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Automatic Control For African Palm Fruit Sterilization

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ABSTRACT: *This paper presents information about automatic control for african palm fruit sterilization.For this, it was necessary bibliographical consultations of technical information and database. Calculations developed are in the document corresponding to the design that allowed obtaining as results the selection of materials, programming of the Programmable Logic Controller (PLC) and a mathematical modeling of the process. Ladder facilitated the simulation of the system, which could be done through programming, communication and simulation tools. As relevant results it is mentioned that it was possible to demonstrate the functioning of the sterilizing plant through a mathematical model that confronts reality by comparing the behavior graphs emitted by the signals of the elements.*

KEYWORDS *-Automatic Control, sterilization, african palm fruit, modeling.*

I. INTRODUCTION

It has become a necessity of the human, the improvement of it senvironment and the adaptation of technological too ls for it sefficient development in the world. From the temperature control at home where it is necessary to maintain a pleasant environment, to the industry with it smass production processes where the products must satisfy requirements of precision and cost.

Modern control simplifiedthedesign of control systems, becauseitisbasedon a model of the real systemto be controlled [1].

African palm industry is a guild that has grown considerably over the years and Colombia has become the protagonist, because it is the leading producer of in Americas and in the world it is located in fourth position. With the growth of the guild, there is a need to improve efficiency giving way to new technologies and automations. The process of sterilization is the most important in the extraction plants [2], it largely depends on a good extraction of oil, so it is convenient to propose their automation to improve sterilization times, avoid human errors and therefore their efficiency.

Operation process of a sterilizer involves fruit entry, safe seal of access door, valves operation of entry and exit of steam and condensates, data records. All these activities are carried out manually, which implies a physical and mental wear and tear since it is necessary to be concentrated for the manipulation of the valves and the data collection at the appropriate moments, in order not to affect the quality of the process.

To solve problems, this paper presents how through technical arguments to select the appropriate elements for automation, and indicate the way which the sterilization process could be mathematically modeled and, thanks to this modeling, simulation can be done in which the results were in accordance with reality, which allowed having the reliability of the system's response and then modifying it and making the process more efficient based on those responses.

The article is divided into 3 main sections, where the first section is called "Methodology", containing controllers, Programmable Logic Controller, process requirements, materials selection, system design, plant modeling, programming. The second section called "Results and discussions" refers to graphicinterface, curves analysis and finally “conclusions”, where the findings are exposed after the development of the article.

II. METHODOLOGY

Controllers

An automatic controller compares the actual value of the output of a plant with the reference input (set point), determines the deviation and produces a control signal that will reduce the deviation to zero or a small value. The way in which the automatic controller produces the control signal is called the control action [3].

Controllers are additional elements to original system to improve their operating characteristics, with the aim of satisfying the design specifications both in transitory regime and in steady state.

The first way to modify the characteristic response of the systems is gain adjustment (which will later be defined as proportional control). However, although generally the increase in gain improves the operation in steady state, there is a poor response in transitory regime and viceversa. For this reason, it is necessary to add elements to the simple gain variation, which gives rise to the different types of controllers [4].

Design specifications are often used to describe what the system should do and how to do it. These specifications are unique to each individual application and often include specifications such as relative stability, steady state accuracy, transient response and frequency response characteristics [5].

Almost all industrial controllers use electricity or the pressure of a fluid such as air as an energy source. Controllers can also be classified, according to the type of energy they use in their operation, such as tires, hydraulics or electronics. The type of controller used must be decided based on the nature of the plant and the operational conditions, including considerations such as safety, cost, availability, reliability, precision, weight and size.

To control industrial processes, distributed control systems, computers for control, or a combination of both are connected through appropriate interfaces. Although the systems are designed to obtain the best results, either in the stability of the process or to optimize it, the final element of control is still necessary to control the flow of a fluid.

In the final control elements it is important that the final control element works in a stable manner and has a good behavior [6].

