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PASTEURIZATION AUTOMATION WITH SIEMENS S7-1200 PLC

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RESUMEN

Las operaciones en la industria láctea han cambiado rápidamente en los últimos años, la industria se maneja a base de equipos manuales que se han convertido en obsoletos y han sido reemplazados por unidades más grandes y automatizadas. Es por esto que en el proyecto actual se integra un sistema de control automático a un equipo pasteurizador con más de 15 años operando. La metodología que se utilizó consiste en una división modular del proceso completo. Se realizó el diseño de la automatización por medio de diagramas de flujo para ser llevados a la programación en escalera, para proceder a pruebas de calibración y validación se crea la interfaz de operador con capacidad de modificaciones durante la operación. Los resultados de este proyecto reflejaron que el sistema de automatización ayudó en la reducción de tiempos de producción al tener una secuencia del proceso controlada sin paros.
Palabras Clave: Automatización, Pasteurizador, Interfaz de Operador.

ABSTRACT

Operations in the dairy industry have changed hastily in recent years, the industry is managed by manual equipment that has become obsolete and had been replaced by larger and automated units. This is why in the current project an automatic control system is integrated to a pasteurizing equipment with more than 15 years' operating. The methodology used consists of a modular division of the entire process. The design of the Automation was done using flowcharts to be carried to a ladder programming, to proceed to calibration and validation tests an operator interface is created with the ability to changes during the operation. The results of this project reflected that the automation system helped in the reduction of production times by having a sequence of the process controlled without stopping times.
Keywords: Automation, Pasteurizer, Operator Interface.

1. INTRODUCTION

Pasteurization is the thermal process made to liquids (usually food) in order to reduce the pathogenic agents that may contain, such as bacteria, protozoa, molds and yeasts, etc. The warming process is named after its discoverer, the French scientist-chemist Louis Pasteur. The first pasteurization was made on April 20, 1882 by Pasteur himself.

Currently the equipment that are counted in many companies is outdated. The regulators for different loops of control such as flow, level, temperature, etc. do not make their functions correctly, that causes problems with product safety and low production. In addition to cleaning problems caused by the lack of speed control, the operation staff requests support to the project department in order to design a work plan, which could solve the present quality problems from the root cause and at the same time to be able to increase the production processed by the equipment. Reviewing previous works that were carried out by specialized companies in food and beverage industries, it is concluded that a better solution would be the implementation of an automatic control system, which provide the actions necessary to control a process with optimal efficiency through a control system based on programmed instructions, the process operator uses an operator interface to communicate with the control system and the equipment [1]. Furthermore, a typical modern automation system includes management data, information used for reports, statistics, analysis, etc. In an automated process the control system must communicate with each controlled component and each transmitter.

This work is divided into six sections determined as follows: In section two, the basic engineering of the system is described, section three shows the monitoring interface, the description of the Pasteurizer´s operation. Section four describes the PID controller design, including the tuning process. Section five shows the results and performance of the controllers. Finally, the last section six presents the conclusions obtained from this work.

2. PASTEURIZATION SYSTEM

One of the objectives of the heat treatment is the partial sterilization of liquid foods, altering as little as possible the physical structure, the chemical components and the organoleptic properties of these. After the pasteurization operation, the treated products are rapidly cooled and hermetically sealed for food safety purposes; this is why, the knowledge of the mechanism of heat transfer in food is basic in pasteurization. Unlike sterilization, pasteurization does not destroy the spores of the microorganisms, nor removes all cells from thermophilic microorganisms, but the constituents of milk degrade. To overcome these problems, heat treatment should be applied as quickly as possible after the milk has reached the company.

The intense heat treatment of milk is desirable from the microbiological point of view, but such treatment also implies a risk of adverse effects on the appearance, taste and nutritional value of milk. The proteins in the milk are drastically damaged by the intense heat treatment, the powerful heating produces changes in taste, first the cooked and then the burned flavor. The choice of the time/temperature combination is therefore a matter of optimization in which both the microbiological effects and the quality aspects should be considered [2]. Thus, heat treatment has become the most important process in milk production; the categories of heat treatment have been listed as shown in Table 1.

Table. 1 Thermal treatment categories in the dairy industry.

