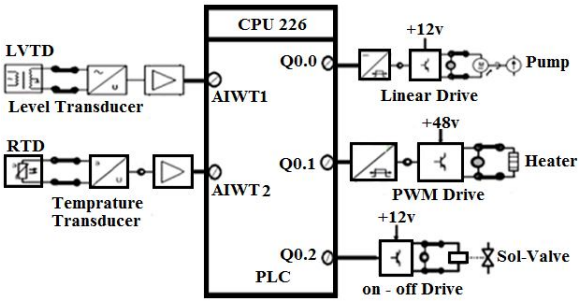


Figure 5. The block diagram of the system design.

C- **Hardware implementation**

Figure (6) shows the practical connection between S7-200, level circuit, and temperature circuit with the computer.

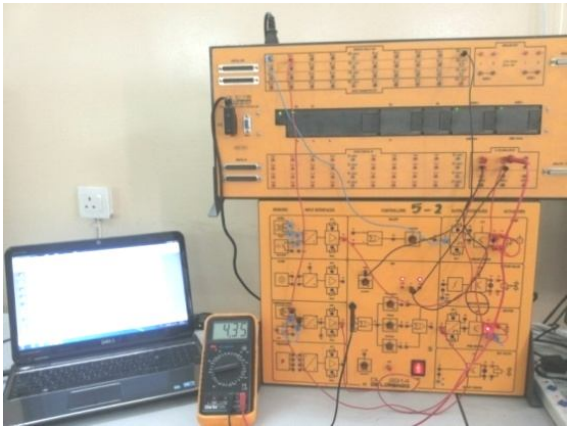


Figure 6. S7-200 PLC connected to level, temperature circuits and Laptop computer.

D- **Programming Steps**

At the first time the pump is ON and it starts working to fill water in the tank. The pump will continue work until the water reaches to upper level (10 cm), then is turned OFF. At this stage the heater is ON. The water temperature increases until reach 35 °C. Thereafter, the heater is OFF, and the solenoid valve will open to flow the water out. When the level reaches at low level (0 cm) the pump work again to fill the tank and the cycle will repeat according to the program burned in a PLC. Figure (7) shows the principle of system work as flow chart. Table (1) shows the operation steps of the system. These setting points can alter accordingly to application needed.

In addition Table I depicts the different operation steps of the proposed system design.

Table I. Status of different operation steps

Step	Pump	Heater	Sol. Valve
1	ON	OFF	OFF
2	OFF	ON	OFF
3	OFF	OFF	ON

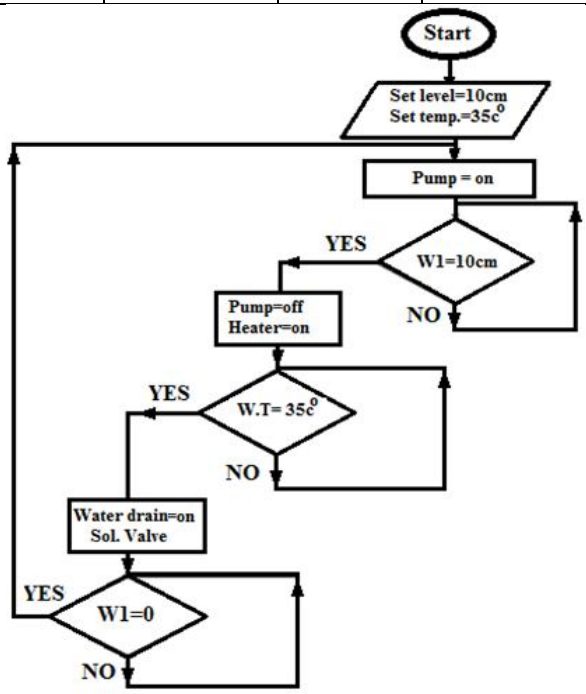
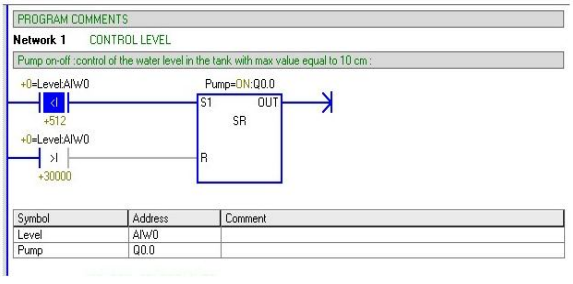


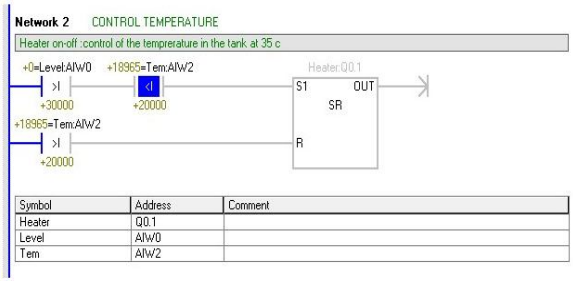
Figure 7. Flow chart of control system.

V. RESULTS

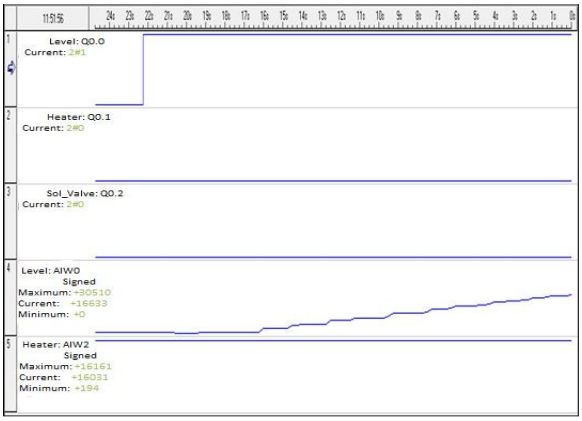
Figure (8) illustrates when the pump Q0.0=ON, the water level AIW0 increased, the heater Q0.1and Sol. Valve Q0.2 is OFF.



