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Automated drainage system for thermoelectric power plant

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ABSTRACT

The Chilca 2 thermoelectric power plant, located in the province of Lima, Peru, has an open cycle gas turbine and a combined cycle steam turbine, whose combined capacity is 112.8 MW (Mega Watts). This plant requires auxiliary equipment for its operation, which is why it consists of electrical systems, lubrication system, hydraulic ventilation, pumps, vacuum systems and drainage of condensate generated by the difference in temperature in the steam conductor. Said drainage system is inside a 5-meter-deep basement that, being exposed to the elements, is exposed to falling drops of water that are generated by the vapors that are released due to the difference in temperature, repeatedly flooding and exposing to hazards that affect the normal operation of the thermoelectric plant. The proposed solution is based on the philosophy of a feedback control system, which uses a programmable logic controller (PLC) Siemens 1214AC/DC/Relay programmable logic controller, which, through a frequency inverter, activates the drainage pumps; the frequency range at which the variator works is linked to a 4-position level sensor. The result shows that it was possible to activate the frequency variator in a controlled manner through frequencies of 10 Hz, 30 Hz and 60 Hz, in this way a sustained operation of the drainage system is guaranteed.

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1. INTRODUCTION

Today the prevalence of state-of-the-art integrated devices accompanied by characteristics linked to a greater processing, integration and communication capacity, is allowing the transformation of industrial automation [1], and it is that there is a trend towards integration based on information that enhances the interactions that give way to the implementation of new technologies in the industry [2]. In the productive sectors, it is always necessary to maintain a technological advance as well as a permanent optimization of all processes, so automating it is relevant in these times [3]. Automating a process implies providing added value and competitive advantage, and it is that strengthening technological management in organizations, especially the formulation and development of technological plans, contributes to closing technological gaps between organizations [4], [5]. In this regard, in [6]-[8] they point out that the progress and complexity of new industrial processes have forced productive organizations to seek solutions for the integration of different technologies, such as the use of control systems as well as monitoring systems acquisition, supervision and control (SCADA). By supervising and controlling data remotely and in real time, this system manages to improve the maneuvers of the process [9]. Among the various systems that make use of automation today are thermoelectric plants, because they represent energy conversion systems, they require a high degree of reliability to guarantee a permanent supply, without affecting the electricity supply of a specific sector. that demands such energy [10], therefore, all the subsystems that comprise it, such as the fuel supply subsystem, the water subsystem, gas and steam turbogenerators, steam recuperators and generators, the high voltage subsystem, the transmission subsystem, and the auxiliary subsystems, must be integrated in such a way that lead to maintain an availability, above 90% [11]. These subsystems must interact harmoniously to achieve the highest quality in the operation and performance of the process [12]. In addition, thermoelectric plants generally have a gas turbine and a combined cycle turbine, these systems make use of seawater pumps to maintain the delivery pipe and provide a continuous flow to the heat exchanger, as well as use pumps of closed loop recirculation, boiler recirculation pumps and high pressure feedwater pumps for engine cooling [13].

However, drainage systems have drawbacks related to the exfiltration of residual water into the ground and the possibility of infiltration of water from different sources into the drainage, and this has a lot to do with the infrastructure used [14], [15]. The well used in the drainage systems fulfills two important functions, the first is to accumulate the water from a wastewater collection system of the generation system, and the second is to accumulate the water from the suction tubes of the generation units, it is therefore very necessary to use technology linked to automation and control to guarantee its correct operation [16]. Thus, when automating a process, it is not enough to store or transmit information to a local environment, but it is necessary for industrial processes to have monitoring and control systems [17], [18]. In this sense, the control systems linked to water distribution show that there are unresolved problems, both theoretical and practical, that make it impossible to obtain a high performance in the control of these processes, even when there are various control strategies, not all of them these have been implemented in practice and their effectiveness has not been proven [19]. Thus, as an alternative solution, frequency-controlled actuators, when integrated into various programmable controllers, guarantee the optimal operation of pumping systems [20]-[22].

