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RESEARCH ARTICLE OPEN ACCESS

SCADA SYSTEM FOR CHEMICAL WATER TREATMENT PLANT OF THE THERMOELECTRIC POWER PLANT “JOSÉ MARTÍ”

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ABSTRACT

The monitoring and control of all industrial processes in today's society is an essential requirement to achieve efficient productivity. The main objective of the work is to design a SCADA system for the chemical water treatment plant of the Thermoelectric Power Plant “José Martí”. For this, the architecture and the SCADA were designed, the results and contributions obtained from the tests carried out were evaluated. In the work, the PLC M221CE24R was used, which has very good computational performance and an adequate cost/benefit ratio. The design was carried out using the Eros Cuban development platform, version 5.11, and the Modbus TCP/IP protocol was used for communication between the automaton and the Eros. The SCADA that was designed allows to know in real time the parameters and alarms of the plant and the same actions can be executed locally and remotely. For what is viable and necessary, because it guarantees technological independence. The simulation and the tests carried out, both in the laboratory and in situ, validate its functionality and it is designed in a scalable and flexible way to assimilate future extensions.

I. INTRODUCTION

Today, the basis of electricity generation in Cuba is constituted by thermoelectric plants [1]. These plants are characterized by being of the steam type, since in these, the chemical energy of the fuel is transformed into heat energy, in order to produce steam in the boilers, then this is conducted to the turbine, where its kinetic energy is converted in mechanical energy, which is transmitted to the generator to produce electrical energy [2].

Said boiler-turbine-generator system also needs enormous amounts of water, which is added from an external source, to replace that which is lost in the boiler and the steam distribution system, which includes purges, steam leaks, losses of condensate and steam used directly in the processes. Thus, the efficiency with which steam boilers operate and consequently their operating cost, the safety of their operation and their durability, depends to a large extent on the quality of the water with which they are fed [3].

Therefore, this water requires a special quality, so its treatment is essential. The objective of this treatment is to prevent possible corrosion and incrustation [4]. For this, chemical water treatment plants are installed in each of the CTEs with the aim of purifying and demineralizing it.

A large part of the causes of these deposits of salts and encrustations on the walls of the boiler tubes is due to the previous treatment that the feed water receives. According to studies [5], the electrical industry in Cuba is one of the largest consumers of energy carriers and other inputs such as water, therefore, the rational and efficient use of these resources is a matter of utmost importance. Thus, in recent years the country has worked successfully in the design and implementation of a policy of saving power plants.

Currently the status of the automatic in the Chemical Water Treatment Plant of the Thermoelectric Power Plant "José Martí" is not the best, the measurements of the main physical process variables that determine the quality of the water produced are performed at the laboratory level, therefore their monitoring and supervision is inefficient. There is no record of the magnitudes of the aforementioned physical variables evidenced by the non-existence of a PLC.

The operation of the water chemical treatment process is done manually. The foregoing evidences the non-existence of a SCADA system to carry out any of the aforementioned tasks or others that this application is capable of carrying out and that have an impact on a great improvement for the plant, such as alarms, graphs of the behavior of variables over time, records of these magnitudes for statistical and performance analysis, among others.

II. MATERIALS AND METHODS

The elaboration of a SCADA system is the final stage of a study process of characterization and evaluation of the operating conditions of the different processes to automate, in conjunction with the client's and economic requirements. These systems can monitor and supervise from a control center, the processes of distant remote stations, with the use of various types of communication links such as satellite systems, field buses, radiocommunications, cellular telephony, among others [6].

In the aforementioned plant it is of great interest to monitor the levels in each tank of demineralized water, raw water and filtered water, as well as the levels of the different water storage tanks and the levels of the soda and acid tanks.

Figure 1 shows the proposed general architecture of the system, in this figure it is observed that the first level or field level is made up of the entire network of sensors-transmitters and final action elements. The instrumentation has a standard 4-20mA output and they are acquired by the PLC through its analog input modules. The control level is the PLC M221CE24R. The last level or supervision level is the SCADA software Eros.

