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AUTOMATION OF STORAGE AND DOSING PROCESSES IN TANKS WITH SULFURIC ACID

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ABSTRACT

This study involves the filling automation and dosing control of a sulfuric acid storage tank with a capacity of 20000 liters. The filling control to carry out the reaction of sulfuric acid with bauxite more precisely avoiding risks and accidents to workers is proposed. To achieve this, a system that uses a flow sensor, a transmitter, and a PLC (Programmable Logic Controller) which performs the control actions on the solenoid valves and the centrifugal pump has been designed and implemented. Also, an HMI (Human Machine Interface) that allows the operator to manipulate and interact with the system to perform storage and dosing operations automatically or manually is performed. As a result of this work, a system in which the operator can store and dose sulfuric acid automatically or manually from the operating panel safely is achieved.

Keywords: control, automation, sulfuric acid, PLC, HMI, transmitter.

1. INTRODUCTION

Nowadays, companies seek to improve their making processes to be more competitive in the market and provide security to their employees, with an important electronics contribution to perform control and automation of industrial processes (Itei ingenieros, 2015), where automation is understood as a part of the technological advances with which it seeks to operate and control the manufacturing processes through the use of mechanical, electronic and computational devices, reducing the intervention of the human factor within the process, eliminating the deviations generated (Montemayor, 2012). Automation is a system where production tasks are transferred, usually performed by human operators to a set of technological elements (Maser Group, 2015). For different automation problems, a variety of solutions are mentioned, some more sophisticated than others, whose application depends not only on the knowledge of the technique, but also on the personnel who will be responsible for its execution (Tecsup, 2015). Proposals arise like Industry 4.0 that connects system production technologies and intelligent manufacturing processes to give way to a new era in technology (Gtai, 2014). PLC's are controllers for use in machines and industrial processes, which can be programmed for the specific application (Cobo, 2015). The control algorithms developed in PLC must ensure the reliability of the process by means rules that allow "all" the risk possibilities to be included, both for people and for the plant itself (Konaka *et al.*, 2003). HMIs are currently used to represent the reality of the processes "identically", allowing operators to interrelate the physical equipment of the plant with the virtual equipment (Mathiesen *et al.*, 2006).

This project is developed in a sulfuric acid storage area, which there are 10 tanks, each with the capacity to store approximately 20000 liters of sulfuric acid (Quinsa, 2018) as shown in Figure-1. The plant has 2 dispensers, which sulfuric acid with water and bauxite are mixing to obtain batch of granulated aluminum sulfate type B. Before the automation implemented in this project, all the processes were carried out manually through an operator. The storage tanks level measurement and dispensers were made by mechanical methods of measurement. The length measurement of one meter extended along the tank determined the tank filling level. The tanks filling control and dispensers was done by turning the pump on and off by the operator, by opening and closing the ball-type valves.

Figure-1. Storage area.

Tank number 4 in the sulfuric acid storage area and dispenser number 1 are chosen for the project development. The project stages are executed as follows: First, a study of the MAG 3100 sensor and the MAG 5000 transmitter is achieved. Then the system design and search for its appropriate elements is carried out. Next, the programming of the PLC and the HMI devices is implemented. Afterwards, the simulation test in the laboratory correcting and adapting the system to conditions that arise when it is in operation is performed.

Finally, the system is installed for functional tests and modification.

2. MATERIALS AND METHODS

The filling automation control in the sulfuric acid storage and dosing processes of this project is based on four main elements, which are MAG 3100 flow sensor, MAG 5000 flow transmitter, PLC V120-22-T2C and Maxtech MT070 HMI. The connection between them and the solenoid valves and centrifugal pump, creates a system that allows the operator to store sulfuric acid in the tank number 4 and the dosage of the same liquid in the number 1 dispenser in a safe and controlled way.

2.1 MAG 3100 sensor and MAG 5000 transmitter

The function of these equipments is to produce an analog signal from 4 to 20 mA, in which the sulfuric acid flow rate circulating through the sensor is indicated, then this signal is received in the PLC to perform the calculations and the actions to follow are determined.