The frequency variator is considered as a regulator that is normally found between the energy supply and the centrifugal electric pump [23], and it is that using frequency variators allows to have a better control in the starting of pumps, this is due to the fact that they do not present over current peaks avoiding disturbing the operability of the process [24]-[27]. Another aspect to highlight in the use of a frequency inverter in the automatic control for centrifugal water pumping is that it allows to guarantee a constant pressure in the system, for which it is important to link the sensors and actuators with the monitoring and supervision systems [28]-[31]. In this sense, the purpose of this article is to describe the procedure to automate the drainage system of a thermoelectric plant, in order to reduce the accumulation of residual water in the pump basement, for which initially the sensors and actuators of the system will be identified process, with which from them the electrical control circuit will be designed through CadSimu, and then through the feedback control approach and through the TIA portal software, the programming of the programmable logic controller will be developed.

2. LITERATURE REVIEW

Chávez [32] designs a control and supervision system for a drainage well in the machine room of a hydroelectric power plant, in whose well there are two tape-type sensors that allow level measurement, which gave operating problems due to its deterioration, which led to a preliminary analysis to solve problems and create a backup system that allows optimizing the control and supervision of the level of water captured in the well to avoid problems. Signals to the programmable logic controller (PLC) installed for the system were used and indicate when the designated pumps will start to act for each level change. Arenas *et al*. [33] describe the solution of a drainage problem, for which one of the control techniques is performed through the interface of a digital system through the labView software. Also Chinchayán [34], designs an industrial automation system for the pumping system, in which Step 7-Micro/Win was used between the software for process control, achieving as a result that the loops programmed in Ladder language achieve perform the required functions operations.

Chaudhari and Gajare [35] describe a control process of a drainage system, whose solution proposal is based on a system in a motor that achieves the permanent rotation of a chain, whose elevator collects all the residues and avoids blockages by isolating the waste solid liquid waste. The control of the work organs such as sensors and actuators was controlled through a semi-automatic module. In the same line of research, Gondane [36] develops a proposal that consists of improving a manual drainage system that becomes congested due to the poor precision of its sensors, which will be replaced by an automatic control mechanism. The drainage system was able to operate efficiently even in conditions of high rainfall intensity, managing to keep the volume of water in the storage well under control.

3. METHOD

The scientific article took as its starting point the identification of a specific problem, linked to the research line of industrial automation and process control, in the field of the drainage system of a thermoelectric power plant, for which an information survey was carried out of the current state of the system. Figure 1 shows the method used in which initially we proceeded to identify that the problem was centered on the accumulation of residual water in the basement of the pumps. Then we proceeded to design a drive circuit based on the interaction of sensors, actuators and the PLC. With this, the PLC was dimensioned, as well as the programming via the TIA portal software. Once the solution proposal was developed, it was validated by collecting data on its operation, progressively at different times through a monitoring system linked to an human machine interface (HMI) interface.