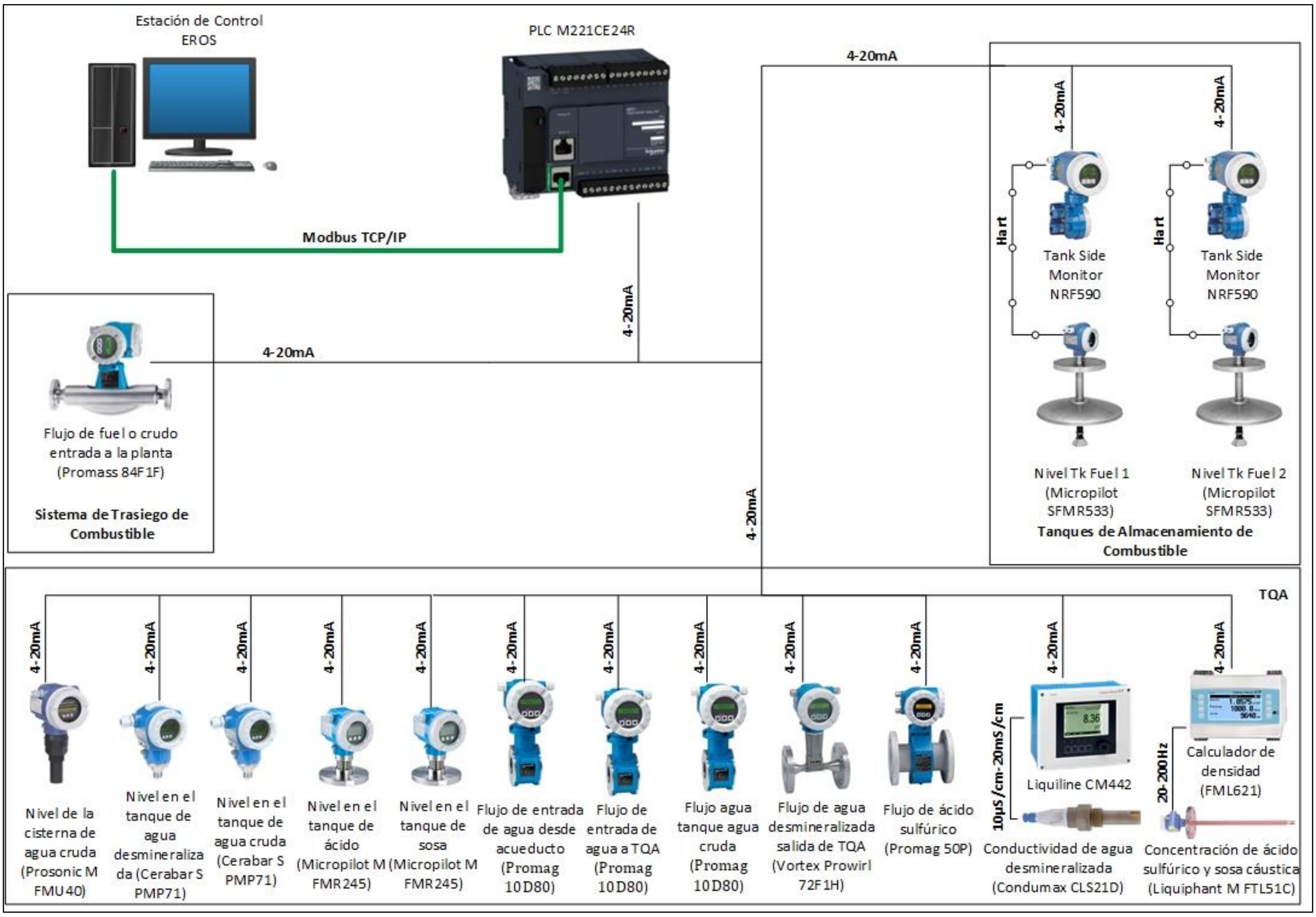

Figure 1: SCADA system architecture.
Source: Authors, (2020).

II.1 PLC M221CE24R

The PLC used is Schneider Electric's Modicon M221CE24R (Figure 2), which is modular in structure. This device constitutes the core element of the system, as it collects all the signals from the field and acts on the final action elements. On the other hand, it is in charge of the primary processing of the information, the implementation of the control ties and the communication with the supervisory level [7].

For the configuration and programming of the PLC M221CE24R, the EcoStruxure Machine Expert Basic software was used, which supports the following IEC-61131-3 programming languages [8]:

- Ladder diagram language
- Instruction list language
- Grafcet (List)
- Grafcet (SFC)

Figure 2: PLC M221CE24R.
Source: [7].

Figure 3 shows a fragment of the PLC M221CE24R programming related to the demineralized water production process.