The MAG 3100 sensor and the MAG 5000 transmitter belong to the SITRANS FM family characterized in that it measures the flux by electromagnetic principles. The flow measurement principle is based on Faraday's Law of electromagnetic induction which states that when an electric conductor of length L moves at speed and perpendicular to the flow lines, through a B intensity magnetic field, a tension Ui at the conductor ends is induced. A pulsating magnetizing current that activates the sensor coils is generated by the current module in the transmitter coils. Cable errors or failures are recorded by a self-monitoring circuit in the transmitter. The coils in the sensor are mounted diametrically in the tube to be measured generating a pulsed electromagnetic field; When the liquid flows through this electromagnetic field a voltage is induced. The induced voltage signal proportional to the flow from the electrodes is amplified by the transmitter input circuit. Measurement errors caused by the cable capacity are determined by the active shielding of the cable. In the transmitter the analog flow signal is converted into a digital signal by the digital signal processor and suppresses the electrode noises by means a digital filter. Any inaccuracy of the transmitter, as a result of long-term derivatives and temperature, is continuously monitored and compensated through the self-monitoring circuit. The conversion of analog signal to digital takes place in an ultra-low noise ASIC (Application Specific Integrated Circuit), with a signal resolution of 23 bits.

The transmitters are based on a microprocessor and have an alphanumeric display in several languages, evaluate the signals of the electromagnetic sensors, then convert them into appropriate standard signals (such as 4 to 20 mA) and also perform the function of a power unit that provides a constant current to the coils. Finally, the transmitter consists in a function blocks series that convert the sensor voltage into flow reading by displaying it on the screen.

2.2 PLC Vision V120-22-T2C

The function of this device is to receive the signal from the MAG 5000 transmitter and handle the valves and centrifugal pump, according to the programming that is being executed.

The V120-22-T2C PLC is a small and compact size PLC with good performance to be used in not much effort works, they also come with a screen and keyboard in such a way that it can be used as an HMI. The main features of the PLC are mentioned below.

- 10 digital inputs, including 3 inputs that can function as high-speed counters, axis encoders, frequency meters or normal digital inputs.
- 2 analog / digital inputs, the analog inputs are multi-range: 0-10V, 0-20 mA, 4-20 mA. Which can be configured through an internal switch.
- 12 digital outputs type P-MOSFET.
- Power supply: 12/24 VDC, the digital outputs and inputs are the same as the power supply.
- Additional 128 I / O with expansion modules.
- Programming memory: 448k.
- Graphic LCD display, with resolution of 128X64 pixels.
- 16 keys
- 2 RS232 / RS485 communication ports selectable.

The programming is done in the VisiLogic software in its version 9.4.0 which was supplied by the manufacturer together with the sensor and transmitter, the programming is done using the LADDER method as shown in Figure-2.

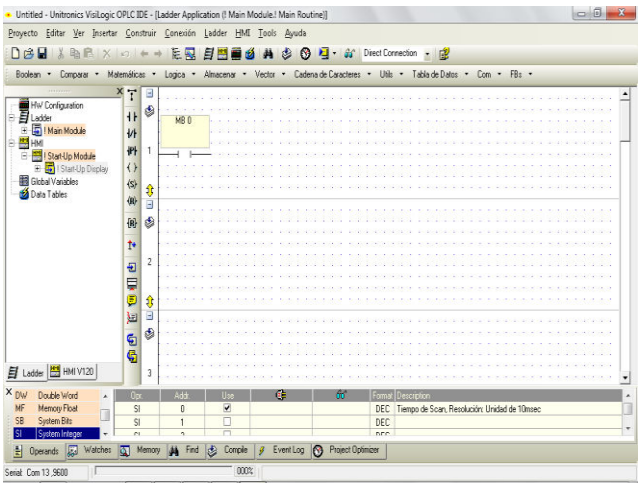

Figure-2. VisiLogic interface version 9.4.0.

2.3 Maxtech MT070 HMI

This interface is a 7-inch HMI with resolution of 800x480 pixels, in which several screens are programmed to establish communication between the operator and the system, and this carried out the actions that the operator wishes to perform either store, dose or turn on / off any element connected to the system such as solenoid valves or centrifugal pump.

HMI programming is done in the Maxtech Designer software version 1.2.98.00, as shown in Figure-3. Programming is done by creating screens, buttons and macros, and relating them to each other. Programming is done in macros and these can be associated with screens and buttons. The buttons have addresses which are used to operate in macros.

To perform communication between the PLC and the HMI, a UTP cable from the COM 1 port of the HMI to the PLC port 2 is connected, configured in RS232 protocol.