Process	Temperature	Time
Thermisation	63 – 65°C	15 s
LTLT pasteurisation of milk	63°C	30 min
HTST pasteurisation of milk	72 – 75°C	15 – 20 s
HTST pasteurisation of cream etc.	>80°C	1 – 5 s
Ultra pasteurisation	125 – 138°C	2 – 4 s
UHT (flow sterilisation) normally	135 – 140°C	a few seconds
Sterilisation in container	115 – 120°C	20 – 30 min

The objective of milk pasteurization is to eliminate microorganisms that can cause harm to the consumer, modifying as little as possible their chemical and physical properties, as well as their nutritional characteristics.

Heat treatment also causes changes in the components, the higher the temperature and the longer the heat exposure, the greater the changes. Within certain limits, time and temperature can be balanced against each other [3].

Short heating at a high temperature may have the same effect as prolonged exposure to a lower temperature, (Figure 1). Both time and temperature should always be considered in relation to heat treatment.

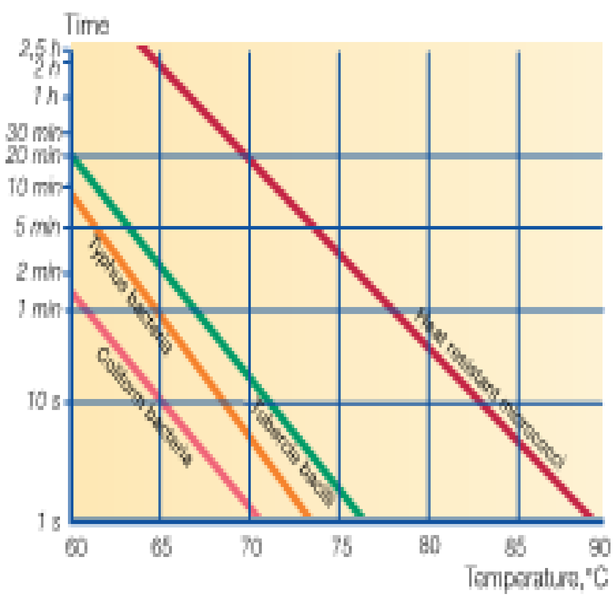

Fig. 1 Exposure and resistance times.

2.1 Process Flow Diagram (PFD)

This section supplements what was mentioned in the previous one through the graphical representation of the process, in which, in general, the systems inputs and outputs are shown, the main equipment that is part of the system, and the conditions and status of the variables that are known prior to the start of the project, see Figure 2.

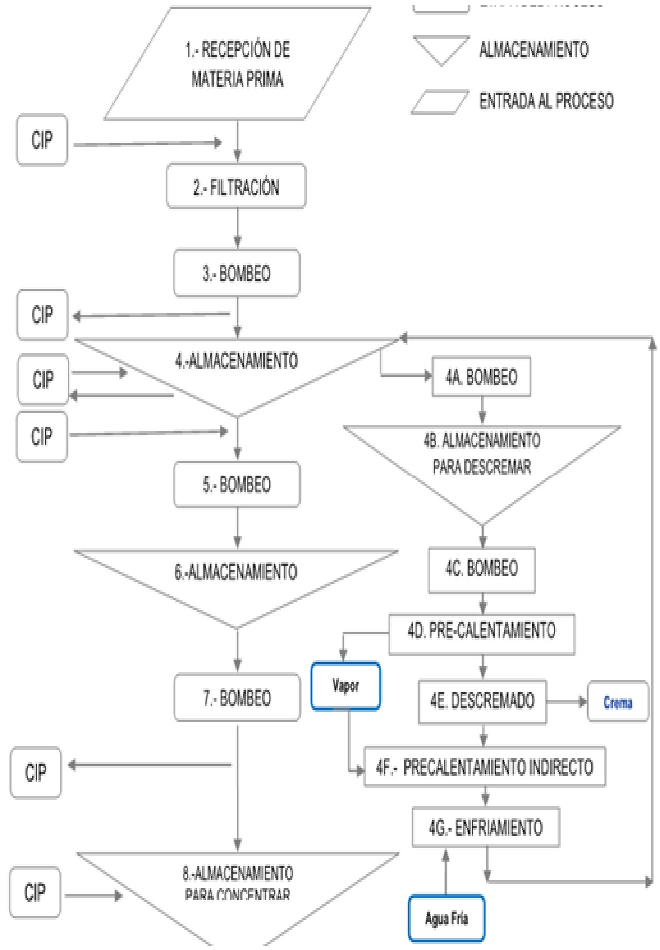

Fig. 2 Pasteurization system flow diagram.