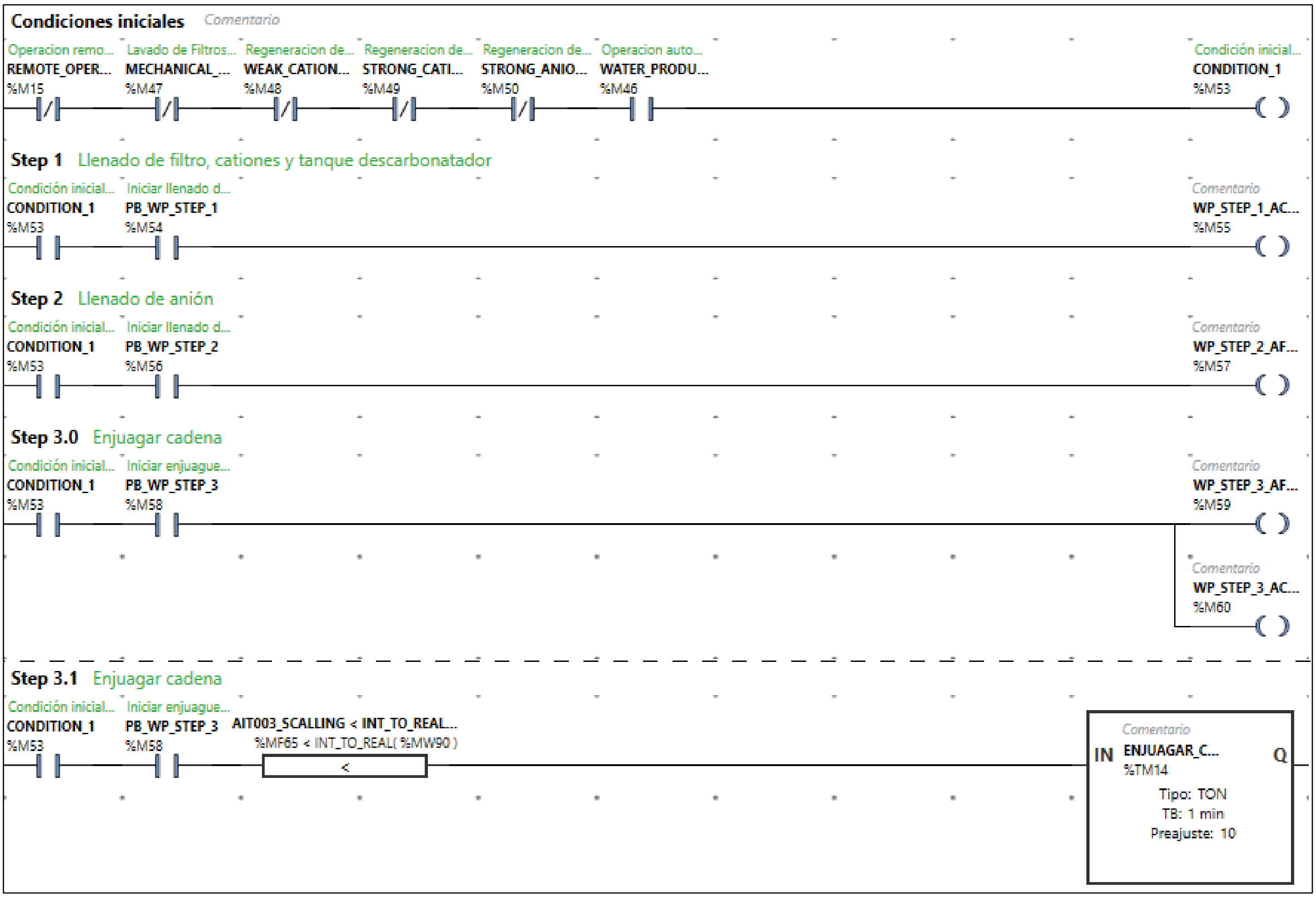

Figure 3: Fragment of the PLC M221CE24R programming using EcoStruxure Machine Expert Basic software.
Source: Authors, (2020).

Modbus/TCP was introduced by Schneider Automation as a variant of the Modbus protocol family, widely used for the supervision and control of automation equipment. Specifically, the protocol defines the use of Modbus messages in an intranet or internet environment through the TCP/IP protocols. Figure 4 shows the configuration of the PLC's Ethernet network as Modbus TCP Server.