Programmable Logic Controller

Programmable Logic Controller (PLC), is a computer used in automatic engineering or industrial automation, to automate electromechanical processes, such as the control of factory machinery in assembly lines or mechanical attractions [7].

PLCs are used in multiple industries and machines. Unlike general-purpose computers, PLC is designed for various types of input and output signals, among the advantages of using PLCs are: extended temperature ranges, immunity to electrical noise and resistance to vibration and impact. The programs for the control of operation of the machine are usually stored in backups in non-volatile memories. PLC is an example of a "hard" real-time system, where the output results must be produced in response to the input conditions within a limited time, otherwise it will not produce the desired result [8].

System Design

Use of sensors in technology, both in the industrial and domestic field, has become usual the measurement of mechanical, thermal, electrical and chemical magnitudes in sectors such as automated industries, robotics, experimental engineering, energy saving, environmental control, automobiles, appliances, computers, are tasks that would be unthinkable without the application of sensors [9].

Design of the automation for sterilization is directly related to the sterilizer or autoclave (figure 1). The operation of this equipment is done by means of inlet and outlet valves, which control the steam flow.

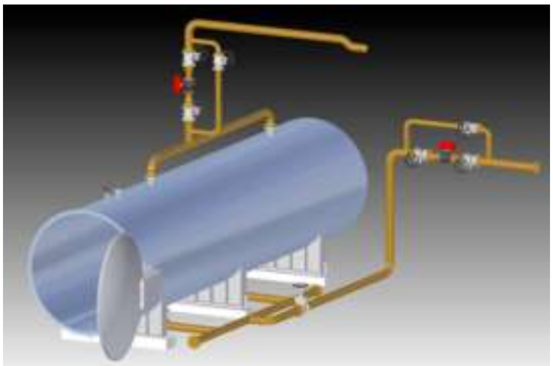

Figure 1.Sterilizer

A. *Following aspects were taken into account for design:*

Process requirements

Requirements of the process and the physical conditions of the area are determined by the operating conditions of the process and equipment inspection, all with the aim of adapting as much as possible to the plant installed, so that a future implementation and thus obtain results that improve the efficiency of the plant.

B.

Materials selection

Elements involved in automation are the following:

Selection and sizing of valves

For sizing of both the steam inlet and outlet valves, the formulas and procedures established by the standard [10] ANSI / ISA-75.01.01-2012 (60534-2-1 MOD) were used. The technical specifications of the equipment and some operating conditions can be seen in table 1.

Table1. Processconditions

Characteristics	Value
Fluid	Saturated steam
Temperature	T=162,194 °C
Ratio of specificheats	γ=1,3872 @ 80 PSI
Compressibility factor	Z = 0,9469 @ 80 PSI
Upstream pressure	P1 = 80 PSI
Design speed	V = 40 m/s
SteamDensity	ρ= 3,43174 kg/ m3
Dynamic viscosity	$\mu = 14,4115 \times 10^{-6}$ kg/m.s @ 80 PSI
Kinematic viscosity	υ= 4,1994x10-6 m^2/s @ 80 PSI

Internal diameter of the tube	D= 154 mm

According to the conditions of the plant, the flow at the entrance of the sterilizer is calculated with equation (1).

$$W = \rho A V \qquad (1)$$

W=9204,6679 Kg/h

Then, by means of ANSI / ISA-75.01.01-2012 (60534-2-1 MOD) a valve is calculated capable of exceeding the flow demanded by the process. The results were:

W=10082,0494 kg/h

Diameter of the valve: 3”

As: Wvalve>Wprocess, it is guaranteed that the process flow demand will be supported by the selected valve.