2.2 Control System

In this project, the control strategy to use was raised, here is shown descriptively and graphically the overall operation of the system and the actions of control to be carried out depending on the state of process where it is, and the conditions of the relevant variables in each one of these states. The pasteurization system is composed of the phases described in sections 2.3 to 2.5.

2.3 Sterilization

Sterilization is the process of eliminating all forms of life, including spores. It is an absolute term that implies loss of the viability or elimination of all the microorganisms contained in an object or substance, conditioned in such a way as to prevent their subsequent contamination. The sterilization process is carried out thermally and is carried out by circulating water at 90°C throughout all the equipment. After sterilization, the heating is turned off and the cold is turned on, in this way the water is taken to the point of operation for production.

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2.4 Stabilization

Once the sterilization time is complete, the equipment begins to work as if it were producing, but with water, thus avoiding the loss of milk while the controllers and actuators look for the points of operation.

2.5 Pasteurization

Once the equipment has stabilized it goes to the pasteurization stage, which consists of transferring thermal energy to the milk using water that has already been previously heated by means of steam, this is done in the final stage of the heat plate exchanger. After the energy exchange, the final temperature of the milk should be 75°C, to ensure that it has been well pasteurized, then it must be taken to the retention zone, in which the milk is kept at 75°C for 15 seconds, this ensures good pasteurization. If the temperature is less, the final product is rejected and re-sent to repeat the whole process, this is known as “fun”. The use of seven control loops is specified by operation:

a) The level of the balance tub to maintain a constant feeding.
b) The feed speed to keep flow.
c) The pumping speed to maintain the feed pressure of the homogenizer.
d) Steam opening with pasteurization temperature.
e) Cold water opening with output temperature.
f) Valve opening controlled by output flow equipment.
g) Vision system for future interface change.

2.6 Piping & Instrumentation Diagram (P&ID)

It is elaborated following the standard 5.11984-(R1992) Instrumentation symbols and identification [5], see Figure 3. This document has the following information:

a) Instrumentation representation. The representation indicates the general location of the instrument and its conditions in the process.
b) Instrument identification. The type of instrument is known through identification.
c) Connection. It describes the way in which the instruments and equipment that are part of the process are related, it may be electrical connection, piping, pneumatics, communications, among others.

See Figures 4 and 5 where the Pasteurizer plant is shown.

2.7 PLC programming

Automation is not used for the operator to be superfluous, but to extend its scope and power. The more sophisticated the system, the operator worries about fewer details. The program must handle all the routine functions of the process, the tactics, while the human operator is responsible for the command decisions, the strategy [4]. Figure 6 shows the PLC Siemens 1200.

