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AUTOMATED CONTROL SYSTEM IN POTABLE WATER PLANT FOR LOAD OF TANKERS

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ABSTRACT

This project involves the design and implementation of a computerized control system for the automation of a potable water loading plant using tank trucks. Pumps and valves of the storage tank are controlled through a set of electronic instruments, especially the ultrasonic sensor, which is essential in monitoring the plant. Graphical LabVIEW interface is used to monitor the valves' control, the switching of the submersible pumps, and the level of the tank. It also allows taking the user data who makes a service request and saving it in a database for future use. As a result of this work, a fully automated plant is obtained; it is capable of automatically supplying the volumes of water required by the user. All is controlled through an application in LabVIEW that allows monitoring and visualizing in real-time the events generated by the process from the loading of drinking water to tank trucks.

Keywords: sensor, database, actuator, automation, instrumentation, LabVIEW.

1. INTRODUCTION

Automation is a process where the production tasks that are performed by humans are transferred to the machines to apply the use of technology (QuimiNet, 2012). The importance of automation in the process industry has improved incredibly in recent years and has become a driving force for the entire chemical, oil, gas, and biotechnology sectors. Innovative instrumentation systems control complex processes, complications and process safety, and the basis of advanced maintenance strategies. Technological advances have strongly influenced the increase of productivity and the use of resources, just as much of the world's industrial production is controlled by automatic or semi-automatic control systems (Camilla, 2006). In many cases, automation is implemented to avoid risks and accidents to workers (Robayo *et al.,* 2020).

For almost three decades, engineers and scientists have used and relied on systems design software to acquire, analyze, and visualize real-world data (Interempresas, 2009). The HMI (Human-Machine Interface) is the station through which the operator of the observation control room and taking action on the regulatory control of its production process, arrangements, and equipment, visualizes alarms and graphs of Trends of the different variables (Domínguez, 2007). For the process to work well, it is necessary to permanently maintain the equipment and facilities in their best state to avoid downtimes that increase costs (Atlantic International University, 2008).

Important projects related to the area of water plant automation have been developed, such as the automation and instrumentation of a scale bottling plant that shows the stages of a real bottler educationally using a Programmable Logic Controller (Peñaloza, 2008). However, the development was done on a small scale and for educational purposes. The work of the automation of a water treatment plant is primarily related (Vargas, 2009). They propose the technological update of the instrumentation of the plant that presented manual operation, with excellent results. More recently, related works have been found. The automation system for filling a water tank applying an ultrasonic sensor, an automatic switch module, a water-flow sensor, an Arduino microcontroller is implemented (Prima *et al*., 2017). However, there is no list of automation works carried out in the process of loading water from tank trucks.

This project aims to implement a computerized control system where the monitoring, registration, and visualization of a set of elements and variables of a drinking water loading plant for tank trucks is obtained. Different variables are controlled that provide the necessary and exact amount of drinking water that is transported through tank trucks to various sectors of the city where users acquire it for different purposes.

The development of this proposal will not only bring economic benefits to the owner of the plant and its users but also provides a significant contribution to the technological development of the region. It can be an innovative project implemented in a drinking water distribution plant where all its processes were performed manually by an operator.

2. MATERIALS AND METHODS

The design of the computerized control system in the drinking water plant allows monitoring and control in real-time the level of the storage tank and, from this information, control the volume of water required by the user. The design consists of three stages, the stage of information gathering and selection of the means of communication through the visit to the physical plant, the step of instrumentation and control, and the stage of visualization and data collection.

2.1 Collection of Process Information

This stage consists of studying and describing the drinking water plant taking into account the components that it has for its operation. The plant has a lifting tank with the following dimensions, 5.70 meters long, 3.02 meters wide, and 1.70 meters high, and the highest level of water is 1.55 meters high since from this height, it has an overflow outlet. It is in the capacity to store 26.68 cubic meters of water that are around 7048 gallons of water. The plant also has two wells, each 7 meters deep, responsible for the supply of drinking water. The water is pumped through two submersible pumps of 3 inches of flow that fill the lift tank, in addition to the process of Gravity water discharge has two outlet valves, every 3 inches in diameter. Knowing already the components observed in the visit to the physical plant, the subsequent study of the selection of the type of instruments that best fit the previous characteristics is carried out.