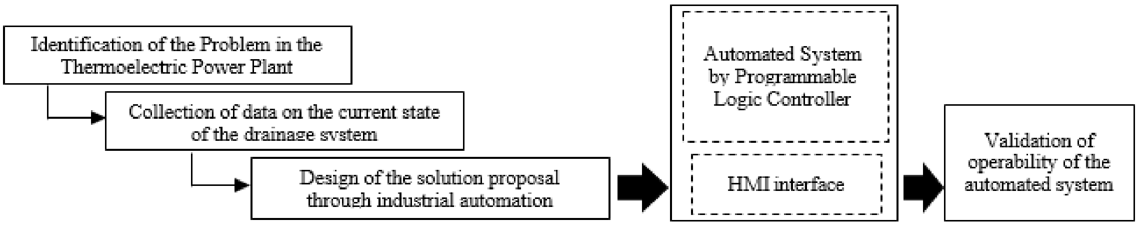


Figure 1. Scheme of the research method

4. DESCRIPTION AND DEVELOPMENT
4.1. Description

The thermoelectric plant under analysis has an open cycle gas turbine and a combined cycle steam turbine, with a joint capacity of 112.8 MW; In the process of identifying the problem in the thermoelectric power plant, it was possible to determine that it consists of subsystems such as electrical subsystems, lubrication subsystem, hydraulic ventilation subsystem, vacuum system subsystem and auxiliary equipment subsystem for the operation of pumps such as part of the condensate drain system. This drainage was identified as being generated due to the temperature difference in the steam duct; Likewise, from the inspection prior to the design of the automated system, it was identified that said drainage system is inside a 5-meter-deep basement that, being exposed to the elements and exposed to vapors that are released by the temperature difference, causes drops to fall water, which over time floods the basement. This flooding is very dangerous since in the basement there are 2 pumps called "drain pump", which are the ones that pump the condensate from the steam line to the condensate tank, and which are not governed automatically, but manually, not achieving precision or responsiveness to the instability condition of the problem.

Figure 2 shows the drainage system in which the input and output elements are identified, and the interaction between them in order to achieve the pumping of water, which, as noted, is activated by the operations personnel. It is done manually, developing a permanent visual monitoring to prevent the level from reaching a maximum of 100 cm. Since after that level it will reach the pumps called "drain pump" that are energized with 220VAC (volts of alternating current), which It would cause a short circuit that would lead to accidents in the thermoelectric plant.

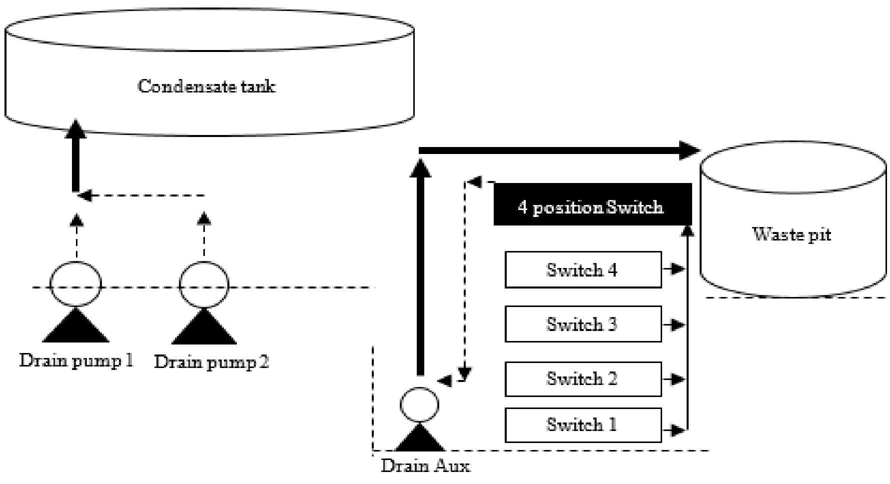


Figure 2. Drainage system

From what has been described, it derives in the solution proposal of designing an automatic drainage system that maintains the level below 100 cm. It is proposed to design an automatic pumping system using a speed variator and a multi-stage level switch to control a pump that will work on three levels and according to this the speed variator will control the revolutions. The operation will respond to the following components, as described in Table 1.

Table 1. Process inputs and outputs

Variables	Description
start	Start button will be connected to the %I0.1 input of the PLC
stop	Stop button will be connected to the %I0.2 input of the PLC
system	PLC internal marker for system startup, which is identified by the PLC mark %M0.0
Level sensor_input	Analog level sensor (0-10 VDC) to be connected to the %IW64 input of the PLC
Level sensor_scal	It is the scaling of the level sensor which is identified with the real mark %MD0 of the PLC
Level sensor_output	It is the output of the scaling of the level sensor which is identified with the real mark %MD4 of the PLC
Drain Aux_10 Hz	It is the first output %Q0.0 of the PLC which is connected to the first speed of the drain pump
Drain Aux_30 Hz	It is the second output %Q0.1 of the PLC which is connected to the second speed of the drain pump
Drain Aux_60 Hz	It is the third output %Q0.2 of the PLC which is connected to the third speed of the drain pump