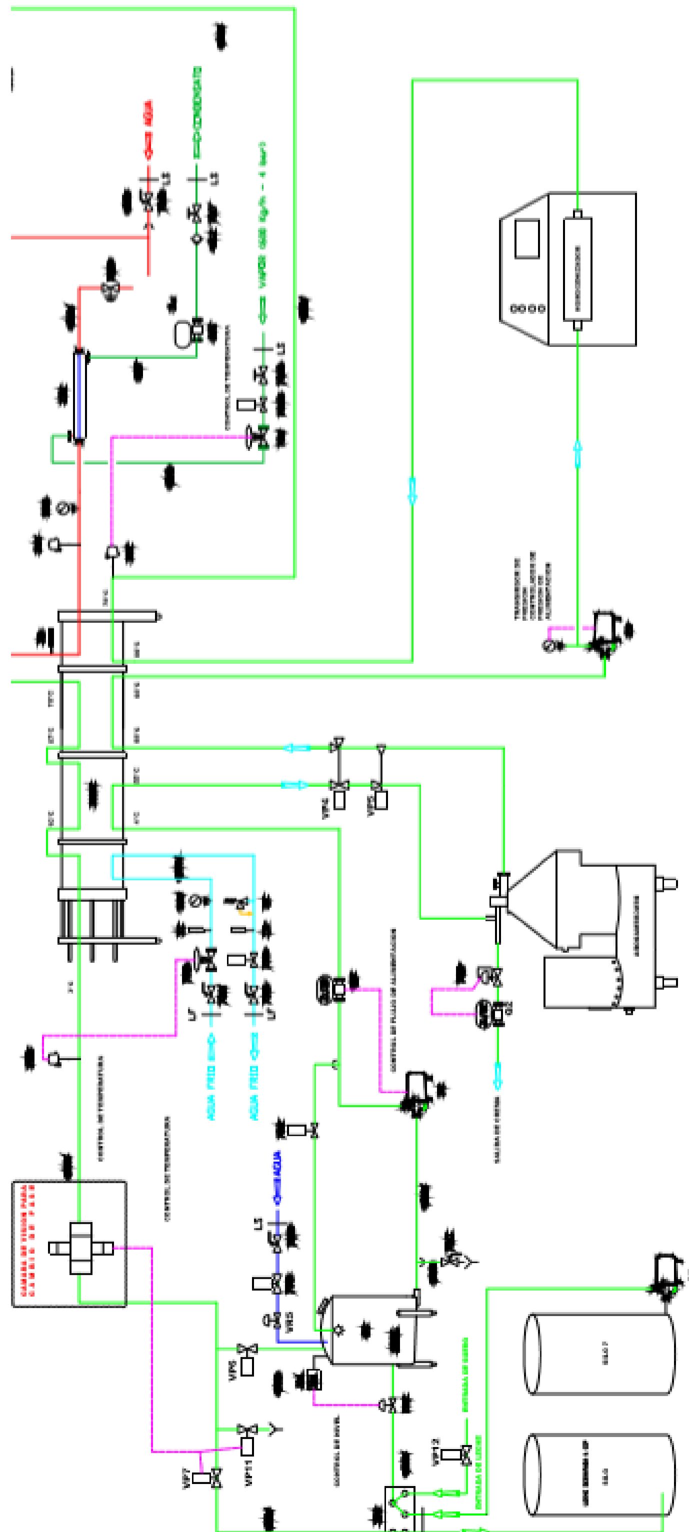

Fig. 3 P&ID.

Fig. 4 Pasteurizer view 1.

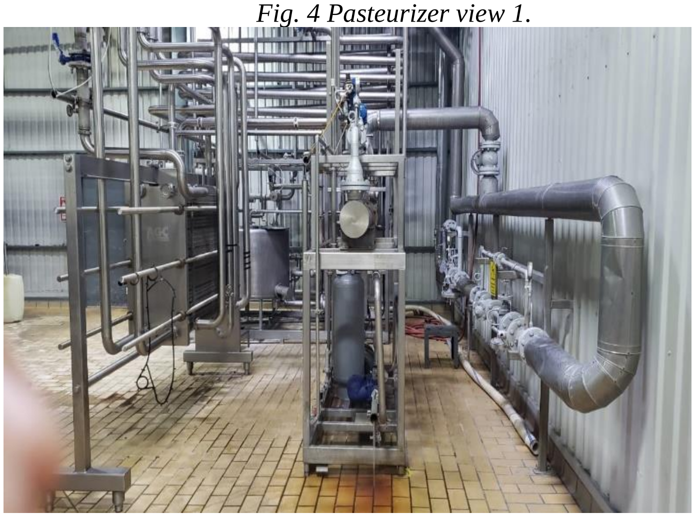

Fig. 5 Pasteurizer view 2.

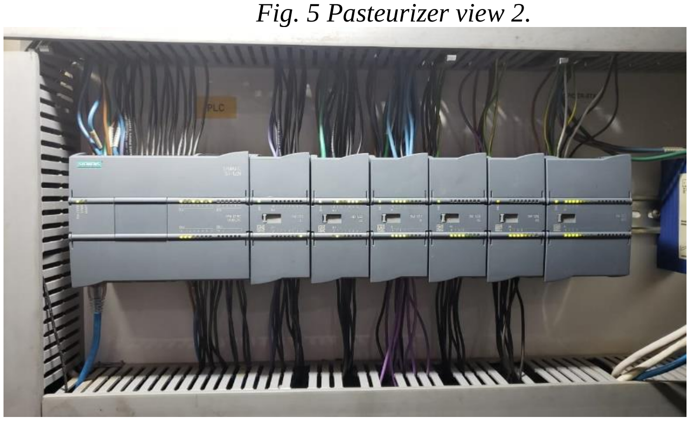

Fig. 6 PLC Siemens 1200.