Figure-1 shows the physical plant in its initial state, that is, without automating, completely manual.

Figure-1. Physical plant, storage tanks.

Before its automation, the operation of the plant is described as a completely manual plant without any level measuring element, without any electronic instrumentation or computer system. The operator carried out the water loading process based on his experience.

2.2 Storage Tank

It is a structure made of cement of cubic form used to store drinking water at ambient pressure. Its measures are 1.70 m high, 3.02 m wide, and 5.70 m long; that is, it can save 7048 gallons; It consists of two input channels, two output channels, and an overflow channel shown in Figure-2.

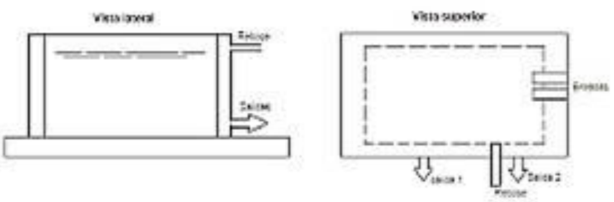

Figure-2. Physical shape of storage tank.

2.3 Determination of the Communication System

For the communication system, characteristics of the medium, different operating parameters of the variables to be controlled, and the cost-benefit ratio that make the selected system adjust without any problem are considered. A wired network is chosen which allows the exchange of electrical signals from one point to another, since the computer center, the sensor and the control card are located at a minimum distance of 5 meters between them, thus obtaining a communication No interference and no loss of information.

2.4 Instrumentation and Control Stage

The instrumentation and control stage is responsible for the adaptation and acquisition of the process variables, the water level control in the lifting tank, and the two-way communication with the visualization and data collection stage. First, the magnitude of the process variable supplied by the ultrasonic level sensor is obtained, then the signal conditioning is carried out to obtain adequate voltage levels for its acquisition. This data is then processed, getting the real value of the water level in the tank to be transmitted to the computer for visualization in the graphical interface in LabVIEW (Roncancio, 2001). For the control stage, a microcontroller receives the water requirement value established by the user from the graphical interface. It performs the necessary processing to know if the storage tank has water availability and then decides to discharge to the tank truck or, on the contrary, fill the container to meet the requirement and its subsequent unloading.

The ultrasonic sensor HC-SR04 is used to measure the water level of the tank. The necessary electronic conditioning is carried out to obtain the appropriate voltage levels at the input of the microcontroller, thereby achieving adequate data acquisition for future processing. The type of controller chosen is ON / OFF used to control two essential processes: first, the opening and closing of the discharge valves of the lift tank, and second the on and off of the two three-inch submersible pumps responsible for water supply drinking and filling the lift tank.

2.4.1 Opening and closing of output valves

For the opening and closing of the valves, the controller receives the value of the gallon requirement requested by the user sent from the graphical interface in LabVIEW. Then, it compares the requested value with the number of gallons of water available in the lift storage tank. Subsequently, if the requested value is below the existence of water in the tank, it automatically puts up an output pin of the microcontroller to open the discharge valves until the number of gallons of water discharged reaches the value of the requirement that the user entered. And then close the valves and leave them in their initial state.

2.4.2 Turning on and off submersible pumps

To switching the pumps between on and off states, the controller is used. It works based on the requirement requested by the user. The user requests a specific value of gallons of water for supply, and this value travels from the graphical interface in LabVIEW

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until the controller. In the processing stage, it is verified if the user's requirement is available or not available for download, if the demand is not complete, the controller does not open the valves; on the contrary, it keeps them closed. Now the pin which is set high is the one programmed for the ignition of the pumps, which is high until the requirement is available and ready to be discharged; at this moment, the controller turns off the pumps, and immediately it activates the valve opening pin for Your download. After completing the download process required by the user, the controller is waiting for a new requirement to restart the process.