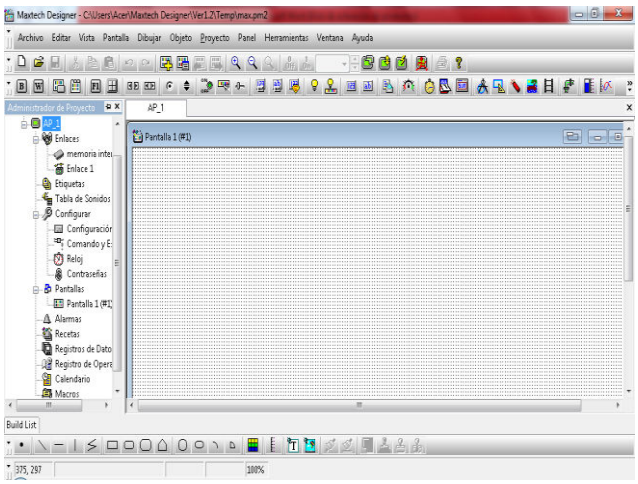

Figure-3. Maxtech Designer interface version 1.2.98.00.

3. RESULTS AND DISCUSSIONS

3.1 Hardware description

The system has three main sections, the operation board is shown in Figure-4, the backup board as presented in Figure-5 and terminal elements such as solenoid valves and centrifugal pumps.

Figure-4. Operation board.

On the operation board the PLC, HMI and power supply, are located in a sealed plastic box to protect these elements from acid vapor and other external agents that can corrode and damage them. The operation board distribution is made up of 5 sections listed in Figure-4. These sections are the HMI, PLC, switches, LEDs and push buttons.

The backup board function is to energize the valves and the transmitter by switching the electrical sockets assigned to each element and allowing the enabling of these same elements in the system, in case the system is damaged or needs reprogramming. It is divided into two sections, manual mode and system mode as shown in Figure-5.

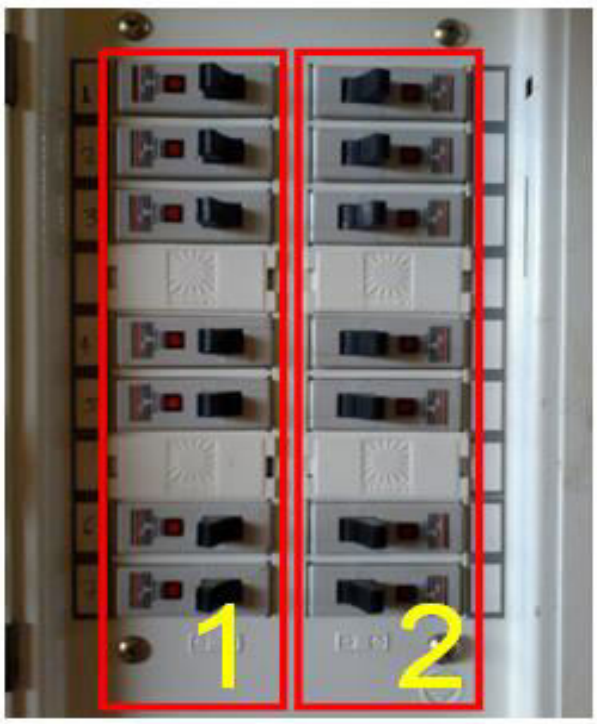

Figure-5. Backup board.

3.2 System operation

The backup board must be configured as shown below.

All electrical plugs in the manual section must be OFF, all electrical plugs in the system section must be ON, this enables the manipulation of the terminal elements by the system. The ON / OFF switch of the system is placed in the ENERGIZE position which energizes the PLC and HMI by displaying the HMI configuration screen on the HMI, in this screen only the RUN button must be pressed. When the RUN button is pressed, the HMI programming is loaded, which shows the Modes screen as shown in Figure-6. By pressing the MANUAL OPERATION screen button, the screen of the same name is loaded as presented in Figure-7, in this screen each element can be energized by pressing the OFF button of the desired element. In the same way each element has a VIEW button which shows on the View screen the element highlighted in red as displayed in Figure 8. This screen exits when you press the EXIT button by reloading the manual operation screen. With the STOP button and the MODE SELECTION button you can stop the elements that are currently energized.

Figure-6. Modes screen.

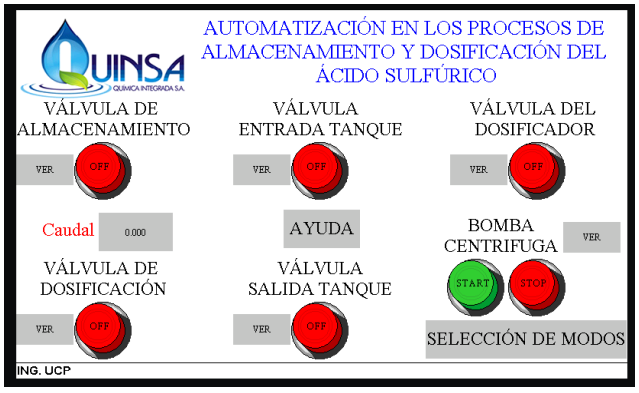

Figure-7. Manual operation screen.