2.8 The Analog Control

It means that an object is controlled by analog signals from the control unit. Normally this type of control is based on another feedback signal (continuous variable) to the control unit, for example, to control the steam supply or hot water in a pasteurizer. The feedback signal to the control unit comes from the transmitter for the pasteurization temperature. Analogue control is often common in the dairy industry. An analog system is used to control the heating in the pasteurizer, while the temperature sensor serves to control the temperature. The sensor reacts immediately if the temperature drops below the preset value then a signal is transmitted to the control unit and the Pasteurizer and it changes to the detour flow.

3. OPERATION ANALYSIS

This section shows the monitoring interface and the description of the pasteurizer operation.

3.1 Instrumentation

The available instrumentation during the development of the engineering is analyzed; a summary of the number of inputs and outputs, as well as the form of communication with the PLC are considered; in this case, inputs of RTD for the sensors of temperature and 4-20 mA signals for the other instruments.

With the requirements of the control loops given by the operation, each one of them will be working individually; this project only focuses on one of them, but the work procedure is the same for each one, only by switching to control variable and the parameters of each controller.

For the first control loop, the level of the balance tub must maintain a constant feeding. This loop has the objective of maintaining a level in the feeding tub, the first objective is to avoid the waste of raw material and avoid cavitation in the feeding pump by lack of level. This controller has the name given in engineering of LIC-01 which emits a current signal of the range of 4-20 mA, and which is subsequently transformed to pneumatic pressure. With the effect of the transduction, the electrical signal of the controller LIC-01 to pneumatic signal, the percentage of opening of the proportional valve is regulated, allowing the input of product corresponding to the level.

The error signal is generated when the LIC-01 transmitter level (4-20mA signal) registers the tank level and retransmit this information to the LIC-01 controller, within it, the signal is compared to the desired signal of the system setpoint and a new control signal is updated and sent to the valves, this closes the level control loop.

3.2 Interface Operation

The Siemens TIA Portal V14 proprietary software and a MP 277 10” touch screen used for the S7-1200 processor control. The main screen shows the complete operating system during development, in Spanish, as it is displayed (Figure 7).

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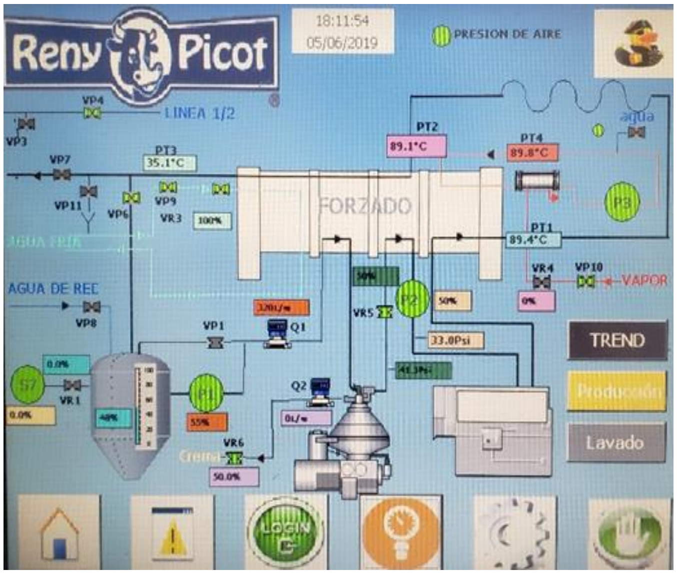

Fig. 7 Graphic Interface.

For the control of the loops, individual screens are used; they help with the monitoring of each one of them, in case that it is necessary to do a manual control over the output of the controller, as mention before. One of the controllers is shown in Figure 8.