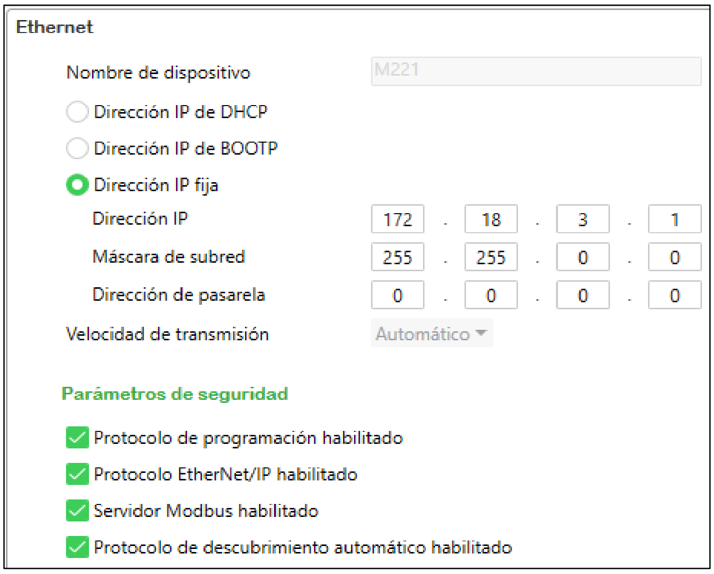

Figure 4: Configuration of the PLC's Ethernet network as Modbus TCP Server.
Source: Authors, (2020).

The communication parameters of the PLC's Ethernet network as Modbus TCP Server are:

Programming protocol: Allows you to enable or disable programming through the Ethernet port.

Ethernet / IP protocol: Allows you to enable or disable the Ethernet / IP protocol to connect to a network for data exchange.

Modbus server: Allows you to enable or disable the Modbus TCP server.

Auto-discovery protocol: Allows you to enable or disable the auto-discovery protocol to automatically discover devices on supported Ethernet field buses.

II.2 EROS

Eros is the Process Supervision and Control System, developed for Windows operating systems, by the Automation Division of the Cuban Nickel Computing, Communications and Electronics Services Company (SERCONI). It contains the experience accumulated for more than 15 years and has been employed in various industrial sectors.

Eros has a programming environment that allows executing blocks of programs. These scripts, as they are also called, are executed within the system in each measurement cycle, to perform a certain task. This allows to substantially expand its possibilities, by being able to link in the scripts, variables and registers that are measured in different devices and even in different networks. For this purpose, there is a compiler with a high-level language similar to PASCAL, which converts the source code into an intermediate code, highly optimized and which is subsequently executed by a virtual machine designed for such purposes [9].

The Eros platform is a modern and modular system. It contains user-friendly interfaces and is packed with production-proven and reliable features. Eros advantageously competes with other similar systems in terms of ease of configuration, always offering functionality by default; The parameterization is done hot, so it does not need, unlike other SCADAs, to stop the supervision process to make changes to the configuration [10].

Multiple industrial process measurement and control devices are connected to the SCADA Eros, such as PLCs, actuators, network analyzers, sensors, etc. from different providers which can be installed on a bus and operated through the MODBUS communication protocol. For this, Eros has a driver called MODBUS MASTER.

The communication parameters of the MODBUS MASTER driver are:

COM: Communications Port Number (COM), up to 255.

Speed: Speed with which it will communicate with the devices (Baudrate).

Parity: Checking the parity of the data (Even, Odd, No parity).

Data length: This can be 5.7 or 8 bits.

Stop bits: The stop bits of the character can be 1 or 2.

Active: Option to activate or deactivate the Port.

Transmission Mode: If the communication will be ASCII or RTU.

Bus flow control: When communication is through a bus, data flow control can be done by hardware.

RTS values for transmission: In the case of using software flow control.

In this case it was only necessary to disable the port as shown in Figure 5.

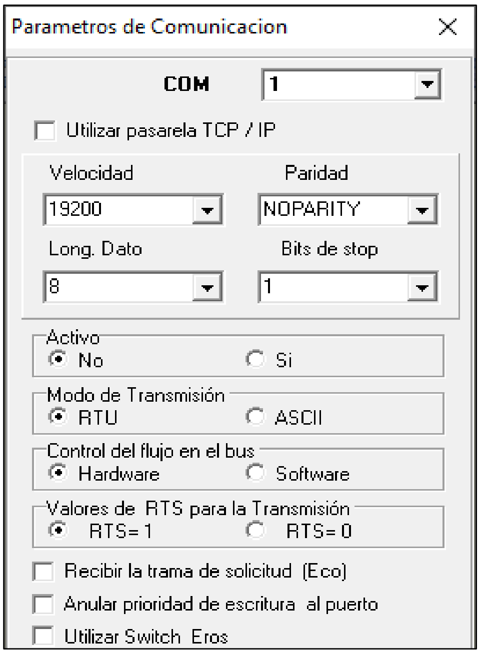

Figure 5: MODBUS MASTER configuration in Eros.
Source: Authors, (2020).

