Water level control system using PLC and wireless sensors

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Abstract—This paper describes a water level control system, using SIEMENS LOGO! 24RL Programmable Logic Controller (PLC), RTX-MID-3V transceivers, converters and a pump controlled by electrical motor. The maximum water level, the minimum water level, the correct functioning of the motor driven system or some errors that can appear during the functioning of the motor driven system are visually signalled by LED-s connected to the PLC-s outputs. The goal of this paper is to present a low cost method for a water level control using a wireless solution.

Key Words-PLC, wireless sensor, transceiver and water level control.

I. INTRODUCTION

Today a very important problem is the management of the water resources from all over the world. Water is commonly used in agriculture, industry and in households.

In practice are known many types of level control that can be done. But the most common ones are those with overflow control used to prevent exceeding the maximum level that a storage tank can hold and those with fully drain for preventing the pump to work without liquid. There are cases when the two methods are combined for a maximum use of pumps capacity, for reducing the frequently starts and to reduce working for a short period of time.

Low power control system are based on a specialized sensor are very simple but must take in consideration the pumps power and the power that the sensor can switch. Some types of water level control systems can be enumerated:

- Water level control systems using programmable logic controller and industrial wireless modules for industrial plants, in this system the process variable is the water level from a tank [1,2,3]. The Programmable Logic Controller (PLC) starts the pump when the water level is minimum and allows it to run until the water reaches the maximum level.

- Water level control systems using optical sensors. Such system can be used for obtaining an error signal depending on the water level in the tank.

A water level control system design must also take in consideration the cost of the system devices.

II. WATER LEVEL CONTROL SYSTEM-IMPLEMENTATION ASPECTS

Sensors with floating balloon are frequently used for small home and industrial applications because of their low acquisition cost.

T20/T21 is a level sensor with floating balloon assembled above the tank produced by Magnetrol (fig. 1). T20 model has only one level contact, and T21 model has two level contacts for the minimum and the maximum level that can appear between the two commutations. Another level sensor produced by Magnetrol is T62/64, but for this sensor the floating balloon is assembled on the side of the tank.

Thermal detection sensors produced by Ameritron are used in the pharmaceutical, chemical, oil and food industry with the possibility of detecting and recognizing a liquid by its heat, a liquid from a solid, the turbulence level inside a storage tank and a fluid flow rate.

Optical sensors for detecting fluid level produced by GEMS are a revolutionary type of sensors for industrial and home applications because of their low acquisition cost.
cost. The main disadvantages of this type of sensors are the periodic maintenance tasks and the impossibility of being used in dirty liquid tanks.

In the magnetic level sensors case the visual system is different by the way it’s attached to the storage tank.

Figure 1. Level sensor T20/T21 [14]

The liquid enters inside the probe offering a level visual indication besides that offered by the analogical output of 4-20 mA or by the modules mounted directly for obtaining by the level that is set the maximum or minimum control.

Contact ultrasonic sensors detect liquids or solids by their viscosity.

Contact guided wave radar sensors have a very accurate liquid or fluid particles level detection principle and they are sensors with GWR (Guided Wave Radar) revolutionary technology. Radar sensors for level detection without contact are Pulsar R50 [14], they are produced by Magnetrol and they are the most advanced generation of sensors.

Theoretical, they can be used for any substance level measurement including substances that release vapours or with surface turbulences, dielectric liquids and volatile particles.

A transceiver that can be used for transmitting or receiving data is RTX-MID-3V. This transceiver has an ASK (Amplitude Shift Keying) modulation, a battery supply and it’s ideal for low cost applications. ASK is a modulation form, which presents the digital information as amplitude variations of a carrier wave. The amplitude of an analogical carrier varies with the modulation signal, keeping constant the frequency and the phase. The amplitude level can be used for binary representing logic 0 and 1. Like amplitude modulation (AM), ASK modulation is linear, sensitive to atmospheric noises and sensitive to distortions.

These wireless sensors are used to hand held terminals and to wireless ringers. All transceiver features can be handled by 5 lines: TX/RX, ENABLE, DATA IN, DATA OUT, ANALOG OUT.

If line TX/RX is driving low then the transceiver is a receiver and if the line is driving high then is a transmitter.

If line ENABLE is driving low then the transceiver is on reducing energy consumption mode, the energy consumption is 8 μA in this case. In this mode the transceiver can’t neighbour transmit or receive data.

If lines ENABLE and TX/RX are driven high and line DATA IN is driven low then the transceiver is on the Idle mode. In this mode the transceiver is on with consumption of 4.5mA, from this mode the transceiver becomes transmitter when DATA IN line is driven high.

The transceiver becomes receiver when line TX/RX is driven low and line ENABLE is driven high.

In fig.2 is presented the RTX-MID-3V wireless sensor. These transceivers can be supplied with a voltage between 2.1 and 3.6 V.

Figure 2. Pin description: 1- antenna, 2- ground, 5- data in, 6- enable, 7- ground, 8- analog out, 9- data out, 10- Vcc [15]

In fig.3 is presented the experimental stand (electronic panel) implementing an automated changeover system controlling the water level and using a resistive electronic sensor. In fig. 4 is presented the diagram of this installation. This diagram can be manual controlled, not only automatic controlled. The sensor used is a resistive electronic sensor with electrodes.

The automatic or manual operating mode can be choose by a function selection key that has three positions. On the 0 position the installation is turned off. On the D position the installation is manual controlled by the buttons: on button, off button and error button which is installed by the motor of the pump for emergency stop in case of need. The L position is for automatic control.