As can be seen, the "start", "stop" and "system" sensors will be used to start and stop the operation of the automated system. The “Level sensor_input”, “Level sensor_scal” and “Level sensor_output”, will be for the normalization and scaling of the level sensor. The outputs “Drain Aux_10 Hz”, “Drain Aux_30 Hz” and “Drain Aux_60 Hz”, will be the ones that manage to vary the speed of the drainage pump, depending on the signal sent by the level sensor. This table also specifies the addresses that will be assigned to each of the variables, and that due to the nature of the signals linked to each variable, discrete inputs, analog inputs (16 bits), discrete outputs and marks have been used double word (32 bits).

4.2. Development

As part of the development, and having identified the sensors and actuators of the process, the programming code for the simenes 1214AC/DC/Relay PLC is shown below, developed through a contact diagram. The stop button (%I0.2) is connected in series with the start button (%I0.1) in order to activate the system call mark (%M0.0), so that the system is interlocked there is a normally open auxiliary of the system mark (%M0.0) in parallel with the start button (%I0.1), as shown in Figure 3.

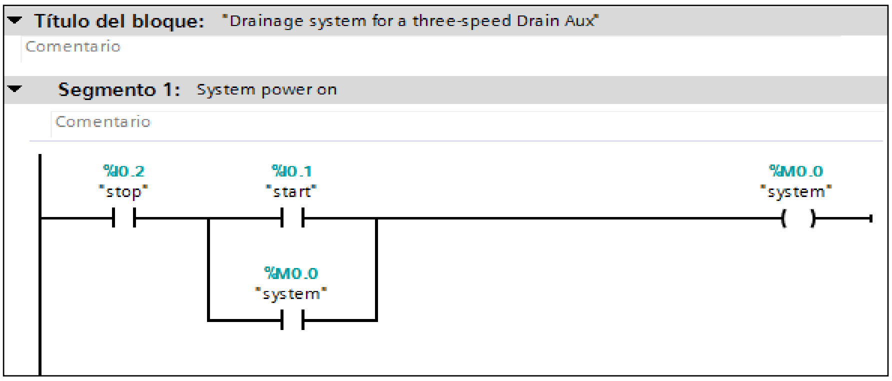


Figure 3. Programming segment for automated system startup

Once the system marker (%M0.0) has been executed, this marker sends an activation signal to the NORM_X command input so that the level sensor input (%IW64) starts to work, the level sensor level (%IW64) is a sensor that works from 0-10V DC, which the PLC will recognize with a digitization of 0-27648 (that is, 0 vdc is 0,27648 is equivalent to 10Vdc). The NORM_X output is given by a real mark (%MD0) which is the result of the level sensor input (%IW64) via NORM_X. The real marker (%MD0) is connected to the SCALE_X command which will be evaluated with the ranges from 0cm to 100cm described in the article, the output of the SCALE_X identified with the real mark (%MD4) is the output of the level sensor that is will be used for the level ranges that will be used to vary the speed of the drain pump Figure 4 shows the programming of the normalization and scaling of the level sensor.