In addition to the driver's communication parameters, each of the devices that will be connected to the bus must be configured. When the Use modbus over Ethernet network option is checked, the screen shown in Figure 6 is displayed to set the parameters for this type of connection:

Encapsulation of the network frame:

- Modbus TCP: Basic configuration.
- Socket: In this case, the Modbus frame is not encapsulated, it is sent as it would be sent through a serial port.

IP Address: This will be the address of the device on the Ethernet network.

Port: Logical port of the Ethernet connection, by default the Modbus by standard uses 502.

Timeout (ms): It is the time to define the communication error (Time Out).

Default values: The values that Eros will define by default in the parameters explained above.

Figure 6: MODBUS MASTER device configuration in Eros.
Source: Authors, (2020).

III. RESULTS AND DISCUSSIONS

Once the mounting and starting up stages ended, the automation engineering service obtained satisfactory results.

The SCADA application has 3 main interfaces, the alarms interface and the history interface, easily accessed through a button navigation system or through the drop-down menu that includes Eros. From each interface it is possible to exercise both navigation routes.

The screen where the application starts is shown in figure 7. This interface allows the operator to monitor the general parameters of the system. The figure shows the synoptic dedicated to different signals of flow, level, concentration and conductivity of the plant, as well as the status of the pumps and compressors involved in the process; which includes a simplified and easy to understand schematic of the different threads. Hovering the cursor over an object or label displays a sign indicating the name of the variable or pump in question.