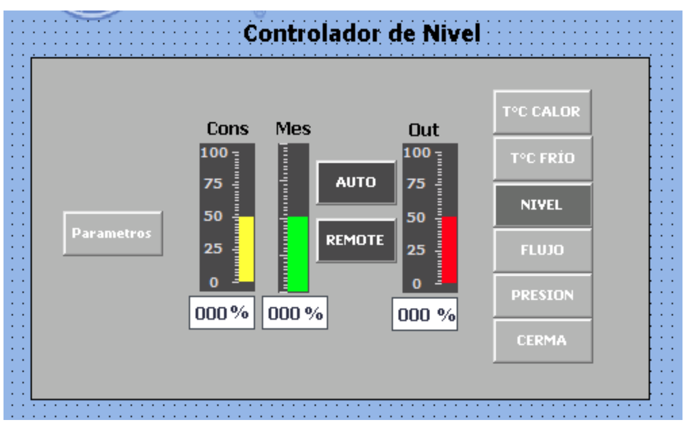

Fig. 8 Level controller.

4. CONTROLLER DESIGN

The development of the PID controller for each loop must be carried out in a dynamic way because there are changing conditions for each startup of the process. The TIA Portal provides an auto-tuning scheme for the PID controller [6][7].

To adjust the controller, it is necessary to integrate it into the PLC. Once the system is configured, two steps are required, prior adjustment and fine adjustment.

a) The Previous Setting.
b) Fine Adjustment.

The Previous Setting determines the response of the process to a change in the jump of the output value and searches for the inflection point. PID parameters are calculated from the maximum rate of rise and dead time of the controlled system.

The Fine Adjustment generates a constant and limited oscillation of the process value.

The parameters are adjusted for the operating point from the amplitude and frequency of this Oscillation. All PID parameters are recalculated from the results.

PID_Compact instruction automatically attempts to generate a greater oscillation than the noise of the Process value Fine adjustment is only minimally influenced by the stability of the process value. The PID parameters are backed up before recalculating. The more stable the process value, the easier it will be to calculate the PID parameters and the more accurate the result. Figure 9 describes the process below.

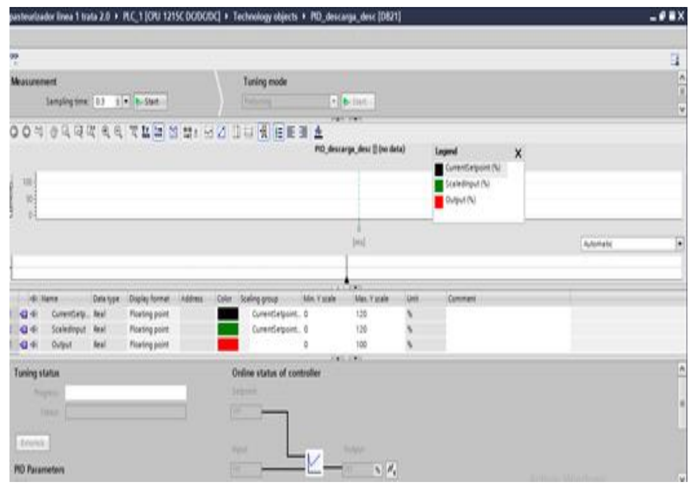

Fig. 9 Automatic tuning scheme.

The diagram of Figure 10 illustrates the integration of the parameters in the PID algorithm.

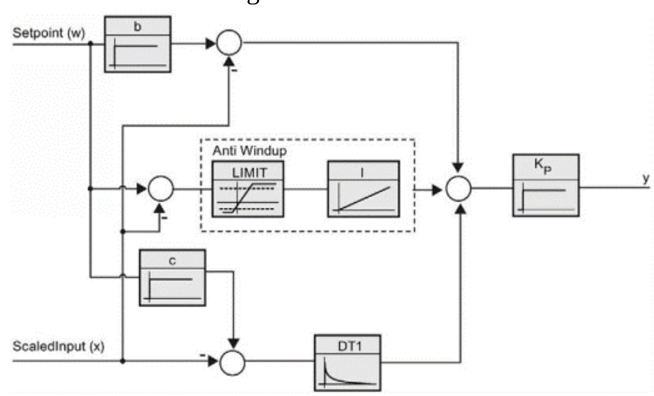

Fig. 10 Integration of PID parameters.