2.5 Display Stage and Data Collection

The main objective of the visualization and data collection stage is to establish two-way communication with the instrumentation and control stage. Also, its responsibility for the real-time visualization of the water level stored in the lifting tank, allowing the input of the required value in gallons of water by the user. And finally, it takes care of the data collection and registration of the user who made the requirement to save all this information in a database subsequently. It can be displayed and keep a record of both the accounting and the plant performance and productivity.

3. RESULTS AND DISCUSSIONS

3.1 Project Block Diagram

The project is represented in Figure-3, where the microcontroller (Microchip, 2006) is shown as the central process system that communicates with the actuators, receives signals from the variables to be controlled, and maintains two-way communication with the graphical interface.

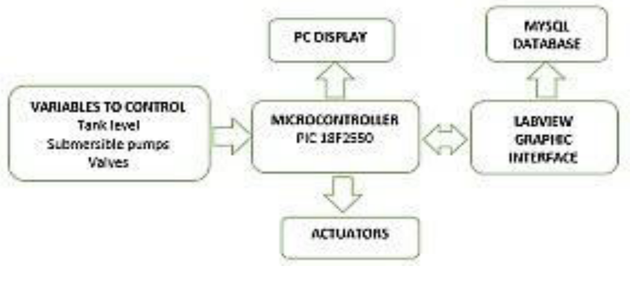

Figure-3. Project block diagram

3.2 Software Development Required for the Control System

The software through the LabVIEW graphical interface is implemented, including the control, visualization, acquisition, and storage of the data obtained from the variables to be processed. The programming for the PIC18f2550 microcontroller is also developed.

3.2.1 LabVIEW graphic interface

The Control Panel is shown in Figure-4. For a better interpretation of the operation of the graphic control and monitoring interface, its controls and functions are detailed in several blocks.

Figure-4. Graphic Interface Control Panel.

3.2.1.1 Real time tank display block

This block is located on the control panel, as shown in Figure-5. It shows the tank level in real-time, and it has a numerical indicator at the top that shows the tank level in centimeters. It also has three indicator lights that show three current states of the tank level: minimum, medium, and maximum. To the right of the control panel, a small block has three more indicators, which show the volume of water stored in gallons, barrels, and cubic meters of water. It is advantageous to know the amount of water with which the plant has in an instant time for distribution. Finally, three circular indicators show the on / off status of the submersible pumps and the solenoid valves of the pneumatic system used for the opening and closing of the valves (tank output).

Figure-5. Real-time tank level indicator block

3.2.1.2 Request block and requirement display

The request and display block are shown in Figure-6, where the operator can enter the numerical value of gallons required by the user. Once the value is entered, the discharge of the required water is started by pressing the "ok" button. An indicator automatically shows the value in pesos that the user must cancel. On the bottom, an indicator tank shows the amount of water discharged from the main tank to the tank truck that is being loaded. And finally, to keep visual control of the water supplied, three numerical indicators show the volume of water delivered in gallons, barrels, and cubic meters. Once the delivery is finished, clicking on the button to clean the system is ready to enter a new requirement.

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Figure-6. Request block and requirement display.

3.2.1.3 Register block

It allows the entry of user information, filling in the respective fields such as the name of the driver of the tank truck, name of the company to which it belongs, numerical value of the supply charged by the user, and value in pesos paid. And a field to add Any comments to take into account, as shown in Figure-7. It is necessary to press the save button and to finish the process, press the clean button, in charge of leaving all the fields blank ready for a new user.

Figure-7. Register block.

3.2.1.4 Manual control block

It controls the opening and closing of the valves, such as the switching of the pumps. It is then pressing the ok button to start the process. A "stop" button is also added, which, when pressed, stops the interface process, as shown in Figure-8.

Figure-8. Manual control block.

3.2.1.5 Water charge interface description

On this interface, the information recorded in the registration block is shown. It allows you to keep track of the operation of the plant, where data such as the date/time, the name of the driver of the tank truck, company, vehicle license plate are observed, supply, price, and finally, some comments regarding the service provided, as shown in Figure-9.

Figure-9. Water charge interface description.