(a)



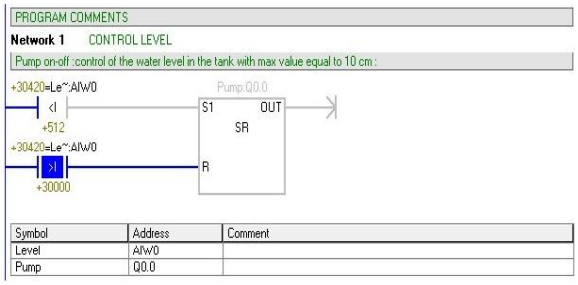
(b)



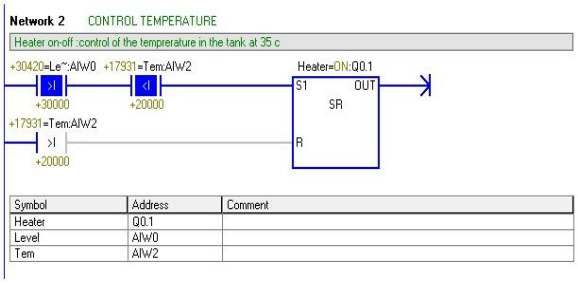
(c)

Figure 8. Level and temperature control: (a),(b) Ladder network (c) Response diagram when Motor= ON, Heater=OFF.

Figure (9) shows when the pump Q0.0=OFF, the water level AIW0 is high, while the heater Q0.1 is ON and Sol. valve Q0.2 is OFF.



(a)



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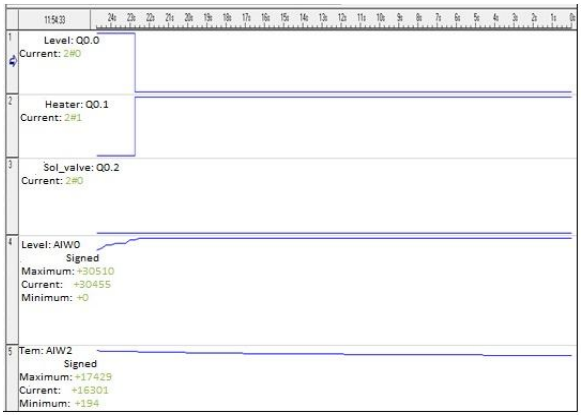
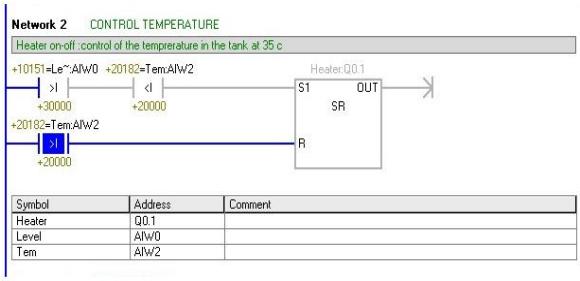


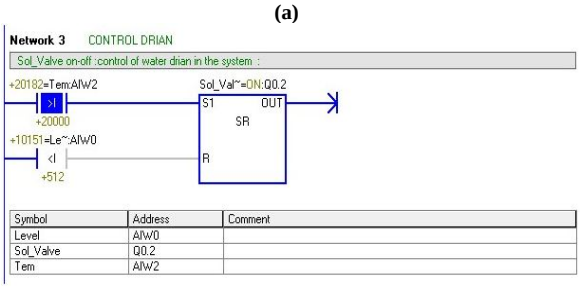
(c)

Figure 9. Level and temperature control:(a), (b) Ladder network, (c) Response diagram when Motor= OFF, Heater=ON.

Figure (10) shows that when the pump Q0.0=OFF, the water level AIW0 pour out, the heater Q0.1 is OFF and Sol. valve Q0.2 is ON.



(a)



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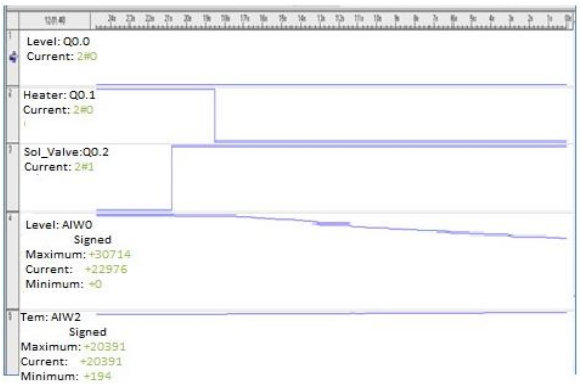

(c)

Figure 10. Temperature and drain control: (a), (b) Ladder network (c) Response diagram when Heater= OFF, Sol. Valve=ON .

CONCLUSION

Automation control of water level and temperature in the tank in case of utilizing Siemens S7-200 PLC has been tested and implemented. The LVDT and RTD sensors are used to measure the level and temperature of water inside the tank, respectively. The sensors are connected to PLC through the signal conditioning circuit. Linear drive circuit connected to PLC is used to control the motor working, and Pulse Width Modulation (PWM) drive circuit is used to control the heater working. The program was made on an experimental panel with programmable logic controller (Siemens S7-200). In comparison with the other conventional techniques, the automatic water level and temperature controller system shows appreciable performance with digital technology. Also the feature of the present design based on a PLC is a

simple construction, flexible, accurate measure, and low cost.

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