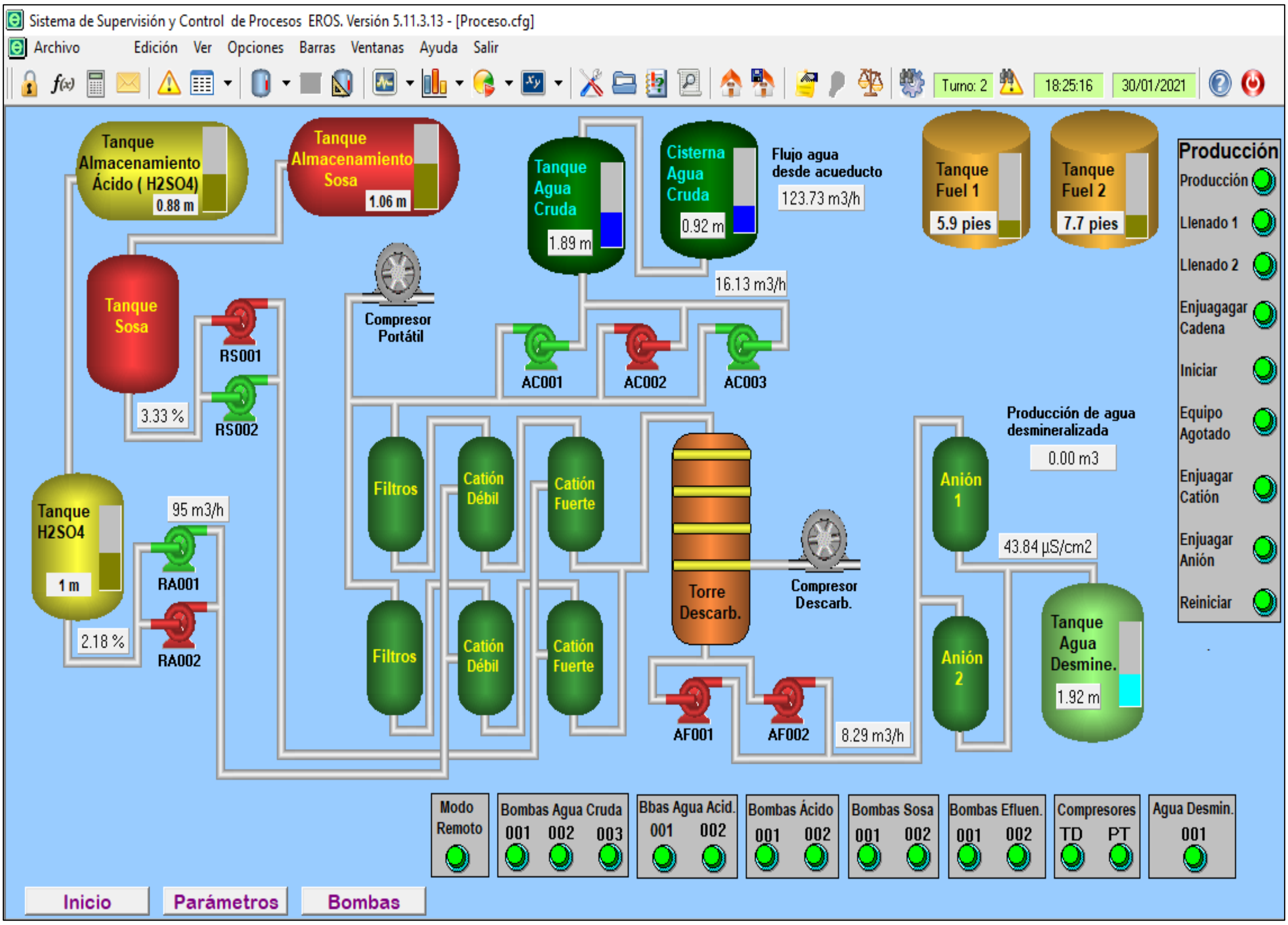

Figure 7: Process interface.
Source: Authors, (2020).

The system parameters screen shown in Figure 8 is used so that operators can enter the parameters through which the plant will operate.

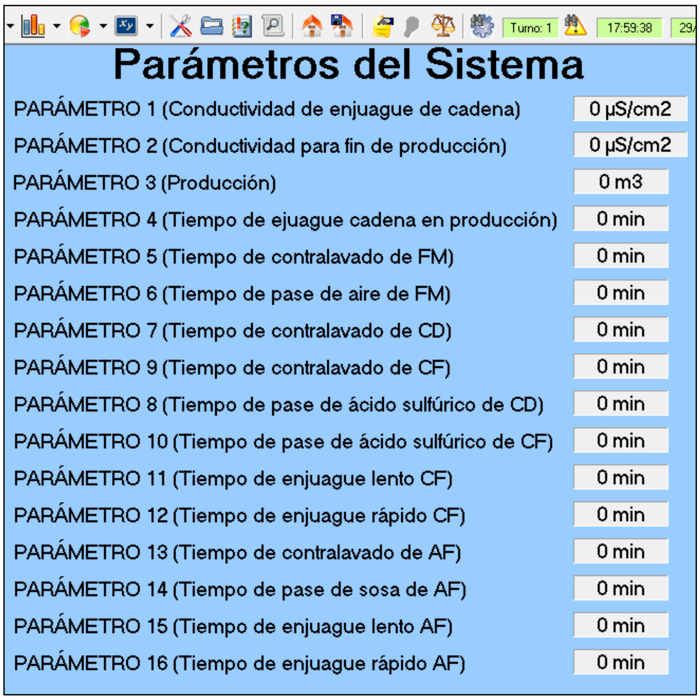

Figure 8: Parameters Interface.
Source: Authors, (2020).

The motor working hours screen shown in Figure 9 is used to display the number of hours that each motor works in the time to be evaluated, it has buttons for resetting the working hours.

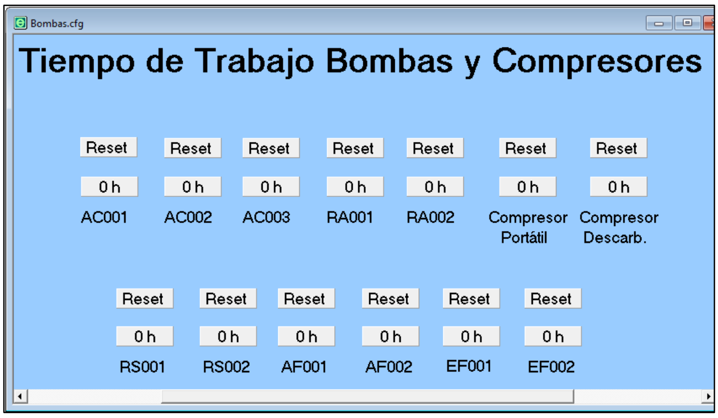

Figure 9: Pump and Compressor Work Time Interface.
Source: Authors, (2020).

The alarms establish signals related to the appearance of anomalous situations or the acquisition of inoperative values in the variables; which generally implies intervention by the operator. From each screen of the supervisor it is possible to access the interface for alarms located in the form of a bar in the lower left part, so that the operator can easily notice and acknowledge it.