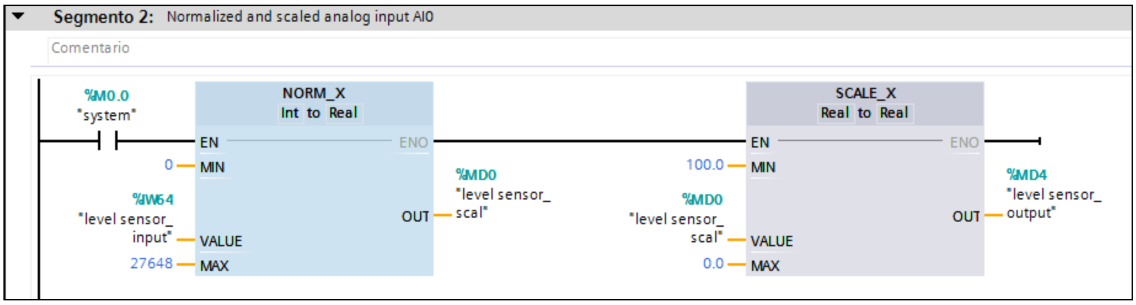


Figure 4. Programming segment for level sensor normalization and scaling

The system mark (%M0.0) is connected to the 3 speeds for the drain pump, so in the first speed two comparators are used which are part of the level sensor output (%MD4) with the ranges greater than 10 but less than 50cm respectively, and with the auxiliaries N.C. of the second speed (%Q0.1) and third speed (%Q0.2). That is, when the tank exceeds 10 cm (%MD4>=10) the drain pump turns on with the first speed of 10Hz (%Q0.0) until it reaches 50 cm (%MD4<=50), all this in series with the second speed (%Q0.1) and third speed (%Q0.2) normally closed (NC) auxiliaries in order to use these auxiliaries as safety. Figure 5 shows the programming for the control of the frequency inverter.

In this program it can also be seen that when the level exceeds 50cm the first speed of 10Hz (%Q0.0) stops working and it would start with the second speed. In the second speed, two comparators are used which are part of the level sensor output (%MD4) with ranges greater than 50 but less than 65cm respectively, and with the NC auxiliaries of the first speed (%Q0. 0) and third speed (%Q0.2). That is, when the tank exceeds 50 cm (%MD4>=50) the drain pump turns on with the second speed of 30Hz (%Q0.0) until it reaches 65 cm (%MD4<=65), all this in series with the NC auxiliaries of the first speed (%Q0.0) and third speed (%Q0.2) with the aim of using these auxiliaries as safety. Once the 65cm is exceeded the second speed of 30Hz (%Q0.0) stops working and it would start with the third speed, if it decreases to 50cm the second speed of 30Hz (%Q0.0) stops working and it would start with the first gear. In the third speed, a comparator is used which is part of the level sensor output (%MD4) with a greater range equal to 65cm respectively, and with the NC auxiliaries of the first speed (%Q0.0) and second speed (%Q0.1). That is, when the tank exceeds 65 cm (%MD4>=65) the drain pump turns on with the third speed of 60Hz (%Q0.2), all in series with the N.C. auxiliaries of the first speed (%Q0.0) and second speed (%Q0.1) in order to use these auxiliaries as safety. Once it is decreased to 65cm the third speed of 60Hz (%Q0.2) will stop working and will go back to the second speed (%Q0.1).