For the controller tuning, proprietary software is used, which uses Ziegler-Nichols rules to tune PID controllers. Ziegler and Nichols proposed rules for determining the values of the PID algorithm based on the transient response characteristics of a specific plant [8][9]. Equation (1) shows the transfer function of the SIMATIC PID controller [7].

$$y = K_p\left((b.w - x) + \frac{1}{T_i s}(w - x) + \frac{T_D.s}{a.T_D.s+1}(c.w - x)\right) \quad (1)$$

Where:

- y Output value of the PID algorithm
- K_p Proportional gain
- s Laplace operator
- b Proportional action weighting
- w Setpoint
- x Process value
- T_i Integral action time
- a Derivative delay coefficient
- T_D Derivative action time
- c Derivative action weighting

4.1 Data Acquisition

The Siemens Data Log was used; this instrument performs a census and storage in an *.xlsx* file. The acquired data used in the evaluation of the process are the input level signal (milliampere 4-20mA) and output signal (milliampere 4-20mA), the opening reference of the valve. These are the two values stored in the *.xlsx* file to perform the process evaluation.

5. RESULTS

After filling the tank, pasteurization by batch, or slow, is done, in which it has as minimum temperature of 62ºC and maximum of 65ºC. In this process, a time of 30 minutes is stablished according to the standard NTE INEN 0010, which specifies the time and temperature; in the tests performed and applying the PID controller, temperature is observed to be maintained within the proposed ranges with small variations, for example 66.4ºC as a maximum value which is acceptable. See Figure 11 and 12.

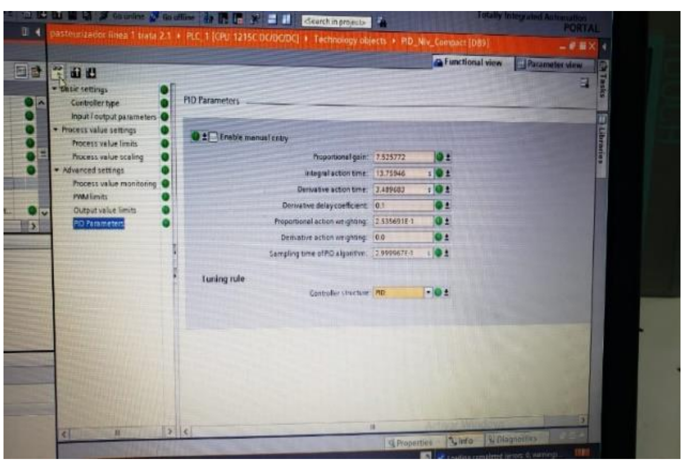

Fig. 11 Results obtained with the proprietary software for the PID control.

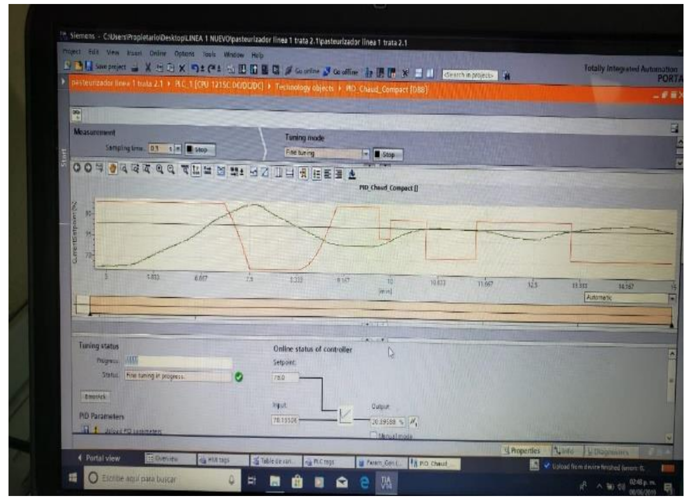

Fig. 12 Curves obtained during the fine adjustment of the proprietary controller.

6. CONCLUSIONS

The automation of the process line with high temperature pasteurization in short time compared to a traditional manual system, offered greater reliability in the quality and safety of the elaborated product; production increased by 10%, which allowed cost savings and better control in the loops. In addition, it provides flexibility to the process given that other activities, such as cleaning of the equipment may be carried out. The control loops are optimized by the proprietary tuning system, as the conditions change as the start-up progresses. The operator has time to be able to make tours to verify other process conditions such as the plant services. We are working within the development of new control loops to improve the quality of production.

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