For analysis, the alarms are stored in a table containing the last 2000 generated by the system. In each column of the table, as shown in figure 10, the label or name, the value it acquires, the type, the start and end date in which they occur, as well as the start, end and recognition time are indicated. Each variable that is associated with an alarm includes two limits (upper and lower), both for operation and for prohibition, and some of them even define limits for checking alarms due to change.

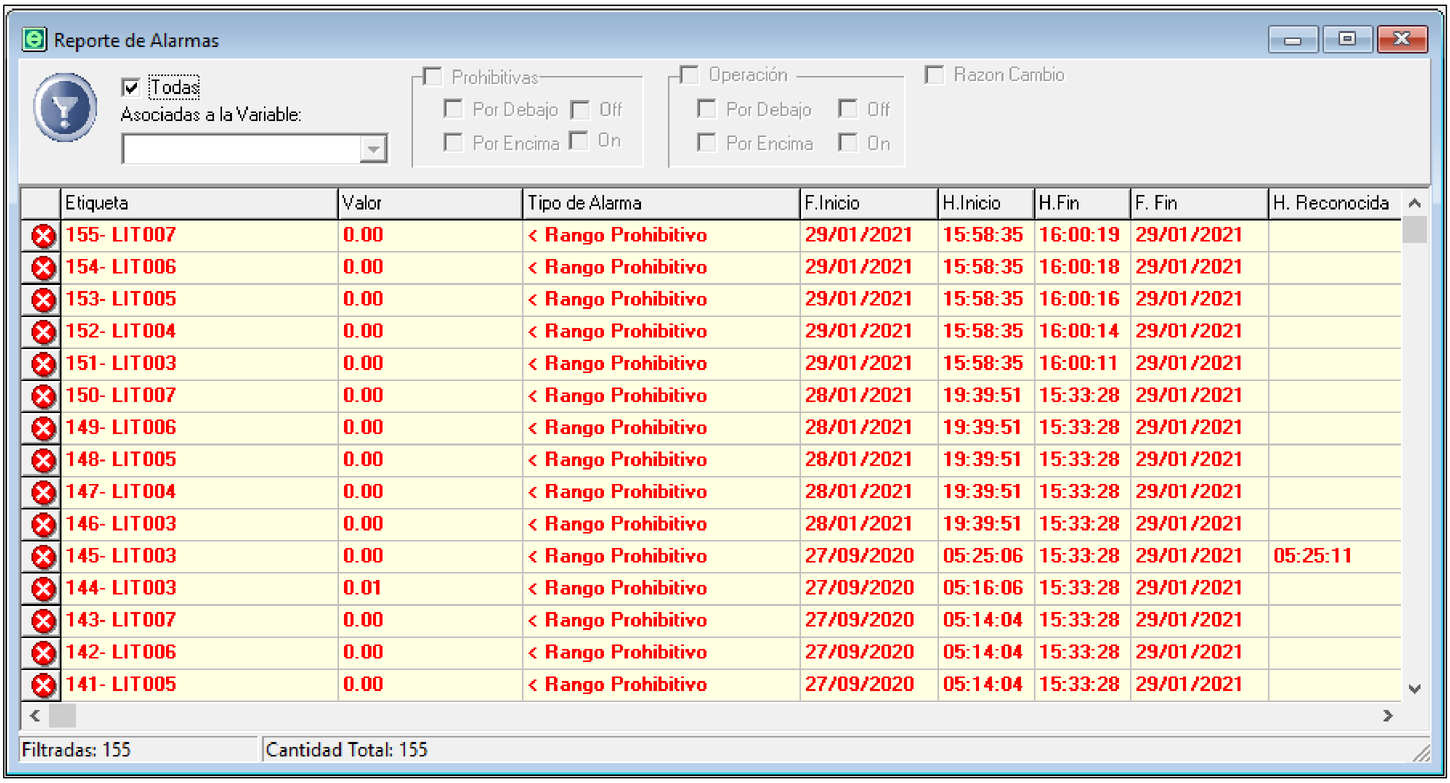

Figure 10: Alarms interface.
Source: Authors, (2020).

Trend graphs are the main means of grouping variables, to create informative diagrams for users. In this particular case, each variable represented in the graphs is stored in the historical ones; therefore, they can be analyzed in different periods of time, and even statistical parameters associated with them can be calculated. For more organization, different groups of historical data were created according to the variables of the plant, as shown in figure 11.