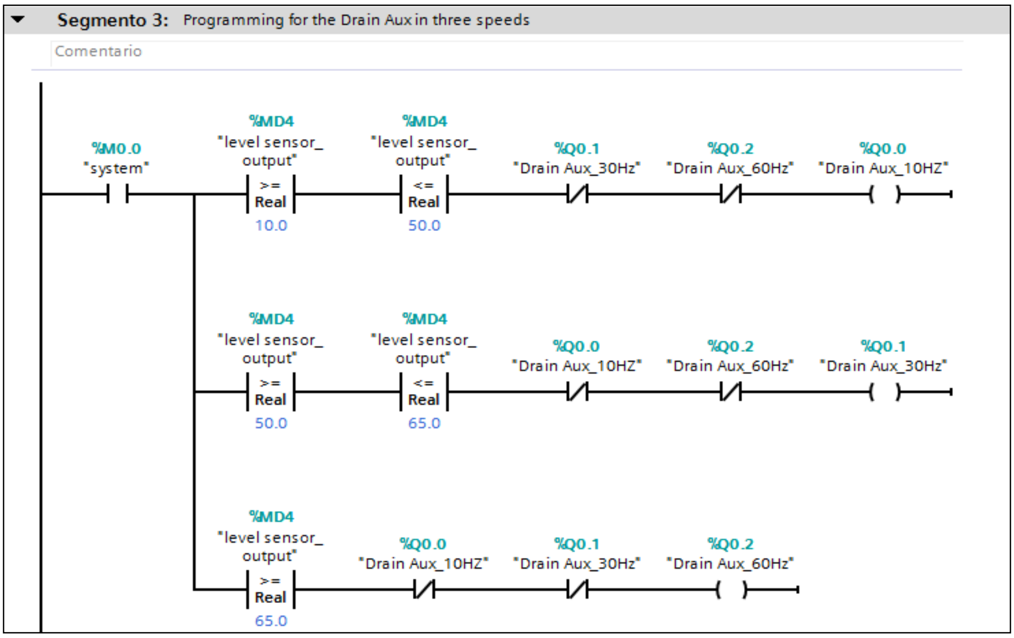
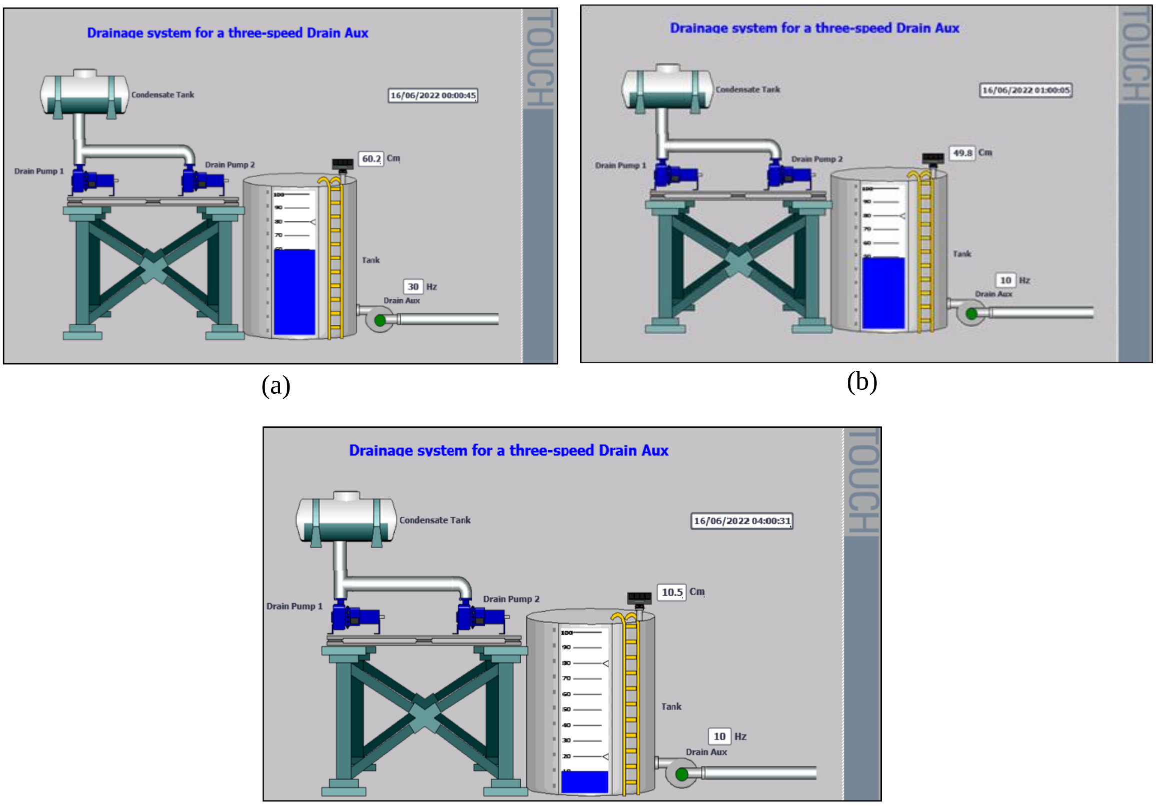


Figure 5. Programming segment for frequency inverter control

5. RESULTS

Figure 6 shows the start-up of the control system through the acquisition SCADA, in which, when starting the system, data collection was carried out through the HMI, as shown in Figure 6(a), the tank located in the basement has a level of 60.2 cm, so the drain pump starts with the speed of 30 Hz (%Q0.1), in this way it will evacuate all the residual water that is at that level. As part of the evolution of the variable under analysis, in Figure 6(b) it is observed that after 1 hour of work the level is reduced to 49.8 cm, so the speed of 30 Hz (%Q0.1) stops run and start 10Hz speed (%Q0.0). Likewise, as shown in Figure 6(c), after a total of 4 hours of work, the water level drops to 10.5 cm, maintaining the speed of 10 Hz (%Q0.0). When the water has been evacuated again, the level of the basement begins to rise progressively, which despite the fact that the pump is working, continues to fill the basement, this is due to the fact that when the steam is drained from some stage of the turbine, for which is part of the process.