3.3 Design and Implementation of Hardware for the Control System

The ultrasonic sensor HC-SR04 is conditioned for the real-time capture of the tank level (Morgan, 2014). The design and development of a metal structure are required for its implementation and location in the tank. It holds above the surface of the tank and protects it from possible damage caused by the surrounding environment, as shown in Figure-10.

The HC-SR04 sensor works with a 5-volt DC supply and has a current consumption of less than two mA; it is composed of a transmitter and a receiver. With the sensor, the distance from the sensor to the water level in the tank is measured. It is done by sending an ultrasound and measuring the time the signal takes to return; with this information, the distance is calculated using the following equation.

$$x = \frac{t * v_s}{2}$$

Where x represents distance, t is the time, and v_s the speed of sound. This data is acquired by the PIC 18f2550 microcontroller and sent to the LabVIEW graphical interface to visualize the level of the storage tank.

Figure-10. Adaptation and assembly of the HC-SR04 ultrasonic sensor.

The electronic card designed as a plant controller has the PIC 18f 2550 microcontroller with a USB connection. It has the signal amplification circuitry using optocouplers 4N25 which work together with 2N3904 transistors. Finally, NRP07 relays that are responsible for feeding the coil of the solenoid valves for the operation of the pneumatic system. It is responsible for opening and closing of the valves and supplying the coils of the relays that control the contactors of the submersible pumps, as shown in Figure-11.

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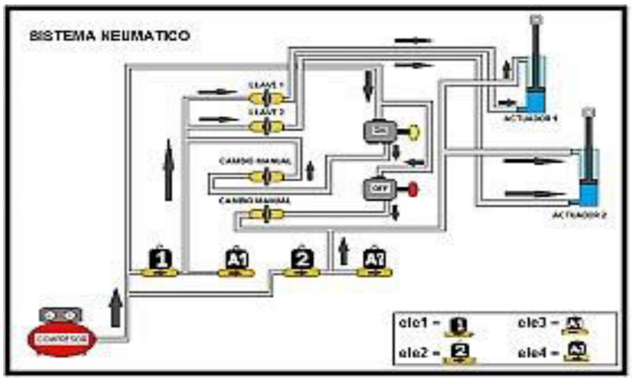

Figure-11. Schematic representation of the pneumatic system.

This card is designed and attached to an acrylic box located in the computer center, as shown in Figure-12 (Ultra Plas S.A., 2012).

Figure-12. Pneumatic system control board.

The control card consists of two stages, the data acquisition, and information processing stage and the power stage, as shown in Figure-13. For the data acquisition and information processing stage, the PIC microcontroller 18f2550 is used. In the power stage, the responsible for pumps, opening, and closing of the valves, are the optocouplers, transistors, resistors, and relays**.**

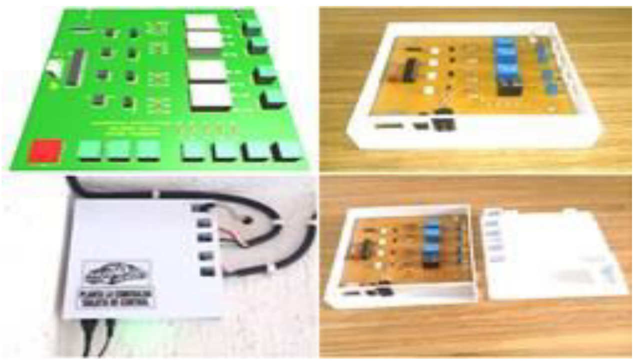

Figure-13. Control card.

4. CONCLUSIONS

An automated system was designed and implemented for the tank for the loading of drinking water for tank trucks capable of controlling the level of the tank and the amount of water required by the user. The implementation of the project guarantees the desired response, avoiding losses for both the owner of the plant and the same user.

Through LabVIEW, an operator-friendly graphical interface was developed that is capable of controlling all the operation of the plant and also provides the option of creating a database with all user information to carry out a better productivity analysis of the plant.

The level control system implemented ensures that the plant's tank is never empty, and there are no gallons of water due to overflow, thus guaranteeing its correct operation.

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