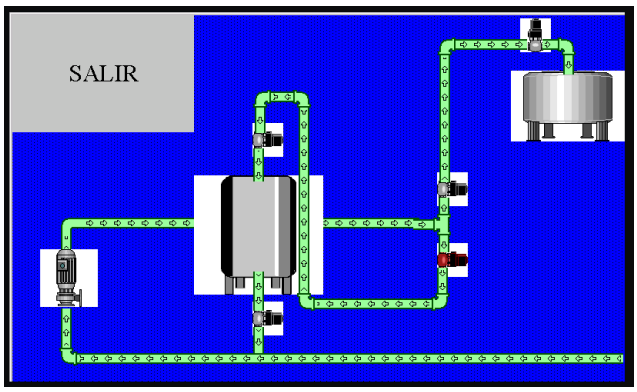

Figure-8. View screen.

By pressing the AUTOMATIC OPERATION button on the Modes screen, two options are displayed depending on the switch position, STORE mode or DOSING mode as shown in Figure-9. On both screens, pressing the CANCEL button loads the Modes screen again. Because the transmitter is a fundamental part of these processes, if it is not energized, a message will appear on the screen asking you to energize it if you do not, you will not be able to advance in the system configuration.

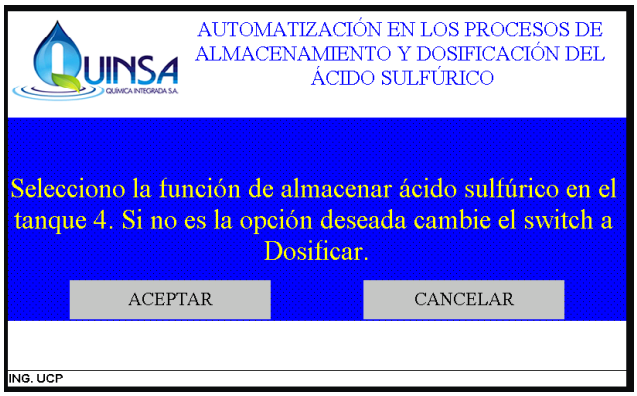

Figure-9. Automatic operation screen store mode.

When the ACCEPT button is pressed on the automatic operation screen presented in Figure-10, the storage mode screen is loaded as shown in Figure-11. When the START button is pressed, the storage process is started by activating the LEDs RUN, SOUL, VALVE SOUL MODE, VALVE INPUT TANK and PUMP. Once the tank is full, the process storage mode screen is shown in Figure-12. In addition, the system has damage detection to the pump since if at the start of the process, after 3 seconds it does not exceed the flow rate 0.5 l / s, the operation is stopped and a message indicating that the centrifugal pump is damaged is shown.

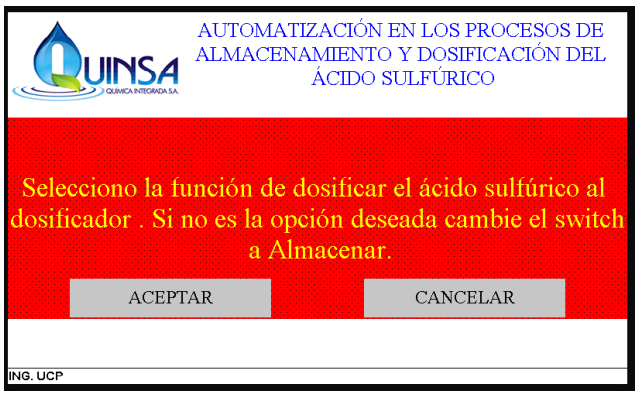

Figure-10. Automatic operation screen dosing mode.

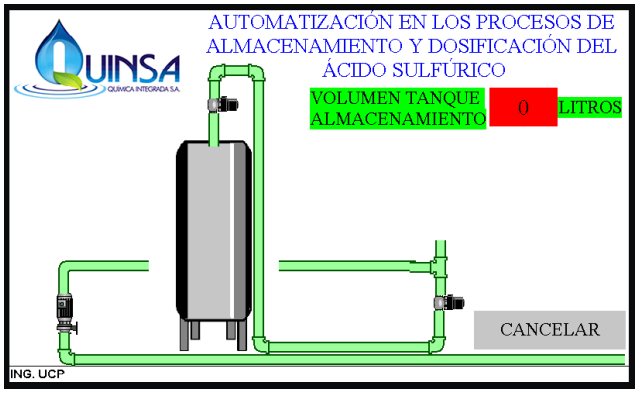

Figure-11. Storage mode screen.