(a) (b)

(c)

Figure 6. Drive of the frequency variator for a level of: (a) 60.2 cm, (b) 49.8 cm, and (c) 10.5 cm

6. DISCUSSIONS

With respect to the results obtained, it is evident that it is possible to control the residual water filling level of the drainage system tank through frequency inverters, the same ones that allow regulating the actuation capacity of the actuators, in order to progressively correct the state of instability, avoiding impressions regarding errors in the steady state, as well as on impulses in its transitory state of the controlled variable. In relation to what was proposed, Chávez [16] develops a control and supervision system for a drainage well in the power house of a Hydroelectric Power Plant, in which for its implementation it makes use of a Siemens 314 programmable logic controller and for the the supervision system used an HMI interface, with which it managed to develop the programming segments in an effective and simple way to control the analog input signal with respect to the control elements, in addition to using a graphical user interface that facilitated the work of operation; It is evident that there is coherence between what is cited with respect to what is described in this article. Rojas [30] also manages to design and implement an automated system in a pump room through frequency variators, thanks to the programming carried out in the PLC and the use of PID controllers (proportional, integrative and derivative); In relation to what the author points out, in his research work he refers to a process with 3 electric pumps and 2 frequency variators, this gives us an idea that this type of control system turns out to have scalability capacity, adapting to drainage system requirements. However, Ibañez and

Contreras [21] develop an automatic control system for the efficient operation of submersible electric pumps, they conclude that through a PLC S7-200, a frequency inverter and an Ethernet module, it was possible to connect all the information of their system to your work computer, on which the SCADA program was installed; As the authors point out, although they use a commercial PLC, however, the controller they use is low-end, so its scalability capacity is quite low, a very relevant aspect that must be taken into account when selecting a controller PLC.

Regarding the capacity of this new automated system through frequency inverters compared to the manual system, it is evident that the new scenario entails multiple advantages, ranging from guaranteeing the optimal operation of all the subsystems of the thermoelectric plant to having monitoring of the drainage system in the event of any type of faults or external disturbances. In this regard, Rendón [24] concludes that the use of a frequency inverter is the most effective way to start electric motors, since it does not present current peaks, and, therefore, does not damage or cause disturbances in the network, resulting in For the programming of the variator, not only the data of the motor plate is required, since they imply variables of the processes that are going to be controlled, but also parameters of the inverter, which must be taken into account, if you want to carry out a programming adequate. Although the criteria by which frequency variators are used are not the same, however, these advantages generated by the use of frequency variators in the motor starting process are valid, which gives greater coherence and support to the proposed solution described in this article.

7. CONCLUSION

In the search for a solution to reduce the accumulation of residual water in the pump basement of a thermoelectric plant, it is concluded that the automation designed by means of a Siemens 1214AC/DC/Relay programmable logic controller, with a frequency variator that acts on the control of the activation of drainage pumps in three frequency levels (10 Hz, 30 Hz and 60 Hz) ensuring that the regulation of the level of filling of residual water, is developed within the setpoint values for the process. Thus, the implementation of an HMI interface system was also achieved, the same one that allowed the data collection process to be carried out and to be able to validate its operability. It is important to highlight that although the drainage subsystem was automated, it is necessary to continue future studies regarding how to implement an industrial network that interconnects this process with the other subsystems that make up the thermoelectric plant, since this would help develop the acquisition, global or holistic monitoring and supervision of all its operating indicators, thus evolving towards the implementation of industry 4.0.

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