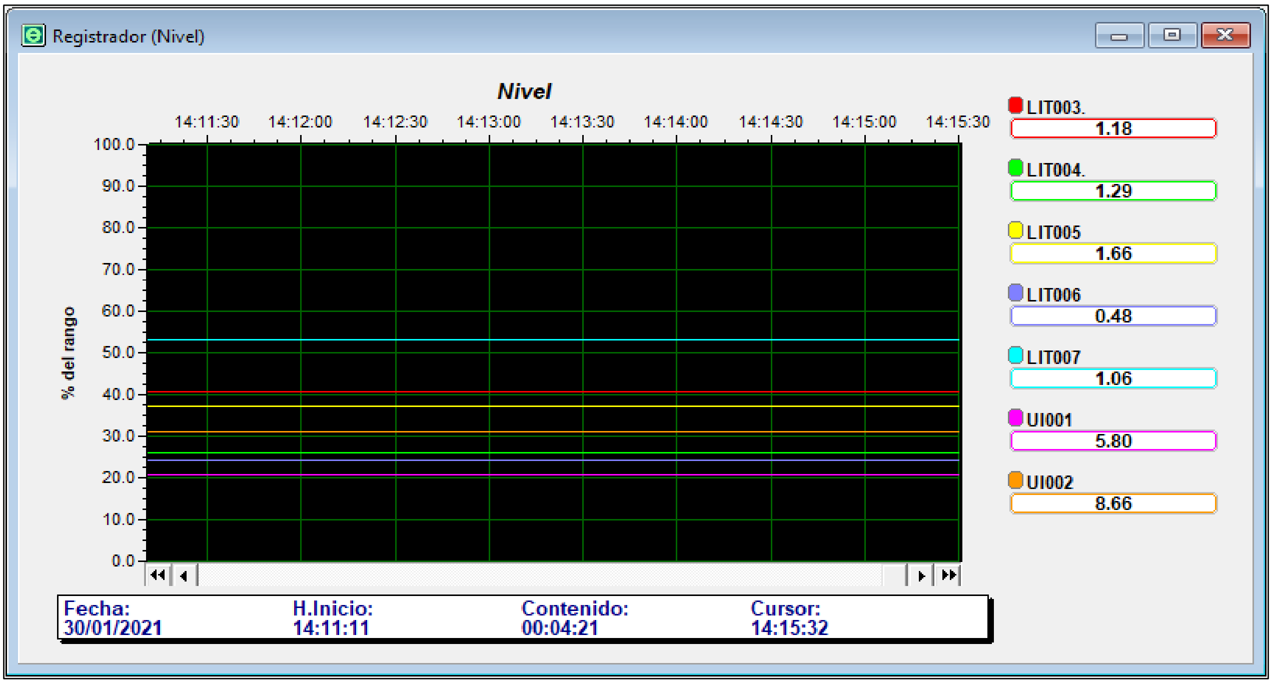

Figure 11: History Interface.
Source: Authors, (2020).

Currently the SCADA system is in operation with very good results. The development of this work allows the systematization of knowledge about chemical water treatment plants and associated SCADA systems, which can be used for other works. A fully operational SCADA system is obtained and easily assimilated by the company's operators and technicians. With the execution of the project, the problems related to the acquisition of highly complex and valuable software are resolved. This is due to a decrease in raw materials and an increase in the quality of the final product.

IV. CONCLUSIONS

The SCADA system designed for the supervision of the chemical water treatment plant of the thermoelectric power plant “José Martí” is viable and necessary, since nowadays new technological solutions are created that allow a better use, rational use and saving of supplies. The use of protocols such as Modbus, offer high reliability in communication, as well as considerable time savings in configuration. The choice of the Eros platform constitutes a technologically and economically feasible solution, which allows integrating the diversity of existing technologies and equipment. The tests made to the SCADA system, both in the laboratory and in situ, guarantee the validity and functionality of the designs created. Likewise, it is a strength of this system to be designed in a scalable and flexible way to assimilate future extensions.

V. AUTHOR’S CONTRIBUTION

Conceptualization: Roberto Luís Ballesteros Horta.
Methodology: Roberto Luís Ballesteros Horta.
Investigation: Marcel Pérez Vazquez.
Discussion of results: Marcel Pérez Vazquez.
Writing – Original Draft: Marcel Pérez Vazquez.
Writing – Review and Editing: Marcel Pérez Vazquez and Roberto Luís Ballesteros Horta.
Resources: Marcel Pérez Vazquez.
Supervision: Roberto Luís Ballesteros Horta.
Approval of the final text: Roberto Luís Ballesteros Horta.

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