Figure-12. Storage term process mode screen.

When the ACCEPT button is pressed on the automatic operation screen dosing mode, the dosing mode screen is loaded as shown in Figure-13. In this screen the volume to be dosed is selected. By pressing the 1375 L CONSTANTS button, the dosing mode screen 2 with the volume to be extracted at 1375 L, is loaded directly as presented in Figure-14. The indirect form is done by entering the sulfuric acid density and mass values in their respective boxes, and in this way in the Volume text box the volume given by the operation is exposed. Pressing the ACCEPT button the dosage mode screen 2 is loaded with the volume to be extracted equal to the result of the operation indirectly. Another possibility is to set the density value to 1 and place the volume to be extracted mass, in this way you can dose any volume.

If the volume value is less than 100 liters in the storage tank, the system does not allow dosing by displaying a message on the screen indicating that it does not have enough sulfuric acid. The OK button on this screen and the CANCEL button load the Modes screen.

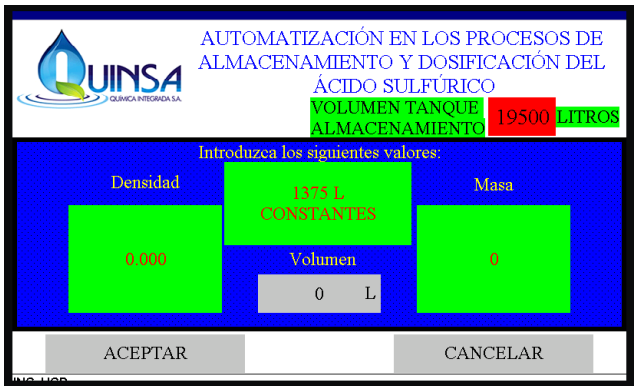

Figure-13. Dosing mode screen.

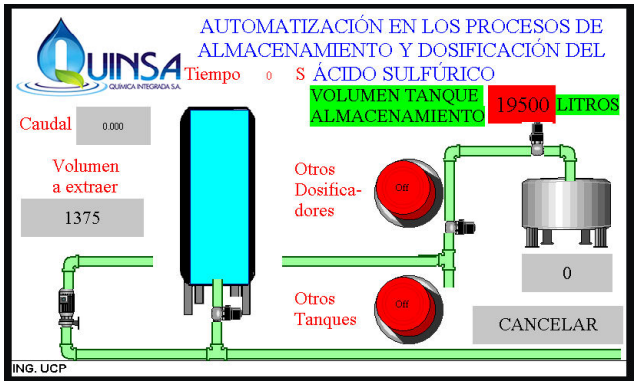

Figure-14. Dosing mode screen 2.

4. CONCLUSIONS

An automatic filling control system for a storage tank and a sulfuric acid dispenser was designed and implemented. The project considered the design from a sensor MAG 3100 and transmitter MAG 5000. This implementation eliminated the operation risk in the tanks, due to the storage tank or dosing tank overflow can lead to human injuries with acid.

The system has the capability to perform the dosage, through its proper configuration. It has information frames when some events such as damaged pump, transmitter off, among others occur. By means of the programming carried out, it is ensured that the value of liters in both the storage tank and the dispenser when the storage and dosing actions are being carried out are not lost in the event of an unexpected power outage.

The software used to program the PLC and HMI are VisiLogic and Maxtech Designer respectively. Its advantage is that they do not need a license and can be downloaded from the web pages of their manufacturers, they are also easy to use and can be configured in the preferred language. Communication between the two elements is carried out by Rs232 MODBUS RTU in an easy way, since the Maxtech Designer has Vision120

series libraries to achieve data transmission. Both have examples of their functions and settings providing familiarization with their programming environment. Besides, it became clear the main disadvantage was that the PLC does not have the option of downloading the programming via USB port and it was not possible to download the programming from a laptop to the PLC by converting USB cables to DB9, forcing to use a desktop computer to perform the Programming download, limiting the mobility of the project.

In case of any event where system must be stopped due to damage or reprogramming, the backup board provides that the storage and dosing processes are not stopped, since in this board the terminal elements can be manipulated directly, ensuring the installed system does not present production problems.

The implemented system can be expanded to the automation of storage and dosing process of other tanks, due to the good results obtained.

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