For the selection of the actuator, the manufacturer's guide is used:

Table 2. Actuator selection

Actuator Size	No. Springs Per Piston	Air Supply Pressure (PSIG							
		40		60		80		100	
		Start	End	Start	End	Start	End	Start	End
48	1	51	32	89	70	126	107	164	145
	2/1	39	10	77	48	114	85	152	123
	2			64	27	101	64	139	102
	3/2			52	5	89	42	127	80
	3					77	21	115	59
63	2	91	65	167	141	243	217	319	293
	3	64	27	140	103	216	179	292	255
	4			113	65	189	141	265	217
	5			86	27	162	103	238	179
	6					135	65	211	141
83	2	210	167	395	352	580	537	765	722
	3	156	76	341	261	526	446	711	631
	4			281	176	466	361	651	546
	5			220	97	405	282	590	467
	6					309	185	554	370
93	2	310	232	570	492	830	752	1089	1011
	3	218	101	478	361	738	621	997	880
	4			386	231	646	491	905	750
	5			294	94	554	354	813	613
	6					462	229	721	488
119	2	692	469	1249	1026	1805	1582	2362	2139
	3	509	174	1066	731	1622	1287	2179	1844
	4			883	437	1439	993	1996	1550
	5			700	142	1256	698	1813	1255
	6					1073	404	1630	961

Source: Actuator Selection Guide. Houston, Texas. Julio, 2010, vol. 1, No. 1005.

To select valve at the exit, the procedure of the ANSI / ISA standard is repeated and the following results are obtained:

W=2491,0955 kg/h

Valve Diameter: 2”

Actuator: size 119-3

C. Pressure indicator transmitter selection

To select transmitter, it begins from variable to measure, in this case pressure, the container can reach a maximum pressure 90 psi and an operating pressure 40 psi. Manufacturer offers transmitters with several nominal ranges of measurement; for the application a range of 232 psi has been selected, sufficient for the conditions of the process. Additional is requested with an adjustment of the range from 0 to 90 psi. As temperature of the fluid is high, transmitter must have a temperature decoupler, the manufacturer offers this decoupler for values up to 200 ° C.

With this information, transmitter with following characteristics has been selected: transmitter for relative pressure, smart, SITRANS P model, DS III / P410 series, with local operation by keyboard and LCD included in a personalized and remote way by HART protocol.

Figure 2. Pressure Transmitter

Sourcee: http://www.aotewell.com/siemens-pressure-transmitter-siemens-7mf

Control device

For the selection of the PLC, the Siemens® selection tool was used, "TIA selection tool" the selected elements are shown in figure 3.

Figure 3. Control system components
Source: Siemens. TIA SelectionTool: versión 2016.3.0.32867.
Marzo, 2017.

PLC SIMATIC S7-1200® with 1212C CPU is selected, this device has 8 inputs and 6 digital outputs of 24V DC, 2 analog inputs from 0 to 10V DC and is powered by 24V DC. This CPU incorporates few inputs and outputs and therefore is among the least expensive, additionally allows the connection of analog input and output modules, these can be configured for standard 4 to 20 mA.

The panel or screen is fundamental for the supervision of the process, in the selection a balance between size and cost was taken into account. The screen is touch and has a USB port used for data storage.

The panel or screen is essential for the operator to supervise the process, the communication switch will be necessary in the future for the customer to communicate the signals to a main control system, the analog input and output modules include reserves for 3 transmitters and 2 additional actuators. These would be the minimum components that can be used without generating unnecessary expenses and are perfectly suited to the needs of process control.

D. Plant Modeling

Mathematical model of the system will be represented by the equation of state of the perfect gases, as shown by equation (2), which after analyzing the conditions of the equipment and the process was considered suitable for representation. It is important to understand that a system is not only governed by a mathematical modeling, there may be different models that represent the same system. In this case, the plant works with saturated steam, which pressurizes a sterilizer that is nothing more than a cylinder with constant volume [11].

$$P_R = \frac{mRT}{V_R} \qquad (2)$$

Any equation that relates the pressure, temperature, and specific volume of a substance is called the equation of state. There are several state equations, some simple and others very complex: the simplest and best known for substances in the gas phase is the ideal gas state equation, which predicts the PvTbehavior of a gas fairly accurately, within certain region properly chosen.