The system works only when is selected the L position, button is on OP position, the delay time has passed and $k_4$ is on close position.

Figure 3. Water level control system - experimental stand (partial view)

The minimum level is detected by $k_1$. When the maximum level is reached, $k_2$ and $k_3$ are switching to logic 1, $k_2$ is ordering through the off button $k_6$ which memorizes the plug in position through $k_4$ and by an auxiliary contactor. When the maximum water level is decreasing the pump is turned ON through $k_1$, when the water level is decreasing under the minimum level the power supply of the $k_6$ contactor coil is stopped and in this way the pumping installation is turned off.
III. WATER LEVEL MEASUREMENT USING WIRELESS SENSORS

The maximum water level measurement and adjustment system accomplished uses a water tank, two RTX-MID-3V transceivers, a SIEMENS LOGO! 24RL PLC, four converters and a pump driven by a motor.

The principle of this system is: when the water in the tank is at the minimum level the sensor detects the minimum level and sends the information to level-logic 1 converter which converts the information in logic 1 to be interpreted by the transmitter sensor $TX_1$. The transmitter sensor $TX_1$ sends the information to the receiver sensor $RX_1$, the information is converted from logic 1 (a signal between 1.2 and 2.6 V, depending on the distance) to 24 V continuous current and then it is introduced into the programmable logic controller by the $I_1$ input. Using $Q_1$ output the programmable logic controller turns off the pump. When the maximum level is reached a LED signals this, the LED is connected to the $Q_3$ programmable logical controller output.

For measuring motor speed pump, at the rotors shaft it’s connected an analogical tachogenerator, which at the nominal motor speed has about 24 V output.

The PLC input $I_3$ is used for measuring the pump motor speed (fig. 6).

$Q_2$ and $Q_3$ programmable logic controller outputs have connected a LED that signals the motor correct functioning or a motor error.

Depending on the relief the distance between the transmitter sensor and the receiver sensor can be hundreds of meters.

The programmable logic controller is powered on 24 V continuous voltage, it has 12 inputs numbered from $I_1$ to $I_{12}$ and 8 outputs numbered from $Q_1$ to $Q_8$.

If it’s considered that the nominal voltage of the LED is 1 V and the nominal current is 10 mA then the value of $R_2$, $R_3$, $R_4$, $R_5$ resistors from fig. 6 is determined with the expression:
The closes nominal value of $R_2$, $R_3$, $R_4$, $R_5$ resistors is $2.7 \, k\Omega$, and the power is $0.27 \, W$. In fig. 9 it’s presented the variation of the exit voltage when the voltage supply is growing from 0.2 to 0.2 V, for the case when the receiver sensor is driven high and low. In fig. 9 the exit voltage is growing faster when the receiver sensor is driven high than when the receiver sensor is driven low. The used PLC has two types of visual programming languages:
- FBD (Function Block Diagram) using its buttons and display
- LAD (LADDER diagram) and FBD- when the programmable logic controller is connected to the computer [16]

The PLC program (FBD) is presented in fig. 10.

While the sensor send information signalling that the water level is under the minimum level ($I_1 = 0$ logic) for the $t_1$ time the pump is turned on. Depending on the motors power, it needs a $t_2$ turn on time from the B07 block (fig. 10). When the $t_2$ time has passed it’s considered that the motor reached to the nominal speed and $I_3$ is driven high. If after the $t_2$ passed the $I_3$ isn’t driven high then $Q_1$ output is driven low and the motor is turned off. By measuring the motors speed with the tahogenerator we can determine if the motor is working correctly.

B06 input, which is a NOT block, is $I_1$ which represents the minimum level detection. The NOT blocks output is B05 input, B05 block is a timing block. The second B05 input is the $T(t_1)$ timing. B07s input, which is a timing block, is $I_3$ which represents the detection of the nominal motor speed and the $T(t_2)$ timing. The two block outputs are inputs for B04 block, which is a NOR block with three inputs. The third input is the expression
1(driven low). The NOR block output is input for the OR block B03, together with $I_1$ input, that represents the detection of the maximum level and the expression lo (driven low). B02 block input, which is a NOT block, is $I_1$, which represents the minimum level detection. B02 block output is B01 block set input, B01 block is a Reset-Set block. The reset input is B03 block output. And the third input is a parametric input represented by the expression lo (driven low).

B01 block output is $Q_1$, which turns on or off the pump.

For detecting the minimum and the maximum level, as well as the correct functioning of the motor are used $I_1$, $I_2$, $Q_1$, inputs and $Q_2$, $Q_3$ and $Q_4$ outputs.

For every block are used logical Or gates and other two inputs driven low.

B01 block is presented in fig.12 it’s input is $Q_1$ and $Q_2$ is it’s output , B01 is an inverter detects if the motor is on (because the maximum level it’s reached or the motor failed).

![Image](http://www.shiva.pub.ro/PDF/SCI/Manual_Logo.pdf)

**Figure 11. Experimental panel for the SIEMENS LOGO!24RL programmable logic controller**

The program was made on an experimental panel conducted in the laboratory (fig.11).

**IV. CONCLUSIONS**

A solution for water level control system using PLC and wireless sensors is proposed, designed, implemented and tested. The advantages of a design based on a PLC are simplicity, flexibility.

The water level control system using PLC and wireless sensors is a simple one and combines wireless sensors and programmable logic controllers.

The program was made on an experimental panel with a SIEMENS LOGO! 24RL programmable logic controller conducted in the laboratory.

Wireless sensors and PLC are modern technologies that can be used for several control systems such as water tank level process.

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