The main characteristic of a perfect gas is that by varying the pressure in a constant volume vessel, the temperature variation is minimal, and is considered constant. For saturated steam this temperature changes considerably when the pressure varies, with this consideration the equation of state for saturated steam can be represented by equation 3.

$$P_R = \frac{mR}{V_R}(1{,}5057x10^{-4}P_R + 357{,}8674) \qquad (3)$$

When graphing equation 3, replacing the values with the data of steam tables, it is observed:

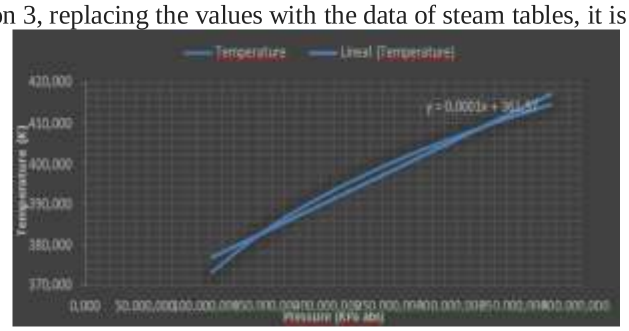

Figure 4.Temperature as a function of pressure

Figure 4 shows linear equation used to represent the temperature, is close enough to the values of the curve and is considered appropriate, it is necessary to linearize the curve so that the equation is not indeterminate.

To determine the mass inside the container, equation 4 is used

$$.m = \int_{t_1}^{t_2} q_{ent} - \int_{t_1}^{t_2} q_{sal} \qquad (4)$$

Finally, replacing in the equations the expression that represents the mathematical model of the process in equation (5) is determined.

$$P_R = \frac{R}{V_R}\left(\int_{t_1}^{t_2} q_{ent} - \int_{t_1}^{t_2} q_{sal}\right)(1{,}5057x10^{-4}P_R + 357{,}8674) \qquad (5)$$

This equation it is possible to model in the Simulink® software. For the flow, equation (6) is used, found in the ISA-75.01.01-2012 standard that precisely defines the flow that passes through the inlet and outlet valves.

$$W = CN_6 F_p Y \sqrt{x_{sizing} P_1 \rho_1} \qquad (6)$$

Another parameter that needs to be linearized is the density, since it varies according to the change in pressure as seen in figure 5.

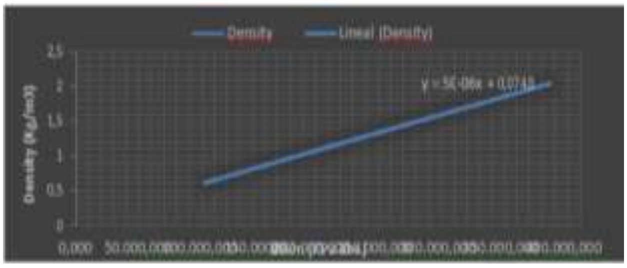

Figure 5.Density as a function of pressure

Another variable parameter is Xt, this changes depending on the opening percentage of the valve, but can be expressed as a function of the flow coefficient based on the data delivered by the manufacturer. The linearization of these parameters is observed in figures 6 and 7, for the inlet and outlet valves respectively.

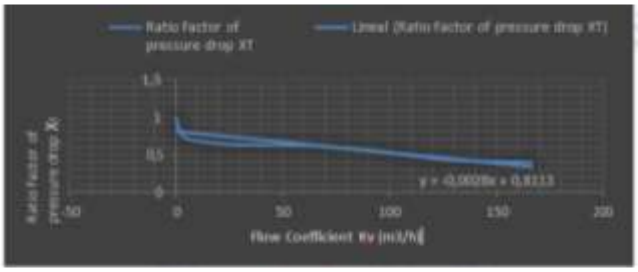

Figure 6. Pressure drop ratio factor for the inlet valve.

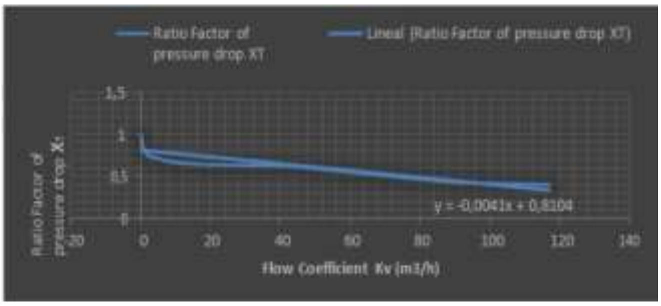

Figure 7. Pressure drop ratio factor for the outlet valve.

PLC Programming

Modeling in Simulink does not involve too much complexity and is very powerful in solving equations, additionally it has a communication module through OPC server, which is used to transfer and receive variables between different types of devices, as shown in figure 8.

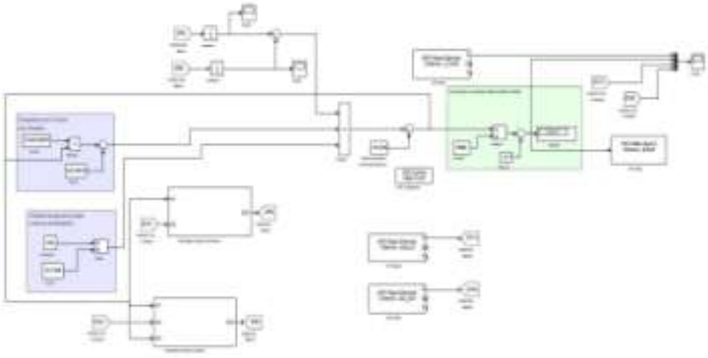

Figure 8. General diagram of Simulink modeling

PLC programming must guarantee the fulfillment of the times and of the pressures inside the sterilizer, to consideration of the user is the selection of some recipes that vary the times according to the state of maturation of the fruit (green, ripe and over ripe). The programming is done with ladder language and starts with a comparison function that reads an internal variable to know which recipe the operator selects.

Depending on the selection, a time value associated with a data block is loaded. This time specifically affects the stage of sustenance, which is the main variation in the recipes according to the state of ripeness of the fruit, then with a ramp function soak the points stored in the data block are taken to generate values that are in straight lines. , these values are the set points that the PD receive to control the container pressure. Each valve has a PD controller assigned to control the inflow and outflow. The pressure value is delivered to the controller by an internal variable modified from an OPC server by the simulation software.

III. RESULTS AND DISCUSSIONS

WinCC Runtime of Tia Portal simulate panel containing the Human Machine Interface (HMI), which starts together with the simulation of the PLC and the plant. When the simulation of the panel is started, a main window is loaded, as shown in Figure 9. This contains 4 buttons, 3 correspond to the recipes and one to emergency stop, if one of the recipe buttons is pressed the PLC takes an action that will affect the times or stop the process.

Figure 9. Recipe selection window

Second panel contains the window that shows the autoclave graph, the two valves, the transmitter, the pipeline, two buttons one to start the process and the other is the emergency stop, it also has two buttons to move towards the others windows, this window also shows the pressure value and the opening percentage of the valves at all times, see figure 10.

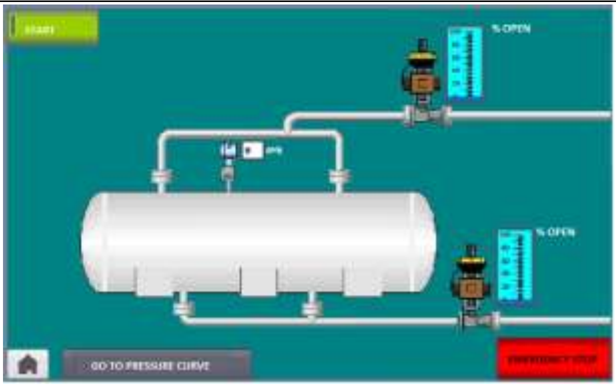

Figure 10. Process window.

By pressing start button, sending points are generated, therefore the process starts. The screen consists of a button to start the process, a button to change to the process window, start button the registration of the controlled variable and another to stop the registration.

Process was modeled mathematically in Simulink software, PLC simulated in the PLCSIM of Tia Portal, reads the variable of pressure during the simulation with the help of software intermediaries and also writes in a variable the values of flow coefficient that corresponds a percentage of opening of the valves, in this way a feedback is created in which the pressure values change depending on the variable manipulated by the controller of the PLC.

Behavior of the variables is shown in figure 11.

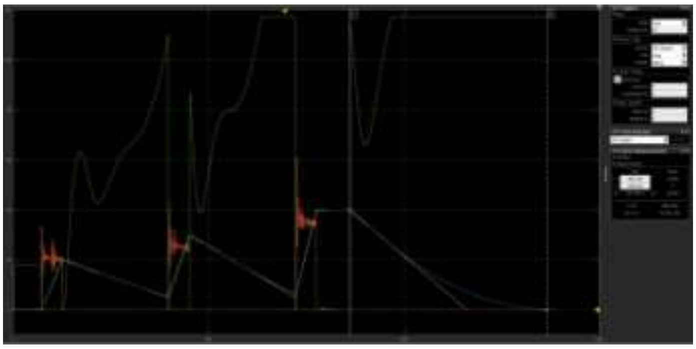

Figure 11.Variable controlled, manipulated and set point graph

Pressure variables change in the way set points (lines light blue), this reflects that the controller is manipulating the variables of the flow coefficients (red color for inlet valve and yellow color for outlet valve) in such a way that it gets a pressure close to the desired one. When the process cycle ends, the ramp generator freezes, so the set point at that moment is zero and the process is waiting to start again.

In figure 11 it can be seen that during the beginning of the process the inlet valve works with a flow coefficient in a range of approximately 10 to 35 m3 / h, equivalent to a range of 40% and 60% opening, then it tries to stabilize about 45% opening, in the next peak of ascent it tries to stabilize at 50% and at the third peak at 56%, these data are determined from the table of coefficient vs% opening that the manufacturer delivers of the valve, if the maximum value reached by the valve is revised, of 70%. Now if you take into account that the manufacturer recommends a valve operation between 20% and 80% we can affirm that the valve size is correct.

A third window contains curves of the variables, a button to start the process from this window, a button to return to the process window, a button to start controlled variable registration and another to stop the record, as seen in the figure 12.

Figure20. History window and record of the pressure variable

IV. CONCLUSIONS

Automation of a process by means of simulation with a mathematical modeling approximated to the real behavior, allows an optimal selection of the actuators and the configuration of the controllers to guarantee the adequate operation in its implementation.

The sizing and selection of the valves calculated by means of an international standard, allowed that in the simulations the behavior of the valves fulfilled our expectations in terms of pressure and response times.

It was a great success to model the system mathematically, thanks to this it was possible to understand by own science, the functioning of the process of sterilization. In the same way, the results obtained after the simulation, comparing them with reality, are similar in a large percentage, demonstrating the reliability of the model.

The analysis of the graphs and the results in general show that the selection of materials, design, programming and simulation were carried out in a coherent and professional manner.

An automated process allows to make more accurate decisions in its improvement, since the historical data it delivers and the techniques or methods that are implemented are more precise.

V. ACKNOWLEDGEMENT

The authors of the present work thank University of the Llanos, who through the last years has significantly influenced our lives allowing us to grow as people and professionals through the development of research projectsperformed in the School of Engineering with the Open Technologies Research Group (GITECX), and in our case,we work looking for technological solutions that facilitate the work developed in the region of the Colombian Orinoquia.

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